NCHRP
Project 25-25 (04)
Interim Report

Environmental Stewardship Practices, Procedures, and Policies for Highway Construction and Maintenance

By:

Marie Venner, Venner Consulting, Inc.

Date:

August 13, 2004

ACKNOWLEDGMENT OF SPONSORSHIP

This work was sponsored by the American Association of State Highway and Transportation Officials, in cooperation with the Federal Highway Administration, and was conducted by the National Cooperative Highway Research Program, which is administered by the Transportation Research Board of the National Research Council.

ABSTRACT

Environmental stewardship practice at state Departments of Transportation (DOTs) has grown exponentially in recent years. NCHRP 25-25(04) presents a compendium of environmental stewardship practices in construction and maintenance, developed from the literature, state transportation agency manuals and procedures, and the contributions of state DOTs and practitioners. The best practices herein serve as a guide to the development of Environmental Management Systems and environmental strategic plans both on the organizational level and in specific functional areas. Practices can also serve as foundational elements for individual environmental guidance resources that DOTs may develop.

ACKNOWLEDGEMENTS

The research reported herein was performed under NCHRP Project 25-25(04) by Venner Consulting of Littleton Colorado as a subcontract to Parsons Brinkerhoff Quade and Douglas. Hal Kassoff of Parsons Brinkerhoff serves as PB's Principal Investigator for the NCHRP 25-25 series. Marie Venner served as Principal Investigator for this project and authored/edited the report. Many state transportation agencies contributed to the collection of these practices for this report and the AASHTO Subcommittees on Construction and Maintenance participated in review of the compendium and addition of further exemplary practices. The author wishes to acknowledge their generosity and invaluable assistance, without which this project would not have been possible.

Acronyms and Links for State Transportation Agencies

- Alaska Department of Transportation (ADOT&PF)
- Arizona Department of Transportation (ADOT)
- Arkansas State Highway and Transportation Department (AHTD)
- California Department of Transportation (Caltrans)
- Colorado Department of Transportation (CDOT)
- Connecticut Department of Transportation (ConnDOT)
- Delaware Department of Transportation (DelDOT)
- District Department of Transportation (DDOT)
- Florida Department of Transportation (FDOT)
- Georgia Department of Transportation (GDOT)
- Hawaii Department of Transportation (HDOT)
- Idaho Department of Transportation (ITD)
- Illinois Department of Transportation (IDOT)
- Indiana Department of Transportation (INDOT)
- Iowa Department of Transportation (DOT)
- Kansas Department of Transportation (KDOT)
- Kentucky Transportation Cabinet (KYTC)
- Louisiana Department of Transportation and Development (DOTD)
- Maine Department of Transportation (MDOT)
- Maryland Department of Transportation (MDOT)
- Massachusetts Highway Department (Mass Highway)
- Michigan Department of Transportation (MDOT)
- Minnesota Department of Transportation (Mn/DOT)
- Mississippi Department of Transportation (MDOT)
- Missouri Department of Transportation (MoDOT)
- Montana Department of Transportation (MDT)
- Nebraska Department of Roads (NDOR)
- Nevada Department of Transportation (NDOT)
- New Hampshire Department of Transportation (NHDOT)
- New Jersey Department of Transportation (NJDOT)
- New Mexico State Highway & Transportation Department (NMSHTD)
- New York State Department of Transportation (NYSDOT)
- North Carolina Department of Transportation (NCDOT)
- North Dakota Department of Transportation (NDDOT)
- Ohio Department of Transportation (ODOT)
- Oklahoma Department of Transportation (ODOT)
- Oregon Department of Transportation (ODOT)
- Pennsylvania Department of Transportation (PennDOT)
- Departamento de Transportación y Obras Públicas (DTOP)
- Rhode Island Department of Transportation (RIDOT)
- South Carolina Department of Transportation (SCDOT)
- South Dakota Department of Transportation (SDDOT)
- Tennessee Department of Transportation (TDOT)
- Texas Department of Transportation (TxDOT)

- Utah Department of Transportation (UDOT)
- Vermont Agency of Transportation (VTrans)
- Virginia Department of Transportation (VDOT)
- Washington Department of Transportation (WSDOT)
- West Virginia Department of Transportation (WVDOT)
- Wisconsin Department of Transportation (WisDOT)
- Wyoming Department of Transportation (WYDOT)

SHORT TABLE OF CONTENTS

DETAILED TABLE OF CONTENTS

LIST OF EXAMPLES

LIST OF TABLES

LIST OF FIGURES (BEING UPDATED)

State transportation agencies or Departments of Transportation (DOTs) are among the largest builders in each state. Projects occur in hundreds of locations around each state and annual budgets exceed a billion dollars in some cases. Furthermore, DOT leadership, commitment, and responsibility have an impact far beyond the agency's own activities. Hundreds of cities and towns apply DOT standard specifications/plans in municipal construction and maintenance annually. Private contractors and developers attend DOT training course and apply best management practices to residential and commercial projects throughout the state. Resource agencies send their employees to be trained by the DOT in some cases and recognize such training as a means of improving environmental performance.

Led by some bold pioneers, state DOTs have begun to embrace new environmental stewardship priorities in construction and maintenance activities. Recognizing their strengths as large public works agencies with significant resources, the ability to interact with the public on a daily basis, and personnel who are committed to excellence in public service, many state transportation agencies are adding pursuit of environmental enhancement opportunities to their standing commitments to comply with environmental laws and regulations.

Many DOT employees are environmentalists in their own right—in particular, those who are at home in and enjoy the outdoors. Those who work at state transportation agencies, like their neighbors, often want to be partners in protecting and enhancing fishing streams, bird habitat, and other aspects of a livable environment for people and other creatures. When given the opportunity and encouragement to make a difference in the work they do on a daily basis, DOT employees are embracing, taking ownership of, and indeed extending and improving upon environmental stewardship initiatives. As a result, DOT credibility is rising with regulators and the public. As an important side benefit, some of the DOTs that have undertaken this journey have experienced reinvigorated employee morale.

State transportation agencies and their federal partners have increasingly integrated environmental stewardship into maintenance and construction activities; however, information on these efforts has not been adequately summarized or disseminated. This project is intended to enable transportation agencies to more fully benefit from each other's experience, to help them more fully integrate stewardship into all aspects of their work in these areas.

Why Focus on Construction and Maintenance in Implementing Environmental Stewardship?

Construction and maintenance operations:

- Employ the majority of the work force.
- Are the locus of some of the most significant environmental impacts and opportunities.
- Have a need for consistent systems.
- Can have significant contact with DOT customers.
- Have the opportunity to show the public and regulators the substance of the DOT's commitment to environmental stewardship.
- Have developed many best practices already, and can benefit from systems, tools, and practices that have been developed by other transportation agencies and industries to improve environmental performance.

CHAPTER 1: INTRODUCTION AND RESEARCH APPROACH

1.1. PROBLEM STATEMENT AND RESEARCH OBJECTIVES

The drafters of the scope for this project recognized a pressing need for information regarding environmental stewardship practices in construction and maintenance, in order to increase environmental sensitivities and help states avoid "reinventing the wheel." Thus, this project was designed to help DOTs apply more quickly and easily that which has already been learned or developed. To this end, this report describes sample practices and then links the user to pertinent examples, design drawings, or more detailed guidance or procedures.

State transportation agencies are increasingly adopting a wide array of stewardship and environmental protection and enhancement practices, many on a voluntary basis. Regulatory agencies, insurers, and interest groups also favor adoption of construction and maintenance practices that protect or enhance the environment. The need for standards and improvements in environmental processes and practices has risen with:

- Public concern for the environment and sustainability.
- Acknowledgement at both the state and federal level of the importance of environmental issues and demonstrating environmental stewardship.
- Proliferating national, state, and local standards.
- Evolution from "command and control" to self-regulation.

DOTs also have efficiency reasons for pursuing environmental stewardship practices. Raw material usage, energy consumption, waste generation, storage, environmental mitigation, maintenance of construction sites and the final facilities and roadsides all require a significant investment of financial resources. Efficient, effective, and environmentally conscious use of these resources can yield both financial and ecological benefits.

The specific objective of this research was to develop a compendium of practices for integrating environmental stewardship into construction, operations, and maintenance activities. The Random House College Dictionary defines a compendium as a list or inventory. The practices included in this compendium have applicability beyond specific state or local regulations. Many environmental stewardship practices and operational controls are commonly employed by state transportation agencies. Those that are self-explanatory as listed are presented herein in bulleted checklist format by functional areas, and in some cases by environmental media. Other more complex/comprehensive and highly recommended models of practices, policies, procedures, or programs are identified and described in greater detail, with examples and links whenever possible. Where states are using performance measures to evaluate practices, or more widespread standards are available, these are included as well.

While "the original project refers mainly to specific technical practices and procedures," a revised scope developed by the panel suggested that "this should be broadened to include policy, organizational and management approaches, up to and including overall environmental management policies [such as] PennDOT's SEMP (Strategic Environmental Management Program)…a comprehensive guide to implementing Pennsylvania's Green Plan…Partnerships between DOTs and resource agencies is another example of an organizational approach to environmental stewardship. The adoption of environmental management systems and policies should be documented in different sections of the report from the compendium of specific best practices." Thus, in addition to construction and maintenance practices, initial chapters were developed on organizational level stewardship practice and requested areas in pre-construction, including context sensitive design, wildlife crossings, and bioengineering.

1.2. The Trend toward Environmental Stewardship

Discussions among environmental leaders at several DOTs led to the genesis of AASHTO's Environmental Stewardship Demonstration Program in the fall of 2001, with financial support from FHWA. The demonstration program acknowledges three levels of approaches to environmental stewardship at transportation agencies, from adding stewardship features to projects on a case-by-case basis, without major changes to financial or organizational systems, to developing programmatic stewardship efforts and institutionalizing changes to the organization and its processes. Cultural and process change may be the most challenging, but can bring about some of the greatest rewards, as leaders in the field testify. Some of these leading states have adopted environmental policies and stewardship objectives in strategic plans, are utilizing and expanding the environmental expertise of all staff, and modifying procedures and business processes to incorporate environmentally sound decisionmaking and action in all parts of the organization.

Participants in a workshop focused on stewardship at the Transportation Research Board's 2001 A1F02 Environmental Analysis in Transportation Committee meeting defined environmental stewardship in transportation as:

- Wise choices based on understanding the consequences to natural, human-made, and social environments.
- Improving environmental conditions and the quality of life when possible, not just complying with regulations.
- Careful management of environmental resources and values through partnerships among public and private entities.
- Attitude, ethics, and behavior by individuals.
- Fulfilling responsibilities as trustees of the environment for succeeding generations, moving toward a cost-effective and environmentally sustainable future.
- Integrating environmental values with partners within all transportation work as a "core business value."

AASHTO has taken steps to try to expand environmental stewardship among DOTs by publicizing DOT success stories, awarding notable DOT initiatives, and starting the Center for Environmental Excellence, a one stop source of environmental information for transportation professionals. AASHTO's Standing Committee on the Environment initiated the NCHRP 25-25 research program focusing on research to "develop improvements to the analytical methods, decision-support tools, procedures, and techniques employed by practitioners in environmental streamlining, environmental stewardship, statewide and metropolitan environmental transportation planning, program delivery, and project development."(*1*) This research program has backed the current study effort, with interest, support, and involvement from the AASHTO

Subcommittees on Construction and Maintenance, as well as the TRB Task Force on Accelerating Innovation.

1.3. SCOPE OF STUDY AND DEFINITION OF ENVIRONMENTAL STEWARDSHIP PRACTICES

The oversight panel for this project discussed and rejected use of the more common terms "best practices" or "best management practices" for this project, in favor of the term "environmental stewardship practices." In this document, environmental stewardship practices address a broad gamut of practices, programs, and procedures designed to better care for the environment.

Whether they are called BMPs or environmental stewardship practices, practitioners faced with specific problems must always take into account the settings in which the practice is applied, and often tailor a more general practice to fit a specific context. Some practices are by necessity highly local, such as roadside vegetation management, while others, such as shop maintenance, have greater consistency and performance across organizations.

Practices are constantly evolving with technological improvements and regulatory changes. Also, what is considered "best" in one locale is not the most appropriate practice in another. By developing a compendium of practice, the panel sought to provide DOTs a way to survey what is occurring at other agencies in their areas of interest at this time, to expedite implementation of good ideas and process improvements most appropriate for their own agencies and situations.

Chapter 2 of this report addresses environmental stewardship and its impact on State Departments of Transportation in its broadest sense – from strategic planning and policy setting to environmental management systems and performance audits. There are several key reasons for this foundation in environmental stewardship to be established as a prelude to addressing the detail of individual construction and maintenance practices covered in subsequent chapters:

- The scope of work for this project wisely reflects the reality that the degree of commitment to environmental stewardship practices in construction and maintenance is rooted in the extent to which the organization's culture and policy framework have bought into environmental stewardship at a philosophical level. It is less likely that exemplary stewardship will be found among DOT staff and contractors engaged in construction and maintenance without such an organization-wide commitment.
- The linkage between what occurs on the front lines of work activity and the front office of policy making needs to be appreciated and understood by all who are involved and affected. Construction and maintenance staff and contractors are generally at home in an outdoor environment—both in their professional and their personal lives, and are perhaps more oriented toward environmental stewardship than we might think. However, they are chronically under-represented in the policy-making and planning activities of most agencies. It is particularly important that they have the benefit of understanding the environmental stewardship concept in its fullest context if they are to be significant contributors to its ultimate success.
- Construction and maintenance is where dirt moves, structures are put up, and pavements are laid down. This is where the impacts really happen. Some DOTs have learned the hard way that having the environmental stewardship concept securely embraced among policy planners, senior managers and environmental staff does not guarantee that what

happens in the field, on the jobsite, will be implementing the spirit or the letter of what was intended by policy or by planning and environmental commitments. It requires positive action facilitated by a durable linkage of communication and comprehension.

1.4. RESEARCH APPROACH

The research approach to this project was designed to accomplish the stated project goal of developing a compendium that would collect a wide range of stewardship practices in use in one convenient place. The study began with a review of literature available through the Transportation Research Information Service (TRIS) including over a thousand references related to construction, maintenance, and environmental aspects. This literature review was accompanied by a review of model BMP handbooks. According to a survey by the author, as of mid-2002, 19 state DOTs and Puerto Rico had developed BMP manuals of various sorts, ranging from herbicide application to erosion control, and in a few cases, broader environmental management practices. In most cases, states developed their policies and procedures independently, without the benefit of prototypes and best practices from leaders in the field. Model manuals, DOT procedures and practices were reviewed, were supplemented with interviews where necessary, and are the primary sources for the compendium of environmental stewardship practices included herein.

The author also drew upon her own experience as an environmental manager within a state DOT, working with resource agencies and their requests, as well as experience working with federal and state DOTs, resource agencies, and AASHTO as a consultant on environmental stewardship practice and process improvement. Previously unpublished research results of environmental practices at state DOTs, conducted in 2002, are also included. That effort reached all 50 state transportation agencies, plus the District of Columbia and Puerto Rico. The examples shared in this document include some previously discussed or written about by the author in other forums for FHWA, state DOT and multi-agency initiatives, TRB, the National Association of Environmental Professionals, AASHTO's Environmental Technical Assistance Program, and AASHTO's Center for Environmental Excellence. Best practices are also included from other relevant industries such as utilities, transit, and railroads; for example, the State University of New York was a key contributor with regard to their work with Integrated Vegetation Management for the utility industry. Stewardship practices from lead agencies in Canada and Australia are included as well; many members of the international community have taken environmental stewardship practice seriously for years, and can provide valuable leadership for state DOTs in the U.S., particularly in fields such as EMS implementation, wildlife and fish passage improvements, and salt management practices.

Environmental stewardship practices are described primarily by example in the section on Organizational Practices, including environmental policies, planning, performance measurement, tracking, staffing and training. Design, construction, and maintenance environmental stewardship practices are presented mainly as bulleted lists under various topic headings. Environmental stewardship practices are included under hundreds of categories. Given the size and scope of this endeavor and to streamline the length and size of the compendium, links to associated on-line resources are included whenever possible rather than including such procedures, guidance, forms, design drawings, and photos in the document. The Word version of this report contains thousands of these links, to facilitate DOT access to existing practice. A number of short examples and examples which cannot be easily located on the web are included throughout the document and in the Appendix.

The review process for various sections of the document included lead DOT practitioners as well as experts from university and research institutes, including the Recycled Materials Resource Center at the University of New Hampshire, the USDOT Volpe Research Center, the Turner-Fairbanks Highway Research Center, and the Center for Transportation and the Environment.

1.5. RESEARCH USES

This compendium of stewardship practices and procedures is designed to have a broad range of uses by the practitioner. It is anticipated that this material can be re-used and easily re-formatted into the following products that can be readily and practically applied by DOTs to improve environmental performance. The primary purpose of the project was to put the world of environmental stewardship practices and resources within much easier reach of the transportation professional. To help accomplish this, links to useful existing resources are included throughout the document. Practices and measures or indicators are primarily listed in bullet format, for easy use as checklists or in different stewardship practice media. Material is presented electronically, in Word, to facilitate re-use of the enclosed stewardship practices as:

- A menu of management or environmental stewardship practices.
- Short 1-2 page bulletins and tail-gate resources for construction and maintenance staff.
- Manuals, handbooks, or guides a DOT can tailor to their specific needs and requirements, or on specific topics of interest or priority.
- Checklists for inspection, evaluation, or benchmarking in various areas.
- Addition of environmental stewardship practices to construction and maintenance activity manuals.
- As proactive environmental stewardship commitments a DOT may incorporate or include in activity or project-specific permits or plans. As such, these practices may serve as a starting point for internal and external discussion.
- Newsletter articles or website overviews on environmental stewardship topics for a DOT.
- On-line resource at AASHTO’s Center for Environmental Excellence, that can be used as a reference with regard to:
    - Environmental Stewardship— How to do DOT work in environmentally sound ways.
    - Innovation — What’s being done in specific program areas and with reference to certain environmental issue areas. What has been effective?
    - Benchmarking — What are others doing and how do we compare?
    - Sharing ideas and experience.

1.6. DISCLAIMER/LIMITATION OF LIABILITY

DOTs are in the process of developing and implementing a wide range of environmental stewardship practices, which should never be viewed as complete. This effort is merely a compendium or wide-ranging overview or sample of practices that currently exist. The reader or user should note that the practices contained in this report should not be considered complete, sufficient, or all-inclusive. Gaps in environmental practice exist and the absence or omission of practices in certain lists does not mean that there are not further practices that could or should be employed.

DOTs are urged to develop and apply practices with consideration for what is appropriate in their own state, on particular projects, and in particular environments, with special attention to legal requirements and public and worker safety. The necessary permits and/or approvals for the operation a DOT is undertaking should always be obtained. The practices herein should not be construed to meet regulatory, safety, or other requirements; practitioners should consult with environmental and other specialty personnel in their own state to decide which practices are appropriate to use, what if any gaps remain, and how practices should be employed and remaining needs addressed. As this effort was intended to help states proactively steward the environment and not meet particular requirements in individual states, practices herein are presented as recommended actions or “should” (not “shall”) statements. Compliance with all legal and safety requirements and avoidance of any sort of negligence, and the responsibility for identifying and implementing appropriate practice to achieve or maintain such performance, remains the responsibility of DOT staff and associated regulatory agencies. DOTs, DOT staff, and resource agency associates who may use this work are entirely responsible for how they choose and apply environmental practices, whether included in this report or not, and for ensuring that all appropriate environmental practices are applied and standards are enforced.

This document should be viewed as a starting point for DOTs, to increase exposure to and utilization of a range of environmental stewardship practices in use or under consideration. It is hoped that as a starting point, DOTs will find ways to use and continue to update and extend this resource and fill the inevitable gaps, accelerating environmental stewardship and implementation of environmental practice across the country. A separate implementation plan addresses these aspirations.

CHAPTER 2: ORGANIZATIONAL ENVIRONMENTAL STEWARDSHIP PRACTICES

2.1. ENVIRONMENTAL POLICIES AND STRATEGIC PLANNING

An increasing number of DOTs are investigating and applying system-level management, environmental performance improvement, and decision-making processes. These take many forms, but most involve elements of strategic planning. Strategic planning is simply a set of concepts, procedures, and tools designed to help leaders and planners think and act strategically; the process is more important than the form that it takes.(*2*) Strategic planning usually involves visioning and setting goals, identifying objectives/priorities and actions, tracking performance, and re-evaluating. As of 2002, about a quarter of state transportation agencies had a strategic, agency-wide plan or process in place for improving environmental quality and performance.(*3*) Environmental management systems are an increasingly common form for this effort.

Environmental Policies and Mission Statements

Many state DOTs have begun to include environmental commitments in their organization's overall mission and policies. Recently revised DOT mission statements usually reference the agency's commitment to maintaining the state's quality of life, and may explicitly mention the environment. Environmental policy statements are typically more lengthy expressions of a DOT's environmental commitments. Both usually extend to the organization as a whole, and include construction and maintenance.

Typical environmental policies state the agency's recognition of the importance of environmental stewardship and commit the DOT to environmental protection, achieving or surpassing regulatory requirements, and/or contributing to environmental enhancement. Some reference a shift in values and organizational structure. Environmental policy statements written with an awareness of EMS requirements often include commitments to pollution prevention, efficient use of resources, evaluation, and continual improvement. Others commit the DOT to incorporating sound environmental practices into all parts of the agency's work, communicating expectations, and partnering or collaborating with other agencies and entities on achieving environmental goals of mutual interest.

Environmental policy statements provide a basis and core reference point for the other elements of state DOT environmental management systems and other environmental stewardship initiatives. Highlights from state DOT environmental policies and commitment statements are included below. Examples of environmental policies from these are listed in the Appendix.

Delaware DOT's Environmental Mission and Commitment to Implement a "Livable Delaware"

Delaware DOT (DelDOT)'s mission to provide a safe, efficient and environmentally sensitive transportation network. DelDOT is also involved in implementing a "Livable Delaware that strengthens communities and preserves quality of life." The Governor's "Livable Delaware" Executive Order seeks to actively manage where growth will physically occur and to accommodate a faster projected population growth rate than any northeastern state. Goals which DelDOT is responsible to help implement include: (*4*)

- Direct investment and future development to existing communities, urban concentrations, and growth areas.
- Protect important farmlands and protect and improve the state's land, air, and water and critical natural resource areas.
- Promote mobility for people and goods through a balanced system of transportation options.
- Coordinate public policy planning and decisions among state, counties and municipalities.

Florida DOT's Environmental Mission

Florida DOT also elevated the agency's environmental commitment to inclusion in its one sentence mission statement. FDOT's mission commits the agency to "provide a safe transportation system that ensures the mobility of people and goods, enhances economic prosperity, and preserves the quality of our environment and communities."(*5*) Florida DOT's environmental policy is a more expansive expression of the commitment expressed in the agency's mission statement.(*6*)

Maryland State Highway Administration's Environmental Mission

The Maryland State Highway Administration's (SHA) mission is to provide their customers with a safe, well-maintained and attractive highway system that offers mobility and supports Maryland's communities, economy and environment. The agency's primary goal is to maintain excellence in the natural and human environment that it serves. The key elements of MDSHA's environmental policy are to: (*7*)

- Meet or exceed all environmental laws and regulations applicable to SHA activities.
- Incorporate and integrate environmental protection and enhancement measures in planning, design, construction and operations.
- Protect and enhance all aspects of the natural and human environment whenever possible, using available state-of-the-art practices.
- Support advancement in environmental protection technology through innovation and technology transfer.

New Jersey DOT Environmental Policy Statements

New Jersey's (NJDOT) environmental policy commits the Department and its employees to act as "responsible stewards of the environment" and "find ways to improve New Jersey's environment and the quality of life of its citizens, within its funded responsibilities for planning, design, construction, maintenance, and operation of our transportation network."(*8*)

New York State DOT's Environmental Mission

New York State DOT (NYSDOT) has incorporated the agency's environmental commitments into their agency's mission "to ensure our customers — those who live, work and travel in New York State — have a safe, efficient, balanced and environmentally sound transportation system." As part of this mission and as New York State's largest public works agency, NYSDOT has publicly expressed their obligation and responsibility to the people of New York to enhance, improve and protect the environment in accordance with state policies and objectives. Notably, the state DOT initiated a proactive approach and environmental initiative to advance state environmental policies and objectives, promote an environmental ethic throughout the Department, and strengthen relationships with environmental agencies and groups. "As an action-oriented agency, DOT can most effectively attain these goals by doing dedicated environmental work in support of its corporate environmental ethic. This, in turn, will advance a shift in attitudes. This will provide real environmental protection, assure staff that the agency has a strong environmental ethic and provide opportunities to engage the environmental community in positive joint undertakings that will demonstrate the Department's commitment."(*9*)

NYSDOT's environmental policy is available online. It commits the agency to become an "acknowledged leader" and gives notice that "Departmental operations, facilities and properties will be audited to ensure that the Department is conducting its business in keeping with our environmental stewardship values."(*10*) NYSDOT's initiative, procedures, and actions will be described in greater detail elsewhere in this report.(*11*)

Kentucky Transportation Cabinet's Environmental Policy

The Kentucky Transportation Cabinet's environmental policy expresses the agency's commitment "to protect, conserve, restore, and enhance the natural and human environment" in the context of the Cabinet's work, work in partnership with the public and other agencies.(*12*)

Maine DOT Environmental Policy Statement

The concept of environmental soundness is part of the Maine Department of Transportation (MDOT)'s core vision or mission statement. MDOT was also one of the first to develop and sign an environmental policy statement, which now serves as a basis for the agency's EMS.(*13*) Maine DOT's Environmental Policy is included in the Appendix.

Mn/DOT's Commitment to "Context Sensitive" Approaches

It is Mn/DOT's policy to use a "Context Sensitive" approach to create excellence in transportation project development - an approach that incorporates design standards, safety measures, environmental stewardship, aesthetics and community sensitive planning and design. Mn/DOT Technical Memorandum No. 00-24-TS-03 outlines the department's commitment to CSD. The agency is incorporating context sensitive solutions into all aspects of transportation project development—planning, design, construction, and operation—through new policies, extensive research, and training programs.

North Carolina DOT and Environmental Stewardship Policy

The North Carolina Board of Transportation adopted the NCDOT Environmental Stewardship Policy in 2002. The policy expresses the agency's commitment to "planning, designing, constructing, maintaining, and managing an interconnected transportation system while striving to preserve and enhance our natural and cultural resources." It stresses the importance of balancing daily operations and environmental responsibility and strongly encourages employees to incorporate the principles of safety, environmental stewardship, and customer focus into their daily activities.

PennDOT's Green Plan Policy

PennDOT's agency-wide "Green Plan Policy" extends beyond compliance to pollution prevention, continual improvement, and measurable performance. PennDOT's Strategic

Environmental Management Program (SEMP) efforts began with two key commitments by State and Department senior executives. At the state level, Executive Order 1998-1, the Governor's Green Government Council, called on the agencies of the Commonwealth to incorporate "…environmentally sustainable practices, including Strategic Environmental Management, into Commonwealth government's planning, operations, policymaking and regulatory functions, and to strive for continuous improvement in environmental performance with the goal of zero emissions. Strategic Environmental Management includes and environmental management system with a strong pollution prevention and energy efficiency program, effective community involvement, measurable economic and environmental performance goals, environmental accounting, and life cycle analysis."(*14*)

Washington State DOT's Environmental Policy

Washington State DOT highlights the agency's environmental commitment and lays the groundwork for an Environmental Management System (EMS), by including those elements required by the International Organization for Standardization (See further discussion in section on EMS). WSDOT's environmental policy statement is readily accessible off the agency's main page on their agency's website.

New South Wales (NSW) Roads & Traffic Authority (RTA) Environmental Policy

The New South Wales, Australia, Roads and Traffic Authority developed an environmental policy which serves as a basis for the Authority's EMS. (*15*) A copy is included in the Appendix. Directors of all functional areas within the RTA are signatories of the environmental policy, which was most recently signed and posted in 2001.

Standards and Performance Measures for Environmental Policy Statements

Environmental policy statements are a required part of an internationally acceptable environmental management system. Section 4.2 of ISO 14001 enunciates a standard set of best practices for environmental policy statements, which says an organization's environmental policy should contain a minimum of three environmental commitments:

- Continual improvement of system
- Compliance with legal or other voluntary, non-legal requirements
- Pollution prevention

Other criteria to consider in setting or evaluating the environmental policy may include:

- Does it address the environmental impacts and opportunities of the business?
- Does it set the course for the agency's environmental program, providing a framework for setting and reviewing environmental objectives or targets?
- Is it documented, implemented, maintained, and communicated to all employees? How is it used to build employee awareness across the entire agency? Is the environmental policy consistently followed? Is implementation periodically reviewed and revised?
- Is the policy available and accessible to the general public?
- Did management approve the current version when it was issued? Does management take ownership for whether and to what extent implementation is occurring?

- Did evidence show that significant impacts were considered when setting environmental objectives?

A recent evaluation of qualitative methods in policy analysis suggested evaluation of the following aspects as well: (*16*)

- Were the needs, values, views and subjective experiences of different stakeholders identified in the policy making process?
- Why, how, and under what conditions (and in which contexts) have the policies worked, or fail to work? What needed to occur in what order for a policy interventions to be successfully implemented?
- What measures or surveys could be employed to determine outcomes?

Staying Abreast of Legal and Other Requirements

One aspect of ensuring environmental stewardship involves maintaining an organizational awareness of legal and other requirements. As regulations are subject to change over time, and as new regulations are promulgated by regulatory agencies, periodic reviews of regulations should occur to stay current on compliance requirements. Likewise, facility operations can change over time, and must also be periodically reviewed to ensure that operations subject to regulation are conducted in compliance with such regulations. DOTs identify and maintain awareness of requirements in this constantly evolving context of regulations, industry standards or best practice, and community expectations. Legal requirements comprise the base minimum of the latter. Hence, some DOTs have developed specific processes for keeping construction and maintenance staff abreast of these changes.

In many cases, a DOT's central environmental office includes specialists who each keep abreast of regulatory changes (and often best practices in the field) in each of their specialty areas. Historically, AASHTO's Environmental Technical Assistance Program has assisted state DOT specialists in this area through the provision of regular newsletters devoted to keeping specialists informed of changes in their field. Now, a variety of on-line resources are increasingly available.

On a formal or informal basis, DOT specialists and/or DOT environmental managers usually ensure that regulatory changes are communicated upward or across their organizations to Regions or Districts, for further dissemination among maintenance, construction and environmental staff. Annual, quarterly, and/or monthly meetings provide other avenues for dissemination of important changes in regulatory requirements and environmental expectations. Frequently, annual trainings and refresher courses provide updates. (See training section for further details).

On-line Legal and Regulatory Resources

AASHTO's Center for Environmental Excellence presents a brief overview of environmental regulations in a variety of DOT functional areas and environmental media, along with recent regulatory developments at http://environment.transportation.org/indexnew.asp.

In 2003, EPA funded a new web-based Construction Industry Compliance Assistance Center (CICA center) developed in partnership with the Associated General Contractors of America, the American Road and Transportation Builders Association, and others. The website, http://www.cicacenter.org , provides plain-language explanations of applicable regulations, as well as links to state and local regulatory agencies. A 1999 EPA study found that out of approximately 60,000 construction starts that were subject to the stormwater control regulations, roughly two thirds lacked the necessary permits. While DOT environmental staff ensure their agencies have a much higher rate of compliance, the site's tools may still be useful to DOTs and contractors in particular. The environmental compliance tool at the site http://www.cicacenter.org/cs.cfm is designed to alert the user to environmental responsibilities and contracts specific to one's project and location. DOTs have developed similar tools as part of the project development and project screening process. Perhaps the most notable DOT tool nationwide for screening projects and identifying environmental issues, not just pertinent regulations, is the Florida DOT's Efficient Transportation Decision-making System. A process overview, guidelines, and tools are available at Florida DOT's Environmental Streamlining Library.

Mass Highway's Process for Staying Current on Environmental Requirements

Mass Highway's EMS manual discusses the environmental laws and regulations that apply to operations at maintenance facilities, and the procedures for identifying proposed and new regulatory changes that affect these operations. Mass Highway routinely reviews federal and state regulatory information sources to stay current on compliance requirements. The agency maintains an Environmental Requirements List, which identifies federal and state environmental regulations applicable to Mass Highway Maintenance Facilities and covers a wide variety of environmental compliance areas including Air Quality, Hazardous Materials and Hazardous Waste, Tanks, Waste Site Clean-up (21E) and Solid Waste Landfill Closure, Water Pollution Control/Underground Injection Control/Drinking Water Supply (Water Quality), Wetlands, and Asbestos. Mass Highway's procedure and roles and responsibilities for managing the Environmental Requirements Component of the EMS are described below, and may be used as a model for other state DOTs.(*17*)

Example 1: Mass Highway Process for Managing Environmental Requirements

Procedure

During the course of the year, the Environmental staff, as summarized in the following table, is responsible for monitoring proposed regulations and policies applicable to current Mass Highway operations. Regulatory monitoring may include but not be limited to periodic review of DEP, EPA and Federal Register websites for information on new or upcoming regulations. Also reviewed are the existing Codes of Massachusetts and Federal Regulations (CMRs and CFRs). Changes in facility operations will be identified through periodic inspections performed by DHC's and through regular communication between Highway Operations, District, and Environmental Section staff.

Environmental staff regularly report information to the Supervisor of the HazMat/HazWaste Unit, and/or the Supervisor of the Wetlands Unit regarding the status of changed or new regulations, or regarding identified changes in facility operations subject to regulation. The Supervisor of the HazMat/HazWaste Unit and the Supervisor of the Wetlands Unit in turn report regularly to the Deputy Chief Engineer Environmental regarding the regulation status and the potential effect on maintenance facility operations. The Supervisor HazMat/HazWaste Unit convenes periodic meetings with the DEP Regional and Policy staff to review pending regulatory changes that may affect Facility operations.

The Supervisor HazMat/HazWaste Unit determines whether revisions are needed to the Environmental Requirements List, and if so, requests approval from the Deputy Chief Engineer Environmental to revise the list and propose necessary changes to maintain compliance. The need for any additional equipment and resources is coordinated within the Department, as applicable. Upon receipt of the Deputy Chief Engineer Environmental directive, the Supervisor HazMat/HazWaste Unit prepares the necessary revisions, posts the revised Environmental Requirements List on the Mass Highway intranet, and informs the Environmental Section staff of the changes to the list and their respective implications on other EMS components.

Each year, the Supervisor HazMat/HazWaste Unit or other Designee coordinates a meeting to review the current Environmental Requirements List and Requirements Program procedures. The meeting will be convened with the Environmental Section Supervisors and Highway Operation's staff and Safety and Security staff between November and January to coincide with the Facility Environmental Handbook, Maps and Standard Operating Procedure review process. The criteria for the review include opportunities to improve effectiveness and efficiency. The Supervisor HazMat/HazWaste Unit collects the comments and reports recommended revisions to the Deputy Chief Engineer Environmental.

Roles and Responsibilities
The following table presents a summary of the roles and responsibilities for review and development of the Environmental Requirements List.

Role	Responsibility
Deputy Chief Engineer Environmental	Assumes ultimate responsibility for managing the requirements component of the EMS
Supervisor of HazMat/HazWaste Unit	Responsible for tracking and review of existing and proposed regulations and policies. Provides regular updates to the Deputy Chief Engineer Environmental on status of pending new regulations or changes to existing regulations or changes to facility operations subject to regulation. Ensures that the updated requirements list is incorporated into the facility self-audit protocol. Maintains current Environmental Requirements List and Requirements Procedure document. Convenes/coordinates annual meeting to review Requirements List and Requirements Procedure. Meets with DEP regional office and policy staff to discuss pending regulations that may affect Mass Highway maintenance facility operations.
Supervisor of Wetlands and Water Quality	Responsible for tracking and review of existing and proposed regulations and policies related to wetlands, waterways, and natural resource protection programs. Provides regular updates to the Supervisor HazMat/HazWaste Unit on status of pending new regulations or changes to existing regulations.
District HazMat Coordinators and Boston Environmental Section Staff	Responsible for review of regulations and policies as directed by the Supervisor of the HazMat/HazWaste Unit. Responsible for reviewing changes in facility operations and receiving input from District Maintenance Engineers concerning facility operational changes that could be subject to environmental regulation/policy. Provides regular updates to the Supervisor of HazMat/HazWaste Unit on status of pending new regulations or changes to existing regulations, or changes to facility operations subject to regulation.
Highway Operations Engineer, Maintenance Engineer and District Maintenance Engineers	Responsible for notifying Environmental Section staff concerning actual or anticipated changes in facility operations that should be reviewed for compliance with regulations/policies.

A number of other DOTs post and maintain information on environmental laws and regulations on-line, convey information at monthly meetings, or publish internal newsletters to keep those in the field abreast of regulatory changes and expectations. Caltrans has some excellent examples. In addition to the agency's notable stormwater pollution prevention bulletins for construction, post-construction, and maintenance, the agency offers a weekly one page newsletter on water quality issues and regulatory changes that can be accessed from Caltrans' on-line stormwater publications page.

Standards and Performance Measures for Organizational Awareness of Legal and Other Requirements

The importance of maintaining organizational awareness of legal and other requirements is recognized by international standards and is included in ISO 14001 section 4.3.2, which states that an "organization shall establish and maintain a procedure to identify and have access to legal and other requirements to which the organization subscribes, that are applicable to the environmental aspects of its activities, products or services.

Most commonly, DOTs track who in the organization has received various sorts of training, including environmental regulatory awareness training. Some DOTs are tracking the training of contractors now as well, as a mechanism for ensuring higher quality products and services.

In evaluating the organization's process for maintaining organizational awareness of legal and other requirements look for:

- Established ways or procedures to identify and understand legal requirements as well as changes to those requirements.
- Established ways or procedures to stay abreast of other requirements, commitments, or even industry best practice, if that is an organizational priority.
- Demonstrated access to and knowledge of changes in those requirements by the work force.

Identifying Environmental Aspects or Impacts of Operations

In order to identify areas of focus for environmental improvement efforts in construction and maintenance, some DOTs have undertaken planning processes to identify environmental aspects of their business, and which of those aspects have significant impacts on the environment and should be prioritized for future action. Environmental impacts of construction and maintenance activities may include surface or ground water contamination, degradation of air quality, noise or light pollution, use of raw materials and depletion of natural resources, production of wastes, spills to the environment, habitat or species reduction or extinction, human health impacts, and consumption of energy. Usually such impacts are under the control of the DOT or can be influenced by the DOT, in which case the next step is for the agency to explore: are the impacts significant? If so, the organization can plan to address and reduce those impacts if so desired.

In considering aspects of an agency's work and the potential significance of environmental impacts, the lifecycle of products may be considered, as well as historic, current and planned activities, and normal and emergency operating conditions. Environmental impacts may also be actually occurring or have the potential to occur. In evaluating the significance of impacts, an organization may consider severity (scale and duration), occurrence frequency or likelihood, detection and degree of control over that, potential costs, regulatory or legal exposure, impact on customers, effect on public image, effect on ability to expand or change operations, and loss of productivity. Some agencies have gone so far as to characterize and quantify their inputs and outputs in raw materials, air, land, water, visual, and noise, but decision-making regarding environmentally significant aspects and impacts of the business does not require this level of detail. The scope of investigation is up to the agency, though as in NEPA, the agency should be able to show consideration of existing data and stakeholder concerns.

At the broadest level, environmental aspect identification can touch on more remote areas that some stakeholders believe DOTs can influence, such as land use or land consumption, a measure used by Canada in assessing transportation sustainability (see discussion on sustainability indicators in section on monitoring and measurement). However, organizations control the scope of their aspect and environmental impact identification and the subsequent planning process. Washington State DOT, Maine DOT, New Hampshire DOT, and PennDOT have all undertaken processes to identify environmental aspects and impacts of their operations, to varying degrees.

Washington State DOT's Activity/Impact Analysis

WSDOT conducted an analysis to compare the department's present environmental management practices with those of the ISO 14001 standard and to identify gaps. WSDOT also conducted an Activity/Impact (i.e., "Aspects") Analysis, which included a series of workshops with WSDOT personnel. The report and database produced out of the workshops rank activities and impacts by various criteria (e.g., frequency of activity, whether positive or negative impact etc.) to aid WSDOT in further decision-making and prioritization with regard to environmental objectives. WSDOT noted that while sophisticated tools are available for aspects and impacts analyses, the final decisions still came down to two questions: what poses an immediate compliance risk and what poses the most significant long term environmental risk? (*18*)

NHDOT's Process for Identifying Significant Environmental Aspects of Operations—Traffic Bureau

New Hampshire DOT's Bureau of Traffic developed simple criteria to identify significant environmental aspects of operating the Department's Bureau of Traffic. The Bureau's procedure for identifying "aspects of activities, products, or services that constitute a significant impact upon the environment," requires consideration of: (*19*)

- Any activity of the Bureau that is expressly regulated by Federal or State laws, rules, or regulations.
- The use of an unregulated product that exceeds 100 gallons per year, or exceeds $10,000 in annual cost.
- Any operation that discharges to surface water any material in excess of 25 gallons, which is not immediately contained and removed within 24 hours, and that has an adverse impact on surface or groundwater.
- Any stream of solid waste that exceeds 2000 pounds a year.

The procedure further commits NHDOT, through the agency's EMS Implementation Team to regularly review and update environmental aspects:

- At least annually, review and update process flow diagrams illustrating each operation of the Bureau that generates a significant impact on the environment as defined in above.
- Review applicable legal and other requirements, as they apply to identifying significant aspects.
- Analyze all aspects of the Bureau's operations using the process flow diagrams, and other tools devised by management, such as the Significance Matrix, to assist them in identifying potential environmental aspects and impacts.
- After reaching a consensus as to the environmental aspects and impacts of their operations, and applying the significance aspect criteria, identify significant aspects of their operations.
- Develop a list of significant aspects. The list shall be reviewed at least annually to ensure that they are current and accurately reflect their operations.

PennDOT's Analysis of Environmental Aspects of Operations

PennDOT's analysis of environmental aspects of operations showed that Maintenance had the second highest potential environmental impacts after Construction. Maintenance comprises a substantial majority of PennDOT employees and the agency's operating budget. Consequently, PennDOT first tackled environmentally significant aspects of their operations in the maintenance area.

Three significant aspects scored highest in an analysis of concerns and impacts, which reviewed surface or ground water degradation, earth disturbance (erosion and sedimentation), floodplain alteration, resource consumption other than paper, waste generation and disposal, and air quality degradation (emissions of volatile and semi-volatile compounds). These three aspects provided the focus and starting point for PennDOT's pilot Environmental Management System:

- Winter services — controlling material usage associated with winter services.
- Stockpile and garage management — maintaining and operating these facilities.
- Highway maintenance — controlling and preventing erosion and sedimentation during roadside maintenance activities.

NSW RTA Environmental Assessment of Construction, Operation, and Maintenance Activities

The New South Wales, Australia, Roads and Traffic Authority (RTA) undertakes environmental impact assessments for its construction, operation, and maintenance activities, in addition to project development. The RTA has committed to addressing environmental aspects in all of its activities and to continuously improving the authority's environmental performance. A primary vehicle for accomplishing this commitment is the RTA-wide environmental management system (EMS), which "provides a structured management system to achieve and demonstrate our environmental performance."(*20*) A Review of Environmental Factors is an internal RTA document prepared to identify and consider environmental impacts, and from which environmental measures may be required.

Standard maintenance activities are assessed on a regular basis, usually annually.(*21*) Other maintenance activities are assessed in a similar way to construction activities.(*22*) For maintenance by contract, requirements for environmental impact assessment are to be incorporated in contract requirements and reviewed by the RTA.(*23*) The following tables summarize construction and maintenance activities and associated environmental aspects and impacts at the NSW RTA.

Table 1: Maintenance Activities and Associated Environmental Aspects and Impacts at the New South Wales, Australia Roads and Traffic Authority (NSW RTA)

ACTIVITY/FACILITY (and related issues)	ENVIRONMENTAL ASPECT (part of activity that could have an impact on the environment)	ENVIRONMENTAL IMPACT (possible effect on the environment)
Resealing (sealed road) *- stockpile management* *- chemical containment*	Possible sedimentation and erosion Waste generation Noise generation Dust generation Potential for explosions Odour generation	Soil/ water pollution Waste disposal Noise pollution Air pollution

ACTIVITY/FACILITY (and related issues)	**ENVIRONMENTAL ASPECT (part of activity that could have an impact on the environment)**	**ENVIRONMENTAL IMPACT (possible effect on the environment)**
	Potential for leaks and spills	
Concrete saw cutting	Dust generation Noise generation Waste generation Wastewater generation	Air pollution Noise pollution Waste disposal Water pollution
Grading (unsealed road) *- vegetation protection* *- drainage*	Waste generation Dust generation Possible sedimentation	Waste disposal Air pollution Water pollution
Resheeting (sealed road)	Disturbance to vegetation Soil disturbance Generation of debris Generation of dust Generation of solid waste	Destruction of vegetation Spread of weeds Waste disposal Air pollution
Drain maintenance *- clean table drains* *- clean benches on a cut*	Vegetation disturbance Possible erosion/sedimentation	Destruction of vegetation Water pollution
Roadside maintenance, painting/replacement: *- guide rails* *- signposts* *- fencing* *- noise walls*	Vegetation disturbance Waste generation Potential for paint leaks and spills Disturbance of natural environment	Destruction of vegetation Waste disposal Water/soil contamination Aesthetics
Pavement sweeping	Waste generation Generation of dust	Waste disposal Air pollution
Illegal dumping *- waste storage and disposal* *- licences*	Dumping of waste	Soil contamination Water pollution
Landscape works maintenance *- herbicide use* *- chemical storage*	Damage to flora Potential spread of weed Potential batter erosion Potential leaks or spills Waste generation	Destruction of vegetation Aesthetics (weed die off) Noxious weed spread Water pollution Soil/water contamination Waste disposal
Vegetation management *- waste management* *- herbicide spraying* *- tree cutting*	Damage to flora Use of herbicides/pesticides Potential spread of weed “green” waste generation	Destruction of vegetation Aesthetics (weed die off) Noxious weed spread Waste disposal Soil/water/air pollution
Roadside rest area maintenance	Litter removal and collection Syringe collection	Waste disposal Medical waste disposal
Bridge maintenance *- flaming off bolts/decking* *- resurfacing with tar/aggregate* *- fuel storage* *- plant/vehicle parking* *- oxyacetylene storage/use*	Generation of hazardous/non-hazardous waste Air emissions Potential for spills/leaks	Waste disposal Air pollution Water/soil contamination
Paint removal	Waste generation (paint flake)	Waste disposal

ACTIVITY/FACILITY **(and related issues)**	**ENVIRONMENTAL ASPECT** **(part of activity that could have an impact on the environment)**	**ENVIRONMENTAL IMPACT** **(possible effect on the environment)**
	Wastewater generation Waste ends up in natural environment Dust generation	Water/soil contamination Air pollution
Wood treatment (creosoting) *- use of chemicals* *- chemical storage*	Potential for leaks and spills	Chemicals in natural environment Soil/water contamination
Line mark removal (grinding)	Sedimentation Noise generation Dust generation	Water pollution Air pollution Noise pollution
Loop Cutting (asphalt road)	Dust generation Wastewater discharge (sediments & oil, fuel) Noise generation Waste generation	Air pollution Soil/water contamination Noise pollution Waste disposal
Septic tank *- maintenance*	Potential leakage Generation of septic tank waste	Soil/water contamination Waste disposal
Road milling	Dust generation Waste generation Sedimentation Odour generation Noise generation	Air pollution Waste disposal Water pollution Noise pollution
Cleaning plant & equipment	Soil compaction Noise production Discharge of exhaust gasses Generation of wastewater from washing Potential for spreading weeds through machinery Potential for spills (fuels, oils etc)	Damage to trees and plants Local noise pollution Air pollution Soil/water contamination Weed spread

Table 2: Construction Activities and Associated Environmental Aspects and Impacts at the NSW RTA

ACTIVITY/FACILITY **(and related issues)**	**ENVIRONMENTAL ASPECT** **(part of activity that could have an impact on the environment)**	**ENVIRONMENTAL IMPACT** **(possible effect on the environment)**
Clearing vegetation *- protection of specific native vegetation* *- revegetation* *- stockpiling topsoil* *- relocation of trees*	Damage to vegetation Dust generation Generation of noise Potential for sedimentation and erosion “green” waste generation Potential killing of fauna	Destruction of vegetation Noxious weed spread Air pollution Local noise pollution Water pollution Waste disposal Impact on fauna
Site compound and facilities *- location of compound* *- reinstate area (landscaping)* *- storage of fuel, oil and chemicals*	Clearing vegetation Potential for spillage and leaks Waste generation	See above Soil/water contamination Waste disposal
General equipment storage and use *- washing machines*	Soil compaction Noise production	Damage to trees and plants Local noise pollution

ACTIVITY/FACILITY (**and related issues**)	**ENVIRONMENTAL ASPECT** (**part of activity that could have an impact on the environment**)	**ENVIRONMENTAL IMPACT** (**possible effect on the environment**)
	Discharge of exhaust gasses Generation of wastewater from washing Potential for spreading weeds through machinery	Air pollution Soil/water contamination Weed spread
Topsoil management and stockpiles *- respreading of topsoil* *- sediment and erosion control* *- location of stockpiles* *- revegetation of temporarily stockpiles*	Stockpiling of weed infested topsoil Possible generation of contaminated soil Generation of waste soil Potential for spreading of material on windy days Potential sedimentation, leaching and run-off of material	Noxious weed spread Soil disposal Waste disposal Air pollution Soil/water pollution
Drainage and sediment control works *- legal requirements* *- sedimentation basin maintenance* *- silt fence maintenance* *- sediment tracking*	Potential for erosion Generation of waste silt Use of straw bales	Water pollution Disposal of silt Weed spread
Earthworks *- waste management* *- erosion and sediment control* *- aboriginal archaeology*	Dust generation Generation of noise and vibration Possible generation of contaminated soil Generation of waste Possible sedimentation and erosion Possible destruction of indigenous and non-indigenous artefacts	Air pollution Local noise pollution Soil disposal Waste disposal Water pollution Impact on heritage relics
Batter stabilisation *- revegetation* *- erosion control*	Noise generation Dust generation Potential for erosion and sedimentation Potential for spills Use of unnatural material	Local noise pollution Air pollution Water pollution Soil/water contamination Visual impact
Bridgeworks	Potential watercourse bank erosion Potential for construction runoff and sedimentation Potential change of stream flow	Water pollution Water pollution To water fauna and flora
Paving Operations	Generation of noise and vibration Dust generation	Local noise pollution Air pollution
Waste Management *- recycling* *- reuse* *- good housekeeping*	Potential for leaks and spills Generation of waste Reuse or recycling	Soil/water contamination Waste to landfill Conservation of resources
Rock Blasting	Generation of noise and vibration Dust generation	Noise pollution Air pollution
Woodchipping	Generation of noise Dust generation Stockpile management	Local noise pollution Air pollution

Standards and Performance Measures for Identifying Environmental Aspects and Impacts

The international standard for this process, ISO 14001 section 4.2.1, states that "[t]he organization shall establish and maintain procedure(s) to identify the environmental aspects of its activities, products or services that it can control and over which it can be expected to have an influence, in order to determine those which have or can have significant impacts on the environment." Furthermore, the organization is expected to use that information in setting its environmental objectives and make sure that information on the organization's evolving activities and potential environmental impacts is kept up to date. Thus, an EMS auditor or an organization's environmental planning process would look for:

- Procedure for identifying aspects and periodically reviewing them.
- Evidence that aspects under normal, abnormal and emergency conditions were identified.
- Cause and effect relationships between processes, aspects and impacts.
- Consistent method of determining and assigning significance to impacts.

Organization Wide Strategic Planning for the Environment

DOTs have undertaken a variety of plans to improve environmental performance and prioritize where to focus their attention and resources. About a quarter of state transportation agencies have an agency-wide plan or process in place for improving environmental quality and performance, though only a handful of states have launched ISO14001 process or other processes for continual environmental performance improvement.(*24*)

Strategic planning determines where an organization is going over the next year or more, how it is going to get there and how it will know if it got there or not. Far more important than the strategic plan document, is the planning process itself. An organization's strategic planners already know much of what will go into a strategic plan or business plan; however, development of the strategic plan greatly helps to clarify the organization's plans and ensures that key leaders are all "on the same script."

In 1982, Olsen and Eadie defined strategic planning as a disciplined effort to produce fundamental decisions and actions that shape and guide what an organization is, what it does, and why it does it.(*25*) Like the NEPA process, strategic planning requires information gathering, an exploration of alternatives, and an emphasis on the future implications of current actions. The process has the potential to facilitate communication and participation, accommodate divergent interests and values, and foster orderly decision-making and successful implementation.(*26*)

Strategic planning can help an organization: (*27*)(*28*)(*29*)

- Think strategically and develop effective strategies.
- More systematically collect information about an organization's internal and external environment and various stakeholder interests.
- Improve organizational learning.
- Clarify future direction and purpose.
- Establish organizational priorities for action and goals and objectives consistent with mission, and define a timeframe within the organization's capacity for implementation.
- Formulate and clearly communicate strategic intention.
- Improve decision-making and the basis for it, with attention to the crucial decisions an organization faces.

- Provide a base from which progress can be measured and establish a mechanism for informed change when needed.
- Enhance performance and improve responsiveness in rapidly changing circumstances.
- Exercise maximum discretion in the areas under organizational control.

A reasonably structured and formalized planning process helps organizations gather the information necessary for strategy formulation and implementation. Like all organizational initiatives, strategic planning requires skills, resources, and commitment. Though both strategic planning and organizational long-range planning are focused on improving organizational performance, strategic planning differs from long-range planning in its focus on identifying and resolving issues.

Some state transportation agencies have sought to elevate attention to environmental concerns by incorporating environmental elements into the agency's overall Strategic Plan. State DOTs that have indicated they have a form of environmental strategic plan other than an EMS include Arizona, Indiana, Kentucky, Louisiana, Maryland, North Carolina, New Mexico, New York, South Carolina, Utah, and Virginia.(*30*)

New York State DOT's Environmental Initiative

NYSDOT's Environmental Initiative began in 1998 with the creation of the Environmental Initiative Statement and announcement of the initiative by the Governor. As New York State's largest public works agency, "NYSDOT affirmed its obligation and responsibility to the people of New York to protect, improve and enhance the environment;" the purpose of the initiative is to "use the organizational strengths of the Department to make an affirmative contribution to the environment" and "become an important part of the State's environmental solution…join(ing) with environmental agencies in a common purpose to advance State environmental programs."(*31*)

NYSDOT's Environmental Initiative has five major objectives: (*32*)

1. *Promote and strengthen an environmental ethic throughout the Department.* Staff should feel a responsibility to leave our project sites in better condition than we found them and look for opportunities to enhance New York's environment.
2. *Advance State environmental policies and objectives with NYSDOT resources.* Advance environmental policies as part of the Department's normal work. Fund environmental benefit projects including: stormwater retrofits, wetland restorations, habitat enhancements, recreational access, informational signs, landscaping and environmental research.
3. *Partner with others to construct environmental enhancements.* Pursue opportunities for joint development and incorporate environmental elements or facilities funded by other agencies, municipalities, or environmental groups into NYSDOT construction and maintenance projects. NYSDOT provides design and construction engineering support.
4. *Pilot new environmental protection and enhancement methods.* Cooperatively research and pilot new methods to: reduce environmental toxins, improve air quality, increase the use of recycled materials, etc.
5. *Strengthen relationships with environmental agencies, organizations, and local municipalities*. Improve communications, streamline permitting, share program

information and conduct joint training. Gain their confidence in NYSDOT's ability to self regulate.

The initiative has created new areas of practice and expectation for NYSDOT, including the following: (*33*)

- Coordinate and communicate closely with State and federal resource agencies to identify opportunities to advance State and federal environmental policies, programs and objectives.
- Ensure that all necessary steps are taken in planning, design and construction to avoid and minimize adverse effects of transportation projects and operations on important elements of the environment and adjacent communities.
- Proactively plan, design, construct and maintain transportation projects in an environmentally sound manner using context sensitive design to meet transportation needs while at the same time protecting, conserving, restoring or enhancing important natural and man-made resources. Context sensitive design is the proactive approach to design that looks at the project within the context of its site, while gathering and including the public's input throughout the design process.
- Incorporate into DOT capital and maintenance projects specific design features or facilities to mitigate unavoidable adverse impacts to the environment.
- Consider and implement, as appropriate, measures to enhance natural and manmade resources above and beyond project-specific permit and mitigation requirements.
- Incorporate, where practicable, environmental projects funded by local agencies or groups into ongoing NYSDOT projects as "Environmental Betterments."
- Promote an environmental and context sensitive design ethic within all Department organizations.

To accomplish the above, NYSDOT has instituted a comprehensive process improvement program in planning, design, construction, maintenance and operation of transportation facilities, developing environmental quality assurance/control procedures and tracking performance. All Region and Main Office program areas are responsible for identifying and implementing specific actions in their areas of responsibility to incorporate the Environmental Initiative into their operating and business practices. Regions and Main Office program areas have developed Environmental Initiative Action Plans based on the goals and objectives of the Initiative and recommendations from NYSDOT's Environmental Analysis Bureau (EAB); each identifies and defines discreet tasks, schedules for accomplishing these tasks, and responsibility for each task to ensure completion. Progress on these plans is tracked monthly.

NYSDOT Regional Directors also meet regularly with their counterpart New York State Department of Environmental Conservation (NYSDEC) Regional Directors to discuss progress under the Environmental Initiative, review NYSDOT's five-year capital construction and annual maintenance program, and identify opportunities to improve resource protection and enhancement practices. NYSDOT Regional Landscape/Environmental Managers meet monthly, or as mutually agreed upon, with their NYSDEC counterparts to discuss progress, to identify specific opportunities to include resource protection and enhancement practices in NYSDOT projects, and to update lists of contact people.

The Environmental Initiative has also been identified as a component of the Department's annual

Capital Program Update process. Regional Planning and Program Managers are required to include Environmental Initiative projects on their updated capital transportation program. Regions are requested to identify those projects that have environmental or context sensitive design work which goes above and beyond regular mitigation or permit requirements. Any external coordination that has occurred with outside agencies or interested groups is also identified. The agency is working with other agencies and the public to discuss and extend NYSDOT's stewardship efforts.

NYSDOT has found it is important to communicate results to the public, government officials, and regulatory agencies and to recognize employee achievements. This helps build employee "buy-in" and input and provides a foundation for enhanced relationships (and shortened review schedules and costs) with external parties. As a result of the agency's commitment and effort, NYSDOT has gained stronger, more positive working relationships with external agencies, citizens, local municipalities and other environmental groups, which in turn have avoided costs by reducing delay, litigation, frustrating rework, and wasted effort arguing contentious issues. Gary McVoy, Former Director of the Environmental Analysis Bureau, now Director of Transportation Maintenance Division said, "The environmental ethic has permeated into the planning, design, construction, maintenance and operations of transportation systems. The Department is now doing business differently instead of progressing a new concept. The Environmental Ethic is more than a vocabulary change or a volunteer effort — it's an integral part of DOT procedures."(*34*) Cultural change within the Department is revealed by NYSDOT's level of management support and executive leadership in conveying the environmental ethic and delivering new environmental staffing resources during a time of overall agency downsizing.

NYSDOT's pioneering commitment to environmental enhancement has made the Department a national model in the field. New York State won AASHTO's first Environmental Best Practices Competition, as well as AASHTO's President's Award, gaining an unprecedented endorsement as a leader in the delivery of environmentally sound transportation services. Department-wide environmental policies and objectives have provided the foundation on which an EMS can be based, including:

- NYSDOT Environmental Policy (MAP 1.6-3)
- Environmental Initiative Guidelines and Procedures (EI 99-026)
- Context Sensitive Solutions Engineering Instruction (EI 01-020)
- Environmental Handbook for Transportation Operations

MDSHA Environmental Strategic Plan and Management Systems

Maryland State Highway Administration (MDSHA)'s Four Year, Managing for Results (MFR) Business Plan is updated annually and acts as the agency's roadmap by focusing on eight Key Performance Areas (KPA) for achieving the agency's mission. Environmental responsibility, stewardship, and community enhancement are key performance areas, receiving a high degree of attention from the Administrator. A central environmental stewardship council consisting of the Administrator and members from construction, maintenance, design, planning, project development, and traffic is working on development of an Environmental Stewardship Strategic Plan. The council sets goals, business plans, and action items and oversees progress and plan refinement. Their goal is to continuously sustain and improve program delivery and environmental stewardship and integrate environmental stewardship into all SHA organizations and activities. The business plan has provided MDSHA an avenue to ensure a funding stream to achieve the stewardship goals in these key performance areas; decisions are made to meet agency priorities encompassed in the business plan goals.(*35*) MDSHA's objectives, targets, and measures are detailed in later sections.

MDSHA leadership has charged all of its offices and districts to use the 2000—2004 Business Plan as a guide to formulate each area's local business plan. The local plans are made up of goals and objectives that closely relate to day-to-day activities in a way that each employee can see his or her role in achieving the goals and objectives outlined in the Business Plan. In conjunction with the business planning process, all offices and districts will implement a stewardship program by the end of 2004. As part of their local business plans, offices are already recycling paper, reducing energy usage, protecting trees, and reducing mowing. Having achieved an excellent track record in permit and environmental compliance, MDSHA is now focusing on proactive environmental improvements and community enhancement. MDSHA's Environmental Stewardship goal not only requires mitigation of environmental impacts but also seeks to create, restore, and/or preserve greenways and other natural settings wherever possible.

The business plan requires quarterly reports and quantification of accomplishments, in order to create a larger, organization-wide picture. In addition to stewardship efforts of offices and districts, MDSHA is undertaking a deeper examination of stewardship opportunities by functional areas. Senior managers will participate in a review of what their functional area is doing in each environmental resource area, and then set commitments and goals for the future, prioritize, and set a timeline for accomplishing those. MDSHA anticipates having a framework in place for the latter and a system for developing the elements or action items and tracking progress by July 2004. MDSHA is considering hiring a coordinator to supplement the efforts of the stewardship core team and especially to coordinate reporting and tracking. MDSHA also anticipates further refinements to currently used measures; for example, the agency has been tracking recycling but not any corresponding reductions in resource usage.

Communication of agency environmental priorities has been a key element of success. The Administrator is leading the way with establishing expectations for 100 percent compliance in implementation and maintenance of all erosion and sedimentation control measures in construction. When MDSHA revisited its mission, vision and values, and updated its Four Year Business Plan, a copy was sent to each MDSHA employee with an introductory letter from the Administrator. This letter explained how the Business Plan was developed and what changes have been made. For the first time, MDSHA also distributed a copy of the Business Plan to external customers, to share MDSHA's goals and encourage a partnership approach to achieve their organizational objectives. MDSHA also displays a poster of their mission, vision and values in each office; and on their intranet site; as well as through columns such as *MDSHA Values* and *Parker's Podium* in *Maryland Roads*, an MDSHA-wide publication.

Delaware DOT's Plan to Support Smart Growth and Implement a "Livable Delaware"

DelDOT's Statewide Long Range Transportation Plan and overarching strategy utilizes a Transportation Investment Areas (TIA) Map developed as part of Delaware's "smart growth" and "livable communities" commitment. The TIA Map was developed to define and direct the varying level of investment the Department would make throughout the State to support "Shaping Delaware's Future." The TIA Map places all areas of Delaware into one of three classifications: Multimodal Investment Area, Management Investment Area, or Preservation

Investment Area. Behind each of these areas is an underlying philosophy describing how the Department will provide transportation facilities and services. For example, Preservation Areas were defined as areas where growth and development did not exist and was not being encouraged. As such, the transportation system in these areas would be maintained and kept safe but not necessarily expanded. As a unitary state policy, the Cabinet Committee on Statewide Planning Issues expanded the TIA Map to create a more gradual flow from one type to the next and described how all types of infrastructure, not just transportation infrastructure, would be provided. DelDOT said, “to this point, the TIA Map has served the Department well. It continues to be used to define how Department initiated plans and projects are developed, how the Capital Improvement Program is developed, and how the Department reviews and responds to regional, county and local development actions and long range transportation plans. The Plan and TIA Map support the following Livable Delaware goals:

- Direct investment and future development to existing communities, urban concentrations, and growth areas.
- Protect important farmlands and critical natural resource areas.
- Streamline regulatory processes and provide flexible incentives and disincentives to encourage development in desired areas.
- Encourage redevelopment and improve the livability of existing communities and urban areas, and guide new employment into underutilized commercial and industrial sites.
- Promote mobility for people and goods through a balanced system of transportation options.
- Coordinate public policy planning and decisions among state, counties and municipalities.

The plan update will “focus on how DelDOT’s goals, strategies, policies, and actions need to change to reflect what was done under the existing plan and to support the Strategies for State Policies and Spending” and Livable Delaware.” Measures for success will include the percentage of capital projects appropriate for the investment area they are being done in, as identified by the “Strategies for State Polices and Spending.” The agency is continuing to assess travel times, customer satisfaction, and “the level to which people understand and agree with the way that we are building, running, and maintaining their transportation system.”

DelDOT’s Corridor Capacity Preservation Program and Prioritization Process for CIP projects are being used to achieve the state goal to “direct investment to existing communities and growth areas.” The Corridor Preservation Program is based on maintaining rural areas, while limiting growth to those areas designated under Livable Delaware and the State Investment Strategies and involves cooperation among state agencies, key cities and counties, and The Nature Conservancy. As indicated in the “Strategies for State Policies and Spending” document, in rural areas “transportation projects will include only necessary drainage, maintenance and safety improvements, and programs to efficiently manage regional highway facilities.”(SSPS, 1999). Also, the pool selection criteria for projects in DelDOT’s existing pipeline are being revised to incorporate Livable Delaware’s goals and strategies. Toward the goal to “protect important farmlands and critical natural resources,” DelDOT will marshall their policy on sale and disposal of excess land, their wetlands mitigation banking, and scenic highways programs.

The agency has also moved ahead with "Mobility Friendly Design Standards" and is encouraging redevelopment and improving the livability of existing communities through revised policies for Context Sensitive Design, Traffic Calming, Transportation Enhancements, and the Roadside Environment. DelDOT's context Sensitive design policy (D-07) became effective on June 30, 2001. The Context Sensitive Design Policy sets aside five percent of project construction costs for improvements to the community or environment immediately adjacent to all system expansion and system management projects. This policy provides a mechanism through which the Department can respond to quality of life issues, such as aesthetics and enhancement measures for farmlands and critical natural resources, not normally addressed through a transportation improvement. A Maintenance Policy is being developed to establish responsibility for care of amenities included as a result of this policy. The policy also allows DelDOT to enter into a formal agreement with the affected community to combine funding, contributions, work, or services, at the request of the community, for coordination purposes or to achieve economies of scale. As a measure to guide progress, DelDOT is tracking the Number and percentage of new projects developed using the five percent set aside. Conduct a follow-up customer satisfaction survey, another to wrap-up our project to determine whether the affected community is satisfied with the results.

NCDOT's Use of Baldrige as an Environmental Management Framework

In recent years, the North Carolina Department of Transportation (NCDOT) has taken remarkable strides in encouraging and allocating resources for environmental stewardship and streamlining. Specifically, NCDOT has institutionalized and heightened the importance of environmental stewardship through policy, organizational structure, strategic planning, process improvement and partnering. NCDOT is committed to providing for North Carolina's transportation needs while protecting the State's environmental resources (see policy—NCDOT Environmental Stewardship Policy). Environmental stewardship within NCDOT became a primary focus in 1999 when NCDOT's Strategic Plan for Transportation was developed and adopted through public and stakeholder input. The plan outlines numerous goals that reflect stewardship of the human and natural environments. NCDOT was subsequently designated by the Federal Highway Administration as a "TEA-21 Environmental Streamlining Laboratory," serving a model for other states.

The approach NCDOT is using to achieve environmental excellence throughout the organization began with the creation of an inventory of approximately 150 institutional and program environmental-related initiatives underway at that point, in addition to future initiatives under consideration due to issues related to project delivery and environmental decision-making. This inventory identified stakeholders, the impetus for the initiative, initiative goals and objectives, performance measures, and the amount and type of resource allocation. Each initiative was categorized using Malcolm Baldrige criteria as a way of determining the breadth of current activity in certain focus areas.

The Malcolm Baldrige model is a tool used by thousands of organizations and companies to improve overall organizational effectiveness. NCDOT used the following Baldrige criteria as an environmental stewardship and management framework to inventory and assess what the agency is currently doing, and to identify gaps that exist and improvements that could create a significant return on the agency's investment.

- **Leadership** - How senior executives guide the organization and how the organization addresses its responsibilities to the public and practices good citizenship.
- **Strategic planning** - How the organization sets strategic directions, determines key action plans and translates the vision into action.
- **Information and analysis** - The management, effective use, and analysis of data and information to support key organization processes and decision-making.
- **Process management** - Aspects of how key production/delivery and support processes are designed, managed, and improved.
- **Human resource focus** - How the organization enables its workforce to develop its full potential and how the workforce is aligned with the organization's objectives.
- **Business results** - Organization's performance and improvement in its key business areas: customer satisfaction, financial performance, human resources, partner performance, and operational performance.
- **Customer focus** - How the organization determines requirements and expectations of customers.

In addition to the seven Baldrige categories, NCDOT added the criteria of "trusting partnerships" as an eighth category for evaluation and improvement since many of the environmental processes used to deliver transportation projects are implemented in cooperation with others.

- **Trusting partnerships** - How effective the organization is in building trusting partnerships, maintaining and enhancing communication, establishing mutual goals and conducting collaborative problem-solving.

NCDOT operates on the premise that in order to systemically change the way the agency conduct business on a day-to-day basis, attention must be given to all focus area. In other words, the organization must be working on and be successful in the eight categories listed above in order achieve sustainable organizational excellence.

Some examples of NCDOT's environmental programs and institutional initiatives, as categorized by Baldrige criteria, are listed below.

- The creation of the North Carolina Board of Transportation's Environmental Committee and appointment by the Governor of the first Transportation Board Member with the designated responsibility of representing environmental issues. NCDOT also appointed the department's first Deputy Secretary for Environment, Planning, and Local Government Affairs and created NCDOT's Office of Environmental Quality (OEQ) to help execute the agency's environmental policy (Leadership).
- Development of NCDOT's *Strategic Plan for Transportation*, which includes environmental goals and objectives, through public and stakeholder input (Strategic Planning).
- Expansion of the North Carolina's Geographic Information Survey, in collaboration with state and federal resources agencies, for the use in early identification of sensitive environmental resources and the avoidance and minimization of impacts (Information and Analysis).

- Documentation, analysis and reengineering of project development, permitting and mitigation processes to achieve the timely delivery of NC's transportation program while protecting the environment (Process Management).
- NCDOT's funding of 34 positions in state and federal resource agencies for the purposes of early identification and resolution of environmental issues associated with the planning, construction and maintenance of transportation facilities (Human Resource Focus).
- Metrics and associated performance measurement related to NCDOT's Erosion and Sedimentation Control Program (Business Results).
- Shared transportation and environmental decision-making with federal, state and local agencies to provide transportation facilities that fit into the surrounding environment (Customer Focus).
- Partnership between NCDOT and NC Department of Environment and Natural Resources that includes establishing of mutual goals and developing and implementing one- and three-year joint work plans (Trusting Partnerships).

NCDOT reviewed all in the initiatives and respective Baldrige criteria/categories to determine if the initiatives were balanced throughout the categories, asking the following questions:

- Are there areas where a lot of resources are being applied? Is so, why?
- Are there categories where few initiatives are occurring? If so, why?

The analysis helped NCDOT determine where large amounts of resources were being applied and whether large initiatives address one or more of the Baldrige criteria. The absence of activities for a specific Baldrige criteria were taken to indicate a "gap" within the organization's management and approach to creating organizational change. NCDOT determined where the opportunities for improvement were, given the goals and priorities of the organization and its stakeholders. Then, comparisons between the current initiatives and the opportunities for improvement were made to determine which initiatives were complimentary and which showed the highest potential return on the investment. NCDOT then made decisions on resource allocation to facilitate continuous improvement that would be well-rounded, according to the Baldrige principles and consistent with the established strategic plan.

NCDOT liked the Baldrige criteria as a framework for environmental management because it built on what the agency was currently doing. The use of existing momentum and support for current initiatives encouraged synergy that NCDOT contrasted to "starting a new program that creates anxiety associated with change." The model was easily understood and communicated. NCDOT's quality manager felt that the use of Baldrige criteria as a framework for organizing programmatic and institutional environmental initiatives established a solid foundation for future organizational change.(*36*)

NCDOT has numerous environmental stewardship activities that have been institutionalized through development of departmental policy, changes in organizational structure, development of formal and informal partnerships, process improvement and redesign, strategic planning, and performance measurement. As of April 2004, NCDOT also decided to hire an EMS coordinator for the department to develop, implement and monitor EMSs; facilitate the development of tracking and reporting systems for environmental-related programs and processes; and to provide training and internal consulting on EMS. The EMS coordinator will assist in the management and facilitation of process improvement activities, and hence the agency has sought staff with expertise in ISO 14001, ISO 9000 and/or Baldrige Assessment.(*37*)

Environmental Strategic Planning at PennDOT via the Strategic Environmental Management Program (SEMP)

The Pennsylvania Department of Transportation (PennDOT) has a long history of performance measurement within a strategic planning framework. The National Research Council recognized PennDOT as one of the first public transportation agencies to adopt a strategic management system. The National Academy of Public Administration has reported on this work, a summary of which is included in this section.

Incorporating the environment into the agency's Strategic Plan became a key objective for PennDOT following the Governor's Green Government Council, which called on agencies to strive for continuous improvement in environmental performance with the goal of zero emissions."(38) PennDOT led the way among Pennsylvania agencies in implementation of Strategic Environmental Management within the state.

PennDOT's SEMP provides a mechanism for continuous improvement of PennDOT's environmental performance, a systematic approach to monitor effectiveness, and corrective action for nonconformance. Each PennDOT division now incorporates SEMP objectives, actions, measures, and targets into their annual business plans under their high level goal of "Demonstrate sound environmental practices," within the Quality of Life strategic focus area. Business plan objectives further detail priority tasks and strategies, deliverables, measure/review cycles, and potential barriers regarding this goal. A "Green Smiley Face" draws attention to environmental objectives, measures, and targets throughout the business plan. (See further information on PennDOT's process under the objectives and targets of this report.) In a 2001 presentation at the TRB annual meeting on PennDOT's strategic planning and performance measurement improvement effort, PennDOT Secretary Brad Mallory discussed key aspects of PennDOT's approach. Heading the list were: top leadership engagement throughout the process, broad organizational participation with ongoing feedback, and an "adapt, don't adopt" philosophy toward best practices.(39) The next year at TRB, Secretary Mallory discussed significant gaps the initiative was addressing, including uneven deployment of management with measures; lack of fresh data and analysis of strengths, weaknesses, and opportunities for some categories; and lack of alignment with many individual employee work plans.(40)

PennDOT has seen progress in addressing maintenance needs and has seen customer satisfaction rise. According to PennDOT's Director of Fiscal Management and team leader for the agency's strategic planning and performance measurement improvement effort, the agency has also benefited from consistent gubernatorial and legislative policies, customer and stakeholder support, and innovative agency leadership— factors that led to a multi-modal funding package that provides the current level of financial stability. As a result, PennDOT's strategic planning and performance measurement process have persisted across administrations, helping incoming leadership teams shape and implement transportation programs to advance the agency mission.

New Brunswick, Canada, DOT Strategic Plan and Environmental Protection Plan

The New Brunswick DOT Strategic Plan (Protecting the Environment Element of NBDOT Strategic Plan) includes goals, objectives, and measures for protecting the environment. NBDOT has outlined their current challenges as:

- Minimizing the impact of highway construction and maintenance on the natural environment.
- Engaging the public and stakeholders in productive discussions aimed at resolving specific transportation-related environmental issues.
- Meeting commitments to monitor the effects of transportation on the environment.
- Working with regulatory authorities to ensure the timely acquisition of environmental approvals.

To respond to those, Strategic Objectives for 2002 — 2005, for Goal 7 — Environmental responsibility and proactivity are:

- To integrate the concepts of continuous improvement, environmental protection and pollution prevention in all aspects of DOT's work.
- To take special steps to protect the environment surrounding DOT's maintenance facilities.
- To ensure all field staff have appropriate training in environmental protection.
- To investigate new, environmentally responsible technologies and methodologies.

NB DOT developed an Environmental Protection Plan, Environmental Field Guide and Standard Specifications to assist the agency in taking proactive and responsive approaches to environmental protection.

New South Wales, Australia Roads & Traffic Authority Strategic Plan and EMS

The New South Wales, Australia, Roads & Traffic Authority (RTA) Corporate Strategic Plan outlines the requirements of the New South Wales Government for the RTA's environmental performance, that is, to minimize adverse impacts on the natural and built environments. This requirement is in addition to meeting all statutory obligations and demonstrating due diligence in all activities which may affect the environment. The RTA's Environment Policy sets out general processes to achieve these requirements and to continuously improve its environmental performance, one of which is the RTA's Environmental Management System (EMS). Through the agency's EMS, the RTA is committed to integrating environmental issues into all of its activities and to continuously improving its environmental performance. The development and implementation of the EMS has been organization wide, and has provided a structured management system to achieve and demonstrate our environmental performance.

2.2. Setting Objectives and Targets & Tracking Environmental Commitments

Establishing Environmental Objectives and Targets

Once a DOT, Maintenance & Operations Division, or an Engineering Region/District has identified environmentally significant aspects of operations and organizational priorities within those, a DOT may want to set objectives and targets. Too often, objectives and targets are identified based only on what is measurable, whereas that which is important and ways progress can be meaningfully evaluated should drive metrics.

MDSHA Environmental Objectives and Targets

MDSHA's Environmental Stewardship Strategic Plan comprehensively addresses MDSHA environmental activities and establishes measurable outcomes. MDSHA is also working on combining management systems, including their permit tracking system, maintenance, and other management systems, which will further the agency's ability to track and measure environmental performance. MDSHA's current environmental targets and measures are to:

- **Meet 100 percent of environmental commitments.** MDSHA is working on this objective or target on two levels. First the agency is making a list of all commitments made in the NEPA Record of Decision and tracking whether they are implemented in design. The next stage is making sure the commitments are implemented in construction and implementation is confirmed or evaluated after construction. MDSHA is using the process designed for the Woodrow Wilson Bridge and lessons learned as a model. MDSHA already utilizes environmental monitors (beyond erosion and sedimentation control inspection and quality assurance inspectors) on all major projects, design-build projects, and those in sensitive environments.
- **Create and restore 200 acres of wetlands and restore 5 miles of streams by June 2006.** This stewardship commitment helps the state achieve regional, watershed, and statewide conservation objectives and is above and beyond what the agency is doing to satisfy Clean Water Act mitigation requirements. MDSHA is using transportation enhancement and other dedicated funds to enable the agency to achieve this objective.
- **Reduce Canada thistle in the right-of-way.** MDSHA has calculated the acres of Canada thistle in the ROW and is coming up with an estimate of what the agency can feasibly eliminate by 2006.
- **Annual "in compliance" rating on NPDES statewide permit.** Every January, MDSHA submits an annual report and receives review and comment from the state water quality oversight agency. MDSHA seeks to maintain the agency's reputation as a leader in the field nationally.
- **80 percent or more of SHA stormwater management facilities rated functionally adequate by 2006.** MDSHA has developed a thorough and duplicable grade-based rating system for stormwater management facilities and has developed an inventory, database, and photo record of all facilities statewide and their maintenance status. Under the rating system, those graded A or B are considered functionally adequate. As of late 2003, between 73 and 75 percent of MDSHA stormwater were functionally adequate (A=everything fine, working fine, no maintenance required, B= minor maintenance, need mowing or trash removal), leaving approximately 25 percent needing maintenance or retrofitting to achieve functional requirements. By 2010 MDSHA is aiming for 95 percent of facilities functioning adequately.
- **Accomplish 35 percent of needed industrial facility improvements by 2006.** MDSHA has assessed shortcomings at industrial facilities from an NPDES or water quality standpoint. The agency is committed to rectifying those deficiencies and is aiming for 100 percent completion by 2010.
- **Achieve 100 percent compliance with erosion and sedimentation control requirements on all SHA construction projects.** MDSHA believes the agency maintains one of the better DOT enforcement systems in the country. To assess

compliance, MDSHA implemented a six-layer system that includes independent quality assurance ratings for each project. Certified Quality Assurance inspectors inspect projects biweekly and rate the sediment controls on a letter grade scale. Projects can be shut down based on these inspections. Ratings for all projects are summarized quarterly and annually to comply with the SHA Business Plan. In the past the agency has pursued ratings of B or better on 95 percent of construction projects annually. As part of a primary agency commitment though, the Chief Administrator is seeking to improve performance to achievement of 100 percent compliance in construction.

In addition to leadership and communication of the agency's commitment, MDSHA has formed a team that is considering certification and recertification of inspectors, contractors, and designers. The certification requires refresher courses and certification could be lost for poor performance. MDSHA is working with private industry and will be training contractors as well as staff.

- **Maintain the priority level accorded to historic bridges on the SHA network so preservation is not in jeopardy.** MDSHA has conducted inventories to identify historic bridges and potential historic bridges. The agency is addressing needs and strategies for 12 different aspects of historic bridge preservation.

The Managing For Results (MFR) portion of MDSHA's business and stewardship plan is being used to measure the progress and success of MDSHA's environmental stewardship and to define timelines and milestones for the numerous elements of the program. Using the MFR approach, progress is measured every month for each of the major elements, and every six months for all the elements of the program. An example of this is the stormwater management retrofits that needed to be completed by December 2003. The retrofit completion progress was tracked every month and new strategies were developed continuously. As a result, this requirement was exceeded by 300 percent. Individual projects, such as watershed retrofits, stormwater improvements and watershed partnerships that are generated as a part of the program are managed using MS Project and milestone reviews.

For maintenance facilities, the discharge sampling of the outfalls is a direct method for measurement of success, which is defined based on state and federal requirements. As a stewardship measure, MDSHA tracks implementation of strategic upgrades to the facilities identified during the pollution prevention plan development and needed changes in systems identified by the independent inspection program.

Charts are developed for all the major programs to visually demonstrate successes and progress. Once a year, an annual report summarizing all the activities, including compliance with the NPDES program is prepared and submitted for review to the Maryland Department of the Environment (MDE). So far, every report was thoroughly reviewed and approved by MDE, which means SHA remains in compliance and is actually being commended for showing stewardship by exceeding the permit requirements. A copy of the recent annual report is attached.

PennDOT's Targets, Scorecards and Dashboards

Beginning early in 1998, PennDOT adopted a scorecard of measures to more clearly link performance metrics and agency goals and objectives. Effective scorecard measures were defined as those that would make a difference to customers and stakeholders, drive behavior throughout the organization, and be used for evaluation and decisionmaking. An internal

Malcolm Baldrige Performance Excellence assessment identified both procedural and technical shortcomings in department strategic planning and performance measurement. Particularly significant among the agency's findings was a lack of focus resulted from the combination of too many "number #1 priorities" and too many measures.

To create a shared vision for 12,000 employees, PennDOT embarked on a four-year improvement effort to link more rigorous strategic planning practices to measurable targets of organization performance. The task was divided into four phases: determine the approach, develop the agenda, align business plans, and manage with measures. PennDOT conducted extensive surveys and interviews to supplement existing data and suggest value-adding strategies. The leadership team reached consensus on eight strategic focus areas that were forwarded to cross-functional teams for formulation of goals and objectives. The cross-functional teams performed an analysis of strengths, weaknesses, opportunities, and threats based on external and internal scan data. In some cases, measurable targets and meaningful performance indicators were considered, so the agency was able to "back in" to goals and objectives.

In 2000, the leadership team adopted thirteen high level goals and twenty-one strategic objectives under the eight strategic focus areas. Goals and objectives were supported by a scorecard of measures consisting of lagging indicators that were assigned short-term and long-term targets. Each major PennDOT business unit used the department level process to develop its own objectives and scorecard. Organization-specific workshops were conducted to help those leadership teams support top-down direction while adding bottom-up priorities. Strategies and performance targets became the focus of their annual business plan and budget presentations to the agency leadership team.

In 2001, the agency added "dashboard measures" to supplement the business plan scorecards. The dashboards monitored progress toward scorecard metrics and other fundamental core business targets. By adding leading indicators and interim outcome measures, the dashboards provided a forum for tactical and resource decisions at monthly reviews by business unit leadership teams. Organizations were encouraged to move from reactive to proactive problem solving with the ultimate goal of focusing on continuous improvement opportunities. PennDOT borrowed the concept of red, yellow, and green flags to highlight how actual data compared to projected targets or acceptable variance ranges.

Standards for Establishing Environmental Objectives and Targets

ISO 14001 outlines standards for establishing environmental objectives and targets in section 4.3.3, which states that the "organization shall establish and maintain documented environmental objectives and targets, at each relevant function and level within the organization." When establishing and reviewing its objectives, the standard further states that an organization shall consider its legal and other requirements, significant environmental aspects, technological options and its financial, operational and business requirements, and the views of interested parties. The views of interested parties may include employee feedback, issues in the community, or regulatory hot topics or high level concerns.

Standards for evaluating a DOT's environmental objectives and targets may include the following:

- Are environmental objectives and targets documented?

- Have environmental objectives and targets been developed for each relevant function and level of the organization?
- Are these objectives and targets linked to a larger framework and based in the organization's environmental policy?
- Do environmental objectives and targets allow for the ability to measure, monitor, and improve?

Environmental Commitment Tracking Through Construction & Maintenance

Many environmental laws and regulations have permitting or approval requirements, and without which approvals or permits a project cannot proceed. While some mitigation may result from requirements for receiving an approval or permit to offset unregulated impacts DOTs make other mitigation commitments as a part of their environmental stewardship role.

Once a commitment to provide any of these mitigation features in a project is included in the final environmental documentation, whether it be a categorical exclusion determination for small projects, an Environmental Assessment/Finding of No Significant Impact for mid-range projects, or an Environmental Impact Statement/Record of Decision for large projects, that commitment becomes a condition of the FHWA project approval. Such a commitment is inadvertently deleted from the project, that removal could jeopardize the project approval and could result in remedial actions such as stopping construction until corrections can be made.

Some practices for ensuring that environmental mitigation features get incorporated into a project include:

- Having a mechanism to relay from the environmental staff to the design staff, the various mitigation features of the project and why they are necessary so that these items are designed into the constructions plans and specifications.
- Emphasizing to both design and construction staff that mitigation features are not the kinds of items that can be Value Engineered or removed from a project just because they do not appear to be directly related to a transportation need. When they inadvertently get removed from a project, this may make the environmental documentation out of compliance and jeopardizes the project until it is fixed.
- Educating highway agency staff and contractors that failure to implement mitigation measures can lead to civil, and in some cases, criminal penalties.
- Hiring "environmental monitors" to ensure that environmental features are implemented as intended and that any changes are processed through the appropriate agencies.

DOT "Green Sheets" and the Emergence of Electronic Commitment Tracking Systems

As of 2002 twenty state DOTs reported having systems for tracking environmental mitigation commitments.(*41*) In many cases, these are paper copies attached to plans, often called "green sheets;" eleven state DOTs used the latter method.(*42*) For example, Georgia DOT's green sheet consists of a page listing the following information, in addition to project number, county, status, and date: commitments/requirements; document in which the commitment was stipulated; responsible offices; whether special provisions are required; and status of the commitment/requirement. Eight state DOTs said they had developed or were in the process of developing electronic tracking systems for mitigation commitments, including Arkansas, Kentucky, Maryland, North Carolina, New York, Texas, and Virginia.(*43*) The above information and some of that which is included in the remainder of this section on commitment tracking was included in FHWA's Domestic Scan on Environmental Commitment Implementation: Innovative and Successful Approaches (*44*).

South Carolina DOT Interdisciplinary Accountability Teams

South Carolina DOT offers an intermediate model: on projects with substantial mitigation commitments an interdisciplinary commitment accountability team has been developed, consisting of the SCDOT Construction Engineer & District Field Engineer, SCDOT Environmental Manager or Specialist, and the FHWA Division Environmental Program Manager and Operations Engineer. This team reviews all environmental commitments made in the Final EIS, Record of Decision, 404 permit, and 401 certification, and any other relevant consultation or permitting areas. The team lists and evaluates each commitment for the degree to which it has been fulfilled or is currently being fulfilled. Issues in implementation and the results of visual surveys, where appropriate, are included in the report, as are copies of the original permits.(*45*)

New Jersey DOT Environmental Re-evaluation Checklists, Meetings, and Construction Field Reviews

NJDOT uses both environmental plan sheets and environmental re-evaluation checklists to communicate commitments throughout all phases of project development. Instead of writing commitments only in the contract document, NJDOT outlines commitments in environmental plan sheets and includes those sheets directly in project plans. By placing the environmental commitments in its project plans, NJDOT increases the likelihood of meeting environmental commitments. The environmental re-evaluation checklist reflects the commitments stated in the NEPA document. The checklist was developed to compensate for the length of time between issuance of the Record of Decision and the acquisition of right-of-way. NJDOT also uses the checklist for any new or supplemental funding requests for NEPA projects. The checklist contains permit information, agency approvals, Executive Orders for wetlands and floodplains, and an environmental inventory of impacted resources.

NJDOT uses pre-construction meetings to communicate with all stakeholders, and NJDOT environmental staff attends pre-bid and pre-construction meetings to ensure that all parties understand a project's environmental commitments. NJDOT also holds post-construction reviews for wetland monitoring to confirm performance and compliance with stated mitigation goals.

NJDOT conducts randomly selected Construction Field Reviews on its construction projects every six months. The one-day reviews are conducted by Environment Teams (E-Teams) that include a NJDOT Environmental Specialist. The E-Team meets with the resident engineer and then prepares a brief written report that not only focuses on compliance, but also identifies unique construction activities. See description of NJDOT's construction audit and contractor rating program under the audit section.

Kentucky Transportation Cabinet "Communicating All Promises (CAP)"

KYTC has developed a commitment tracking approach called "Communicating All Promises" (CAP). The CAP tracks and demonstrates follow through on all commitments made from planning through construction and maintenance. Commitments are posted in the State's online tracking system for use by contractors and placed in the lead project engineer's files. The approach institutionalizes commitments made by the agency and improves communication among all parties involved in the transportation process, increasing efficiency.

KYTC took a "blitz team" approach of "promise makers" and "implementers" to educate the department and contractors about the CAP. Information about the program and approach was also incorporated into the agency's Context Sensitive Solutions for Construction Workshops. All project engineers learn how to develop a Commitment Action Plan as part of their preconstruction planning activities. A Project Commitment Action Plan is a detailed work plan that addresses each of the natural and human issues and other commitments specifically identified for each project in bid documents, and how each issue/commitment will be handled during construction. The plan is developed and agreed upon prior to the start of construction by the contractor, the resident engineer, and the KYTC environmental coordinator.

KYTC's Guidance Accountability Form (GAF) for all environmental base studies and impacts and mitigation commitments from that document and NEPA are summarized in the Project Impact Profile (PIP), which both feed into KYTC's CAP system. Promises are accumulated in KYTC's PRECON database system, which allows entry of a description of the promise, to whom the promise was made, documentation, and the date of the promise. The Project Manager enters the promises from the planning report into the PRECON-CAP system and remains the keeper of the CAP for each individual project. All subsequent project promises are then communicated to the Project Manager and endorsed by the Project Team. The Project Manager retains the responsibility for ensuring that all promises (roadway features, environmental, right-of-way, utilities, structure design, etc.) are ultimately brought to reside in the PRECON CAP. A report function is included in the CAP system, which is run and included in the documents submitted to PS&E for letting, in the bid package, and in the contract document. The ledger of commitments enables tracking of commitments through all phases from planning through construction and maintenance.

Indiana DOT Environmental Compliance Certification

INDOT uses a "Scope/Environmental Compliance Certification/Permit Application Certification" at four different design stages to ensure that its project designs incorporate all environmental commitments. This tool certifies that the requisite permits have been acquired and that the associated conditions/requirements have been included in project plans, specifications, and estimates (PS&E). In addition, a Mitigation Memo is prepared by the INDOT Public Hearings Section, which reviews the six-month letting list to identify projects ready for construction. The Mitigation Memo includes the mitigation chapter of the approved environmental document, a design summary that documents how environmental commitments are implemented in the final design, and the Fish and Wildlife Review Form that documents stream-related restrictions and special provisions. This Mitigation Memo serves as a reminder for project designers and land acquisition and construction personnel to assure that all requisite and special provisions have been included in the final PS&E assembly. In addition, the Mitigation Memo notifies construction staff of the commitments they are expected to implement. INDOT includes its mitigation commitment summary in NEPA documents and project plans; this is being incorporated into the agency's electronic project tracking system.

New York State DOT Environmental Commitment and Obligations Package for Construction (ECOPAC)

NYSDOT's Program Support System (PSS) lists all projects in progress within the department along with information about project costs, status, and anticipated milestones. An Environmental Commitments & Obligations Package for Construction (ECOPAC) records the actual compliance of construction projects. ECOPAC tracks commitment compliance throughout all construction activities with respect to the environmental issues identified and highlighted during project development. The form, which is now being used by all NYSDOT design and construction staff, is available on-line at the link above. It allows NYSDOT to transmit environmental commitments to construction staff.

Caltrans' Environmental Commitment Tracking

Caltrans construction contracts contain environmental requirements in the plans and specifications. In addition, the resident engineer's pending file contains a summary of all project commitments, copies of applicable permits, the environmental document, and other environmental documentation. Some districts produce special publications that detail the environmental requirements for each project.(*46*)

Caltrans District 11 has developed a Mitigation Monitoring and Reporting Record (MMRR) that summarizes environmental commitments (including terms and conditions of permits and other approvals) to be completed as part of the project. The MMRR is used by resident engineers and environmental personnel out in the field to ensure the construction process remains in compliance with all the commitments made during the life of the project. It is also used to track how well the District is doing in meeting its commitments. The MMRR helps identify specific sections and staff responsible for follow-through to ensure the items are incorporated in the PS&E and construction when it occurs. The agency has also developed public websites with environmental permits and monitoring protocols for other projects, notably the San Francisco-Oakland Bay Bridge East Span.(*47*) The agency is now working on quality standards for tracking environmental commitments.

MDSHA Environmental Compliance/Consideration Checklists and Independent Environmental Monitors

Environmental Compliance/Consideration Checklists are prepared for all major projects and summarize all environmental mitigation and project commitments, as well as identify areas that require further study or analysis during subsequent phases of the project. MDSHA also takes preventative action prior to construction to ensure that environmental commitments are not lost through value engineering or other plan revisions. NEPA documentation reevaluation occurs at least twice during design activities to assess whether the approved environmental documentation remains valid. The review occurs at the 30 percent, 65 percent, and 90 percent design completion stage or when major design modifications are proposed.

For large and environmentally controversial projects such as the Woodrow Wilson Bridge, MDSHA has developed a comprehensive tracking system database using Microsoft Access. In the case of the Woodrow Wilson Bridge, the database houses 1200+ ROD commitments and permit special conditions. A 1:400 scale map/plan was developed for each contract depicting permitted impacts. Tracking reports from the database are created for each of 24 construction contracts and compliance is documented in concert with daily compliance inspections. A final compliance tracking report is produced at the close of each contract, complete with a narrative. As part of the final report, MDSHA will show the as-built version of the impacts and compare those to the permitted impacts. Thus far, MDSHA is reducing permanent impacts, due to careful management and minimization efforts throughout each contract.

As previously discussed, MDSHA is now in the process of developing a system, based on that used for the Woodrow Wilson Bridge, for monitoring implementation of ensuring all environmental commitments made in the NEPA Record of Decision are incorporated into designs, and all design commitments and construction process commitments are implemented as promised. MDSHA is working to make the statewide system less labor intensive than that used for the Woodrow Wilson Bridge.

MDSHA also hires independent environmental monitors to work on projects with significant impacts, design build projects, and projects in sensitive environments or that require individual Section 404 permits from the U.S. Army Corps of Engineers. Environmental monitors ensure that the agency and contractors adhere to environmental commitments and that the project is constructed according to environmentally sensitive practice. The monitors serve in addition to erosion and sedimentation control inspectors and regular project quality assurance inspectors.

WSDOT Environmental Requirements in Inspection Format

WSDOT has put environmental requirements in an inspection format, for use in monitoring implement of environmental commitments on construction sites. As with Maryland's Woodrow Wilson Bridge Project, a large and expensive database was developed to track 850 permit conditions covering everything from marine environments to upland. WSDOT will be evaluating effectiveness of the tool over the next year and a half. Simpler tracking tools have been developed for more routine projects.(*48*)

Pennsylvania Turnpike Commission Database for Tacking Environmental Commitments

In an effort to promote environmental accountability and stewardship during final design and construction, the Pennsylvania Turnpike Commission utilizes set of computerized spreadsheet/database tracking systems that identify and monitor additional ROW requirements not addressed in the final NEPA document, changes in environmental impacts that may result during final design, and fulfillment and incorporation of all mitigation commitments into the PS&E packages as well as implementation during construction.

NCDOT Environmental Control Teams, Field Monitoring, and Permits on the Web

In addition to noting environmental commitments on plans and providing summary sheets of environmental commitments, NCDOT has employed pre-construction meetings for the past nine years to help contractors understand commitments, to establish relationships and protocols, and identify whether a project-specific environmental control team is needed. The team decides how often random, periodic field monitoring should occur for environmental compliance, in addition to regular construction meetings and inspections. The agency has recently put environmental permits on the web for reference by contractors and to facilitate incorporation of such information into bids.

Texas DOT Environmental Tracking System

The Texas Department of Transportation (TxDOT) has developed a comprehensive Environmental Tracking System (ETS) to follow projects throughout the planning stages and ensure that NEPA issues are addressed and environmental permits are coordinated before the project is released for construction. TxDOT reports that through use of the system, construction and maintenance personnel have increased their understanding of the implications and importance of adhering to project environmental requirements and other environmental rules and laws. They now take further action to prevent environmental impacts and minimize unavoidable impacts and costs associated with nonconformance/noncompliance during the project construction stages.

All TxDOT districts use an Environmental Commitment Checklist, which was first developed by the TxDOT Houston District, to monitor construction, maintenance, and facilities projects. The checklist is similar to those used by State DOTs to implement traffic controls in a project. By allowing contractors to chose "Yes", "No", or "NA" for specific documentation permits, general conditions, control measures, inspections, water resource compliance, and other environmental requirements, the checklists provide contractors with an easy method to implement and comply with environmental commitments and permit conditions. In addition, the DEQC uses the checklist when reviewing projects for compliance with environmental permits, issues, and commitments. The Texas DOT Environmental Checklist can be found in the Appendix at the end of this section.

The TxDOT Corpus Christi District also employs an environmental compliance inspector to provide continuous reporting on construction and its impacts to the environment. The compliance inspector works directly with construction staff on projects with environmental commitments or permits. For example, in the JFK Causeway project, the compliance inspector monitors permitted construction activities such as placement of fill into tidal waters and the removal of fill to create new bay bottom. The compliance inspector has the authority to stop a construction activity if warranted.

FHWA's Domestic Scan on Environmental Commitment Implementation and Lessons Learned

FHWA's Domestic Scan on Environmental Commitment Implementation: Innovative and Successful Approaches yielded the following "lessons learned," which were summarized in FHWA's Successes in Streamlining Newsletter: (*49*)

- Agency leadership that adopts and promotes an environmental ethic at all levels fosters successful commitment implementation.
- Communication of commitments from transportation planning though maintenance is essential.
- Education and training allow staff and contractors to understand the importance of compliance and to promote stewardship.
- Strong stakeholder relationships allow agencies to develop environmentally beneficial projects, promote efficient and effective processes, and further build trust and respect.
- Learning from past experiences encourages future implementation success.

2.3. ENVIRONMENTAL MANAGEMENT SYSTEMS

Environmental Management Systems (EMS) serves as a tool of reflection/indication of strategic planning. The prime emphasis of this sort of strategic planning is quality improvement and assurance; accomplished through planning, well-documented action, re-evaluation, and implementation of improvements through revisions of plans and procedures. Based on total quality management and implementation of organizational learning, EMS is a tool that can help integrate environmental considerations into an organization's day-to-day operations and management culture.

EMSs provide a standard framework for an organization to establish its own specific environmental goals and then measure its performance in achieving those goals. The tool applies well-accepted business and planning principles to environmental issues and includes the following steps:

- PLAN: Identify the key issues (environmental aspects of operations, regulations, stewardship commitments) and establish what you want to do (policy, priorities, objectives, targets, and schedule).
- DO: Identify those responsible and affected; develop procedures and tools to fulfill objectives and meet the plan; develop and provide training relevant to the plan and the people involved; follow the established procedures and processes in the course of carrying out business.
- CHECK if expectations are met: Assess performance; determine if meeting objectives and targets; identify/audit if things are working as planned and if not, why not; determine corrective actions and measures for the future.
- ACT/ADJUST: Periodically review the entire process to identify opportunities to improve. Identify needed changes and next steps/adjustments; determine if anything should be added to the plan.

Only a handful of states have launched EMSs or other processes with the explicit goal of bringing about continual environmental performance improvement; a wider set of states has implemented one or several components of an EMS, as defined by the International Organization for Standardization (ISO and ISO 14001 in particular).(*50*)

Why EMS for DOTs?

In response to strong public interest, environmental stewardship was established as a government-wide objective, codified in Executive Order 13148, in April 2000.(*51*) Section 401 of this order directs each agency to implement an environmental management system at all appropriate agency facilities. The President followed up on this initiative by asking all agencies to promote the use of Environmental Management Systems (EMS) in federal, state, local, and private facilities, with annual reports on the matter. As part of its stewardship objectives, the Federal Highway Administration (FHWA) is encouraging the use of EMS in the construction, operation, and maintenance of transportation facilities.(*52*)(*53*) AASHTO is promoting the use and implementation of EMS, and has designed a "roadmap" to assist DOTs that are considering implementation.(*54*)

State DOTs have begun to look at EMS as an organizing framework because it responds to some of their key needs, including:

- The desire to systematically demonstrate better environmental performance.
- Responsiveness to stakeholder preferences.
- Efficient use of financial resources.
- Ensuring coverage of complex liability issues.
- Regulators' requests.
- Awareness that environmental stewardship leads to regulatory streamlining.
- Control over priorities and timelines of the EMS.
- Organizational culture and personal commitment.
- Integration of environmental systems into strategic planning processes that are already in place. Environmental management systems include elements of quality control, health and safety, finance, and human resource management.
- Promotion of a positive organizational image.

In addition CEQ notes that under the federal "Modernizing NEPA Implementation" effort, EMS certification could provide advantages in getting projects through the NEPA and possibly the permitting process.(55)

Many of the economic and environmental benefits from implementing an EMS are derived from the proactive approach of pollution prevention. Pollution prevention strategies help reduce or eliminate environmental concerns at the source, resulting in less waste and clean-up, more efficient use of inputs, reduced risk and liability that may be reflected in lower insurance premiums and avoided contingency expenses, and many other environmental, health, safety, and financial benefits. EMSs can provide a way for air, water, waste and other environmental programs to be considered and integrated in a common impact reduction and opportunity implementation program. Under the EMS framework, an agency is able to ensure that major environmental risks, liabilities, and impacts are properly identified, minimized, and managed. It enhances the organization's reputation and image in the local community and creates a greater awareness of environmental performance within the organization across all departments, which can help improve overall management planning and promote cooperation. A more detailed overview of the benefits of EMS follows.

Benefits of EMS — Improved Environmental Performance& Predictability

Environmental management systems have many notable benefits for DOTs; some examples are provided below. Collectively these benefits have the result of increasing predictability in DOTs core business processes. An EMS can take permitting and regulatory compliance issues out of the critical path of project development, by incorporating processes which identify, address, and resolve those issues in advance. Instead the focus shifts to how DOTs can continually improve environmental processes, whether regulated or not. Public support often grows and contractor performance improves as well.(*56*)

Improve Environmental Stewardship

EMSs offer DOTs a way to address the public's interest in environmental protection stewardship, and enhancement. Agencies or facilities that adopt EMSs focus their attention on their highest-priority effects on the environment. Through the continuous improvement process and involvement of employees at all levels—with particular emphasis on ideas and input from the "shop floor"— EMSs can promote realization of new environmental opportunities.

Implement Leadership and Agency Objectives

EMSs provide a way to institutionalize what many leaders in state DOTs are already trying to do. In other places, EMSs emerge from environmental commitments made at the highest levels of executive leadership within a state. Organizations utilize an EMS process to develop goals, objectives, and procedures relating to the organization's environmental activities or performance. Common objectives for public agencies include achieving compliance with all regulations, going above and beyond compliance to voluntary stewardship and environmental enhancement, or implementing systemic process improvement. Implementing an EMS can improve cost savings and improve efficiency—a general objective for all public agencies operating within limited budgets. EMSs are in line with broader state DOT, FHWA and AASHTO objectives to improve environmental performance and demonstrate environmental stewardship.

Enhanced Credibility with External Stakeholders

Public and agency opinions of DOT projects play a large role in transportation decision-making. A 1990 public poll showed that 75 percent of U.S. consumers considered a company's environmental image in their shopping decisions.(*57*) While government agencies are subject to a different set of public decision-making processes through legislative budget-setting and through public meetings for projects on a local level, citizens, environmental groups, and the media can still mobilize public sentiment, alter accepted norms, and change the way people think about the environment and the role of the agency or facility in protecting it. Public interest and information regarding the environmental impacts and activities of DOTs and other organizations have grown, raising expectations of DOTs and the importance of DOTs' responsiveness and credibility with regard to environmental stewardship.

An organization has far more credibility in environmental stewardship when it has in place a process to assess its environmental performance. The general public offers greater support for an organization that can demonstrate how it continuously seeks to improve environmental performance. Improved relationships with regulators and other customers are a common outcome of EMS implementation. Developing and maintaining a positive public image with respect to environmental stewardship assists relationships with lawmakers and the media. For example, by implementing their environmental initiative, the New York State Department of Transportation (NYSDOT) has gained stronger, more positive working relationships with external agencies, citizens, local municipalities and other environmental groups, which in turn and have avoided costs by reducing delay, litigation, and frustrating rework, as well as wasted effort arguing contentious issues.

Improved Relationships with Regulatory Agencies

Although regulators and environmental review agencies will never relinquish all oversight responsibilities, they recognize when an agency with an EMS is taking its environmental responsibilities seriously. Implementation of an EMS signals an agency's serious approach to avoiding and minimizing environmental impacts and frequently leads to stronger interagency relationships. For example, The Pennsylvania Department of Transportation (PennDOT) District 5's efforts for consistency and planning in habitat assessments have improved relationships with U.S. Fish and Wildlife Services (USFWS) and streamlined NPDES compliance and oversight.

EPA, the multi-state working group on environmental management systems, and other regulators at the state and federal levels are moving forward with EMS as a policy option because they believe that organizations that adopt EMSs may be in compliance with environmental regulations at rates greater than non-EMS adopting facilities, over the long run. Regulators suggest that the environmental regulatory system may become less relevant for organizations that adopt EMS, as they continually improve their EMS and upgrade their environmental goals, objectives, and performance.

In some cases, regulatory agencies have specifically requested that an EMS be developed, or established an incentive to that effect. Mass Highway's environmental management program was developed in response to EPA's Environmental Performance Track. The agency reports that their EMS has led to improved relations with regulatory authorities, easing oversight burdens and permitting delays. In other industries, EPA's National Environmental Investigation Center has started to require EMS as a condition of settlement, with accompanying review of current management systems and development of detailed procedures, self-inspection, and monitoring processes which give regulators greater confidence in an entity's future performance and ability to catch and address problems in a timely way.(*58*) EPA's compliance-focused EMS guide is available on-line. EPA's Implementation Guide for Small and Medium Size Organization contains valuable information for DOTs and is available on-line.(*59*)

Improving Compliance and Eliminating Violations

Even if the organization already has a compliance program, an EMS can help enhance consistency and efficiency in compliance, and capitalize on opportunities to move beyond compliance into voluntary stewardship and environmental enhancement. Through developing and utilizing an EMS, organizations can identify and address compliance problems and prevent them from recurring. Once a facility implements its EMS, that facility should be in conformance with all environmental regulations and in the process of exploring further avenues for environmental improvement.

As a result of using a structured, consistent audit program in operations and maintenance, Maine DOT (MDOT) has substantially improved and maintained their level of environmental compliance. In 2000, EPA enforcement staff conducted compliance inspections at several MDOT maintenance facilities and testing labs. Although very minor improvements were pointed out and immediately addressed by MDOT, no major problems were found and no fines were imposed. Employee "ownership" of and pride in their facilities and actions has risen substantially. In turn, the level of compliance achieved is much higher than with prior initiatives. John Dority, MDOT's Chief Engineer, said "[o]ur EMS has been remarkably successful in avoiding environmental penalties and fines. In most cases, the violations just don't exist when enforcement agencies visit our facilities. In cases where violations are found, we have found that the best possible response to the violation is to tighten up our EMS to make sure that similar incidents never happen in the future. Enforcement agencies have been quick to agree that tighter policies or tighter protocols are a more lasting solution than punitive fines."(*60*)

Streamlining Regulatory Responsibilities

EMSs can rationalize and streamline how an agency addresses its various regulatory responsibilities. Eventually, EMS can form the basis for States to seek greater environmental delegations of authority from Federal agencies. Organizations and facilities that adopt EMSs and are able to reduce their environmental impacts beyond regulatory standards may lessen their environmental reporting burdens and the costs associated with them. Those that demonstrate proactive environmental management initiatives are in a better position to negotiate to reduce their regulatory burden and streamline environmental approvals. For example, PennDOT's EMS for maintenance facilities in Districts 10, 11 and 12 has been recognized by Pennsylvania Department of Environmental Protection (DEP) staff as best management practices that, in turn, ease oversight, monitoring, and permitting needs. The procedures and processes of the EMS generated sufficient confidence in state water quality regulators that inspections were reduced. PennDOT's internal documentation began to substitute for other reporting requirements.

Cost Savings

In the process of redesigning operations and reducing environmental impacts, some organizations discover new opportunities to prevent rather than merely control adverse environmental impacts. Reducing resource use saves money while enhancing the environment. Organizations that implement EMSs typically discover ways to manage their operations as a whole more effectively.

During the extreme conditions of a recent winter operators and managers confirmed that materials usage control practices adopted by PennDOT helped them extend the life of their road salt inventory by as much as three weeks (based on their experience under similar conditions). PennDOT District 10 analysis of erosion and sedimentation control procedures and practices estimated training and planning may provide two weeks of work crew and equipment productivity at no increase in cost, by doing things right the first time instead of going back to correct problems, translating to cost avoidance of $25,000/year for District labor and equipment. EMS procedures and processes in Districts 10, 11 and 12 have been recognized by regulatory staff as best management practices that allow for a District-wide permit, eliminating monitoring and analyses, again saving resources.(61)

Improving Environmental Performance: Indicators, Protection, and Enhancements

An EMS can be used to establish quality goals and performance standards for both broad-scale processes, such as project development, and for very specific field functions like materials handling and construction techniques within construction, maintenance, and operations units. Implementation of EMSs has resulted in improved pollution control and resource use, fewer accidents and spills, and improved safety and environmental quality for both employees and citizens. In most cases, EMSs facilitate the agency's move beyond legal standards for regulated activities to identification of opportunities for reducing non-regulated environmental impacts of its activities. Environmental effects of agency operations and the most promising, immediate opportunity areas frequently extend beyond what is controlled by environmental regulations. EMSs allow implementation of change identified by and at a pace set by the action agency. Then the agency establishes targets or indicators they can use to track improved environmental performance.

Research confirms that facilities, agencies, and organizations can reap substantial benefits from improving the management of their environmental impacts and publicizing their proactive environmental activities.(*62*)

Economic Incentives, Including Reduced Liability

EMS implementation typically results in efficiency gains. Public agencies at all levels — federal, state, and local — have begun implementing EMSs in an effort to reduce operational costs by using fewer resources, optimizing the use of resources that are needed, and increasing reuse and recycling. Although it requires an up-front investment in time, staff, and management commitment, an EMS can result in cost savings over time. Efficiency gains may include reduced liability and lower costs, including more favorable insurance and bond ratings.

Among NHDOT's significant accomplishments, the Traffic Bureau eliminated an environmental liability of shipping 6,000 gallons of waste paint to Illinois for treatment on an annual basis. Following review of environmental aspects of operations, this practice was halted. Equipment was purchased to process the waste paint at Traffic's facility, solid waste from which is now used by a start up company in its manufacturing process for plastic construction materials such as noise barriers. In addition to elimination of the environmental liability, NHDOT is saving $15,000 annually through this process improvement. NHDOT also began hydrostripping worn aluminum traffic signs. This has resulted in lower resource use, and lower cost to deploy signing, since the reused blanks are 40 percent less costly than new material. Through inventory controls, the Bureau's target is to utilize 95 percent of recycled sign material for sign manufacturing in five years. New Hampshire's DOT Commissioner was quoted as saying, "we cannot afford not to have an EMS."(*63*)

Other Organizational/Operational Benefits

Efficiency gains also extend to management and operations. Organizations perform better when they systematically manage their affairs. An EMS improves productivity by systematically addressing environmental concerns as part of overall management practices and organizational strategies. EMSs give the people who know operations best a) the responsibility to identify the environmental aspects of their activities, b) the means to measure progress against a baseline, and c) the incentive to make improvements. This results-oriented approach by insiders can be more effective than process-oriented oversight by outside groups that may want to add marginally effective extra steps. In effect, an EMS is a tool for reviewing all the environmental aspects of a job, including external regulatory requirements, and coming up with a systematic way to address them. An EMS provides a framework for examining and collating best practices for day-to-day-operations.

At Maine DOT (MDOT), EMS processes and procedures have enabled managers/supervisors to more efficiently manage their materials (by sharing among facilities) and waste. These actions have provided costs savings. More efficient management of materials and control of facility operations lead to reductions in the space needed to conduct/support maintenance activities. From an immediate perspective, less space means less opportunity for noncompliance and a reduction in the costs and environmental impacts associated with noncompliance. From a long term perspective, a need for less space could lead to savings in land maintenance and acquisition costs.(64)

NHDOT built on and incorporated existing programs in constructing their EMS. The Department realized organizational efficiencies by merging expanded health and safety program requirements into EMS plans, enabling several important elements of department activities (environment, health, and safety) to be addressed in one operational document. Despite these efficiencies, NHDOT found that sufficient new staff resources were required in order to maintain written procedures, support program development, support the internal audit function, and maintain records needed to perform performance measurement and corrective action tasks. Consequently, NHDOT added an EMS Manager to facilitate the steps in developing an EMS, assist in procedure development and implementation, and support internal and external communications.(*65*)

Organizations that have implemented EMSs also commonly report that the organization as a whole and individuals throughout developed a much better understanding of their work, its impacts, and how it all relates to each other. The EMS fostered a greater sense of responsibility, awareness, and meaning in the work at hand, from the corporate to the individual level. EMSs have been a tool for extending employee involvement and awareness in many organizations, with EMS practices providing a foundation for other quality improvement actions and showing all employees that they play a vital role.

Matt Jordan, Director of Public Works & Utilities, Gastonia NC said, "[w]e went from an organization doing a lot of different tasks and jobs to (staff) seeing how it fits into the whole department and feeling they'll make a difference. It's also a good way to meet regularly, respond to their suggestions, and utilize their experience." The Idaho National Engineering and Environmental Laboratory reported, "EMS gave our employees a willingness to take initiative and responsibility for environmental performance."(*66*) During employee interviews for the ISO 14001 readiness audit in PennDOT District 10, an operator commented on Erosion and Sedimentation Control procedures to the third party auditor, saying "I've worked here for more than 20 years. We never did this before but that doesn't mean we were right. This is what I want to do for my children and grandchildren."(*67*)

Mass Highway managers noticed an increased environmental awareness in the substantial majority of maintenance employees. This awareness, coupled with environmental procedures, responsibilities, training, and assessments, helps Mass Highway prevent environmental problems and makes it easier to correct such problems when they do occur in turn, reducing costs of compliance (including potential fines) and corrective actions.

Helping DOTs Respond to the Challenges They Face

State transportation agencies, like all government entities, are increasingly pressured to do more with less. Efficiency and performance measurement have been watchwords, and performance measurement is steadily increasing both on the state and federal levels. Twice as many laws enacted in the 105th Congress (1997-98) had provisions pertaining to performance as the previous Congress.(*68*) A third of state agencies in a recent survey said they measured performance across the agency.(*69*) Not only is such information increasingly demanded by external stakeholders and funders, such documentation facilitates management at the highest levels and increases the ability of agency staff to communicate with key stakeholders and demonstrate responsiveness. EMSs can increase agencies' ability to respond to these demands with solid data and show improved performance.(*70*)(*71*)

EMS and the ISO 14001 Standard

The structure of an EMS may vary, though the most common is the ISO 14001 standard because it offers the opportunity to become recognized and certified. ISO stands for the International Organization for Standardization, which adopted the ISO acronym because ISO means "equal". ISO 14001 certification is an effective and widely recognized method for demonstrating an organization's commitment to environmental performance and quality management.(*72*) Though ISO standards have been developed for hundreds of products and processes worldwide, with the 14001, ISO has suggested a broader, *strategic* approach than most of their other product and process standards. Their purpose was to develop environmental management system standards that can be implemented in any type of organization in either public or private sector (companies, administrations, public utilities). As such the 14000 series share much in common with the ISO 9000 series for quality management.

ISO defines EMS as "that part of the overall management system which includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining environmental policy."(*73*) The EMS provides the structure by which specific activities related to environmental protection and compliance can be efficiently and effectively carried out.

ISO 14001 compliant Environmental Management Systems have six key elements:

1. **Environmental Policy:** An organization's environmental policy serves as the basis for EMS design and implementation. It sets out the organization's goals and defines the actions the organization will follow. Environmental policies should demonstrate a commitment to compliance, pollution prevention, and the well being of employees, customers, and the local community. The policy must be approved by top management and communicated to all employees, since they will play an integral role in meeting the goals of the policy.
2. **Planning:** Careful planning allows the organization to proceed with implementation of an EMS in a logical, orderly manner. Planning should include comprehensive analysis of an organization's operations and the inherent environmental impacts, as well as consideration of the steps necessary to meet new goals. Standard operating procedure may be modified to meet the goals of the new Environmental Policy.
3. **Implementation and Operation:** Roles and responsibilities should be clearly defined for all staff. Implementation of an EMS often requires across-the-board training and other forms of support to acclimate all levels of staff to new priorities and practices. Documented procedures help establish and maintain momentum toward the organization's environmental and economic performance goals.
4. **Checking and Corrective Action:** Maintenance of an EMS fosters a high level of organizational discipline. Auditing, monitoring, and measurement of environmental indicators are necessary to achieve the goals and assess progress toward the objectives defined in the Environmental Policy. They also provide opportunities to create performance incentives for all levels of staff.
5. **Management Review:** The development, implementation, and maintenance of a successful EMS must be strongly supported by an organization's top management. Top management review strengthens the awareness and commitment through leadership of the EMS goals, assigning decisions regarding staff responsibilities and performance evaluation and ensuring continuing suitability, adequacy, and effectiveness of the organization's operations and practices. It should be conducted on a regular schedule.
6. **Continual Improvement:** Continual improvement is an inherent outcome of an effectively implemented EMS. Performance reviews and updating the gap analysis can

help guide the organization's progress. Improvements should emphasize preventive actions.

In considering whether to develop an EMS which could achieve registration to the ISO 14001 standard, Washington State DOT (WSDOT) developed the following comparison table of characteristics of, differences between, and examples of a non-certification EMS, ISO consistent and ISO 14001 registered organizations: (74)

Table 3: Characteristics and Examples of Non-Certification, ISO Consistent and ISO 14001 Registered Organizations

Non-certification EMS	ISO Consistent EMS	ISO 14001 Registration
Focus on components of ISO14001 that make most sense for organization. Usually means much less documentation and less rigorous basic awareness training.	Use all 17 elements of ISO 14001 but not document to the point of certification. Requires much less paperwork and training than certified program. However, builds a foundation to readily move toward certification in the future.	Document compliance with all 17 elements of ISO 14001. Pass an independent certification audit.
Such a model might include written work procedures, training, occasional compliance inspections and corrective action (compliance assurance) procedures.	Such a model would address all 17 elements of ISO 14001. Some elements would be implemented in more depth than others. Policies and support documents would be needed, but agency would not necessarily require in depth EMS training, nor rigorous document control etc.	Train all employees in organization striving for certification on basic environmental awareness and the operation of the EMS, with heavy emphasis placed on EMS operation. All employees in organization must know where to obtain EMS documentation.
Example programs include: Maine DOT maintenance facility environmental program TxDOT construction compliance program NC DOT water quality program NH DOT maintenance facility environmental program	Example programs include: MASS Highway's Facility Maintenance Program ODOT's Facility Maintenance Program (in development) New South Wales (AUS) Transportation Authority construction compliance program	Example programs include: PennDOT erosion control (for Maintenance activities, not construction), winter material storage and maintenance facility waste handling. Registration in Maintenance District 10 only. NYC Transit for all activities.

While ISO and EMSs emphasize a holistic approach, DOTs may find it most practical to look at the individual parts of an EMS, some of which they may already have in place and assess what they are missing or want to do next. This process is typically termed a "gap analysis."

Gap Analysis: What Do You Have Already That Could Be Part of an EMS?

An EMS should build on policies, procedures, processes, and tools an organization already has in place, to the maximum extent practicable. Consequently, many organizations like to start with a "gap analysis," looking at elements of an EMS, often as defined by ISO 14001, compared to what an organization has already done. Gap analysis tools are available for self-evaluation. EMS specialists have such tools available. The sections of this report, especially the conclusion of each section on standards and measures, also contain bulleted lists of questions or elements DOTs can use as checklists in evaluating gaps and/or ways to improve what they may have already developed.

The New South Wales (Australia) Regional Transportation Authority developed the following cross-reference to identify which components of their environmental management system addressed ISO 14001 elements: (*75*)

Table 4: Comparison between NSW RTA EMS and Elements of ISO 14001

AS/NZS ISO 14001:1996 Requirements	Corresponding element of RTA EMS	Corresponding Section in RTA EMS manual
4.1 General		1.0
4.2 Environmental Policy	RTA Environmental Policy*	2.1.1
4.3 Planning		
4.3.1 Environmental aspects	RTA Environmental Impacts Register*	2.3
4.3.2 Legal and other requirements	Schedule of Legislative Requirements* Schedule of Other Environmental Requirements*	2.2
4.3.3 Objectives and targets	Environment Strategic Plan* Environment Strategic Plan* and Directorate	2.1.2
4.3.4 Environmental management programs	Business Plans	2.1.2
4.4 Implementation and Ops.		
4.4.1 Structure and responsibility	Section 3.2 of RTA EMS Manual*	3.2
4.4.2 Training, awareness and competence	Workplace Environmental Training Program (WET)	3.3
4.4.3 Communication	Section 3.4 of RTA EMS Manual*	3.4
4.4.4 EMS documentation	RTA EMS Manual*	All
4.4.5 Document control	*Document Control Process and Procedures*, Appendix D RTA Management System Manual*	-
4.4.6 Operational control	Register of RTA Environmental Policies, Guidelines and Procedures*	3.0
4.4.7 Emergency preparedness	*Emergency planning, Business Continuity Planning, Disaster Recovery Planning*, Section 6 RTA Risk Management Manual* *Disaster Planning and Recovery Guidelines*, Chapter 11 RTA Document Management System Manual*	3.4.3
4.5 Checking and Corrective Action		
4.5.1 Monitoring and measurement	Critical Success Area and Performance Measure Reporting	4.0
4.5.2 Non-conformance and	RTA EMS Improvement Register	4.0

corrective and preventive action 4.5.3 Records 4.5.4 Environmental management system audit	*File Management*, Chapter 4 RTA Document Management System Manual* Environmental Auditing	- 3.5
4.6 Management review	RTA EMS Management Review	4.0

U.S. Resource Centers for EMS Development

While private sector organizations have led EMS development in the U.S., EPA has spearheaded provision of EMS resources for the public sector. Since 1997, EPA has helped 23 local governments adopt environmental management systems using the ISO 14001 baseline. In addition to the information clearinghouse at www.peercenter.net, EPA and nongovernmental partners have established eight resource centers across the country to provide training and information on developing the systems. The seven resource centers are Purdue University, University of Florida, Georgia Institute of Technology, University of Massachusetts at Lowell, Texas Natural Resource Conservation Commission, Virginia Tech University, and the Zero Waste Alliance in Portland, OR.

AASHTO's Center for Environmental Excellence website contains EMS resources developed for the State DOT EMS Workshop in August 2003, including an 11-step EMS "roadmap" for DOTs.

2.4. Operational Controls, Procedures, and Practices

To implement an effective environmental management system, an organization must identify those operations and activities that are associated with the identified significant environmental aspects in line with its policy, objectives and targets. An organization then must plan those activities, including construction and maintenance, in order to ensure that they are carried out under specified conditions in order to ensure that the desired environmental objectives or outcomes are achieved. To accomplish this, organizations typically establish and maintain documented procedures to cover situations where the absence of such procedures could lead to deviations from the environmental policy and the objectives and targets.

Procedures and Manuals

Procedures are commonly established for both wide and highly specific areas of construction and maintenance. Procedures and manuals support environmental stewardship as they function to:

- Provide guidance for employee performance and decision-making.
- Reinforce DOTs' stewardship commitments.
- Help reduce the potential for internal and external conflicts about authorization for stewardship-related activities.
- Help ensure consistency in the completeness, accuracy, and currency of environmental instructions and documents and the delivery of this information to the appropriate audiences.

- Help DOT employees and contractors comply with current environmental commitments and requirements.
- Reduce the number and cost of environmental incidents as well as agency risk.

Typically DOTs already maintain Standard Specifications and Maintenance Activity Manuals. In some cases, stewardship performance could be enhanced by adding expected environmental practices that should occur in conjunction with the activities outlined in the specs or maintenance activity manual. It is hoped that this research project will provide a further source of such practices. Common activities for which subject specific guides have been developed include erosion control, herbicide application, or facilities maintenance. Few states have developed guides to the environmental aspects of maintenance and operations on a broader level, though a few excellent examples exist, including the NYSDOT Environmental Handbook for Transportation Operations, NCDOT Best Management Practices Manual for Construction & Maintenance, and the New Brunswick DOT Field Guide for Construction & Maintenance Operations. NYSDOT and NCDOT have generously made their manuals available for other states to copy and use. Virginia DOT is starting to develop standard operating procedures for environmental practice in maintenance operations. Maryland SHA is working on an Environmental Maintenance manual as well. Neither of the latter were developed to the point that they were available for use in drafting this document.

Oregon DOT's Routine Road Maintenance Water Quality & Habitat BMP Guide, Minnesota's Best Practices Handbook on Roadside Vegetation, Washington State DOT's Best Practices Handbook on Roadside Vegetation, Caltrans Storm Quality Practice Guidelines, MDT's Erosion and Sediment Control Best Practices, and the Transportation Association of Canada's Syntheses Of Best Practices in Road Salt Management all cover narrower sets of BMPs. These compilations were primary sources for best practices in the wider compendium of DOT environmental stewardship practice.

Overviews of a selection of these manuals follows:

New York State DOT Environmental Handbook for Transportation Operations

NYSDOT's Environmental Handbook for Transportation Operations was developed to provide NYSDOT personnel with general awareness of and guidance on the primary requirements that apply to the types of activities conducted by NYSDOT Operations, to further adherence to NYSDOT stewardship commitments. It was published in 2001 and reviews typical issues operations and maintenance staff may encounter, as well as other issues that may require more assistance from Landscape Architects or Environmental Specialists and Coordinators. The manual covers work in the right-of-way and especially sensitive environments therein, as well as facility-based activities conducted at a residency or shop. With the exception of sensitive environments, the manual presents environmental requirements and considerations in the context of the operation or type of facility or equipment most affected by the issue. NYSDOT's Environmental Handbook for Transportation Operations is available on-line.

Mass Highway's Facility Environmental Handbook

Mass Highway published a Facility Environmental Handbook to provide guidance on conducting operations in compliance with environmental requirements, containing standard operating procedures and maps to identify structures and environmentally sensitive areas such as wetlands. The handbook is used to train Mass Highway personnel on an annual basis. The department also has an EMS manual, associated operating procedures, and an EMS website. A committee with District Maintenance Engineers was established to define roles, which are reviewed annually during training events for all facility personnel (training in off season time). Mass Highway's Standard Operating Procedures reference these roles and responsibilities.

North Carolina DOT BMPs for Construction and Maintenance Activities

Published in 2003, NCDOT's BMP manual for construction and maintenance activities focuses on activities that impact water quality and waters of the state, and practices to avoid or minimize those impacts during normal construction, maintenance, and emergency repair situations. The Project Planning and Preconstruction section describes the actions that should be performed prior to any construction or maintenance activities. The General Project Construction Practices/Operations section provides an overview and general guidance for field personnel/contractor to be applied to all projects and activities within or adjacent to jurisdictional areas. Specific construction practices are identified and guidance provided so the project can be completed in an environmentally responsible manner. This section also identifies appropriate BMPs, provides a general overview of the construction sequence as it relates to protecting jurisdictional areas, and highlights specific conditions that must be followed in order to be in compliance with NCDOT Environmental Stewardship Policy, as well as State and Federal regulations. The last section of the manual includes activity-specific information for each individual BMP such as where the practice is and is not applicable, construction standards, maintenance requirements, and typical problems. Some of the BMPs identify the appropriate NCDOT standard and specification for proper construction. While providing guidance to construction crews when working within and adjacent to jurisdictional areas, the manual aims to provide flexibility to the crews to choose which method is suitable for each given situation. The NCDOT Best Management Practices Manual for Construction & Maintenance is available on-line.

Oregon DOT Right-of-way BMP Manual

The Oregon Department of Transportation (ODOT) first developed a program to minimize impacts to water quality from routine road maintenance activities in January 1995. A team of maintenance managers, field staff, and environmental staff reviewed maintenance activity for potential impacts to water quality and developed best management practices (BMPs) to minimize those impacts. The review was documented in the *Oregon Department of Transportation Maintenance Management System Water Quality Guide* and submitted to the Oregon Department of Environmental Quality (DEQ) as part of the ODOT National Pollutant Discharge Elimination System (NPDES) Municipal Separated Storm Sewer System (MS4) permit requirements under the Clean Water Act.

In 1997, a similar team reviewed maintenance activities for impacts to habitat, with an emphasis on habitat and fishery resources that are listed as threatened or endangered under the Federal Endangered Species Act. This review was documented in the *Oregon Department of Transportation Maintenance Management System Water Quality and Habitat Guide: Best Management Practices*, June 1997. The 1997 document served as the foundation for a Programmatic Biological Assessment on certain ODOT road routine maintenance activities that evolved into an updated manual in 1999 with more thorough descriptions of an extensive list of routine maintenance activities and accompanying minimization/avoidance actions, ODOT's training program for routine maintenance and environmental considerations, letters of commitment from the agency directors, relevant references or examples, and description of the process for review, documentation and monitoring implementation and effectiveness of maintenance actions. In addition, the manual includes appendices on:

- Guidelines for maintaining water quality in snow & ice operations
- Guidelines & criteria for stream-road crossings
- Guidelines for timing of in-water work to protect fish & wildlife resources
- Guidance for maintenance activities in wetland ditches
- Guidelines for bridge washing
- Guidance for emergency highway repair

ODOT is now in the process of updating the Manual and the accompanying 4(d) rule with NOAA Fisheries and the Corps. ODOT's BMP manual is available online.

Standards & Measures for Implementing Environmental Programs & Process Improvements: ISO 14001 Practices

As with other aspects of an overall environmental management system, international standards provide a guideline. ISO 14001 Section 4.3.3 says that such environmental management programs, established by an organization to achieve their objectives and targets, should include:

- Designation of responsibility for achieving objectives and targets at each relevant function and level of the organization.
- The means and time-frame by which they are to be achieved.
- A defined period of time between audits of how the system or program is functioning.
- A process for ensuring that new developments and new or modified activities, products or services, program(s) are covered and the plan/program amended.

Thus an EMS auditor would look for the following in evaluating implementation of environmental programs:

- Awareness of roles and responsibilities for achieving objectives and targets.
- Progress on each environmental management program.
- Adequate resources to achieve objectives and targets.
- Appropriate changes to environmental management programs as changes occur within the organization.

Communications

Suggested standards with regard to communications regarding setting environmental priorities and setting and implementing an environmental management system include the following (ISO 14001, section 4.4.3), which DOTs may want to consider as suggestions for non-EMS certified environmental management systems:

- The organization shall establish and maintain procedures for (and be able to evidence):

Internal communication between the various levels and functions of the organization.

Receiving, documenting and responding to relevant communication from external interested parties.

- The organization shall consider processes for external communication on its significant environmental aspects and record its decisions.

Documentation

Organizations which develop environmental management systems and programs should establish and maintain information, in paper or electronic form to describe the core elements of the management system and their interaction and to provide direction to related documentation. State DOTs developing formal environmental management systems often develop an EMS manual and a list of EMS documents and referenced procedures. Though this is not a requirement of the international standard (ISO 14001, section 4.4.4), it helps prove to regulators and auditors that the system is indeed in place.

Documentation is considered to occur at several levels:

- Level 1: Policy
- Level 2: Procedures — who, what, when, where (4.4.6(a), 4.5.1) and other documents
- Level 3: Optional Job Instructions — Describes how tasks and specific activities are done
- Level 4: Other documents prompting recording of evidence of conformity/compliance to requirements (See Records: 4.5.3)

Records, a Level 4 form of documentation, include training records, calibration checks and the results of audits and reviews. ISO 14001 requires certified organizations to establish and maintain procedures for the identification, maintenance and disposition of environmental records, so that

- Environmental records shall be legible, identifiable and traceable to the activity, product or service involved.
- Environmental records shall be stored and maintained in such a way that they are readily retrievable and protected against damage, deterioration or loss, (e.g. back-up systems).
- Retention times shall be established and recorded (e.g. a record retention schedule).

Overall, the extent of documentation an organization chooses to undertake should depend on:

- Size and type of organization
- Complexity of products and processes
- Customer and regulatory requirements
- Industry standards and codes
- Education, experience, and training
- Workforce stability — a very stable workforce may require less documentation of procedures, etc.
- Past environmental problems

Document Control

As managers of very large quantities of documents, whether required by federal law or necessary for design, construction, and maintenance, DOTs face the challenge of document control.

International standards for document control, as enunciated in ISO 14001 section 4.4.5 require that the organization shall establish and maintain procedures for controlling all documents required by this International Standard to ensure that:

- They can be located.
- They are periodically reviewed, revised as necessary and approved for adequacy by authorized personnel.
- The current versions of relevant documents are available at all locations where operations essential to their effective functioning of the environmental management system are performed.

Obsolete documents are promptly removed from all points of issue and points of use, or otherwise assured against unintended use.

Any obsolete documents retained for legal and/or knowledge of preservation purposes are suitably identified.

- Documentation shall be legible, dated (with title, document #, dates of revision) and readily identifiable, maintained in an orderly manner and retained for a specified period.
- Procedures and responsibilities shall be established and maintained concerning the creation and modification of the various types of document.

Thus an EMS auditor will look for periodic review of documents, availability and accessibility of documents, document control methods for electronic and hard-copy documents, and responsibilities and authorities for creating and modifying documents.

To date, most DOT document control initiatives have focused on NEPA documents and the project development process. Pertaining to construction and maintenance, several states have begun efforts to document and ensure communication of and follow up on environmental commitments that have been made, through NEPA and other environmental approval and permitting processes. These stewardship practices are described further under the section on "Environmental Commitment Tracking."

Standards for Evaluating Procedures

For an environmental management system organization-wide or in a specific area of the organization, an auditor for ISO 14001 (section 4.4.6) would look for:

- Evidence that operations/activities linked to significant aspects have been identified
- Appropriate documented procedures and work instructions related to significant activities, products, services
- Applicable communication with suppliers and contractors pertaining to significant aspects

Standards and Measures for Emergency Preparedness and Response Procedures

DOTs and other organizations are required to establish and maintain procedures to identify potential for and respond to accidents and emergency situations, and for preventing and mitigating the environmental impacts that may be associated with them. Spill prevention and control is the most common emergency preparedness and response requirement.

ISO 14001 sets standards for emergency preparedness and response (section 4.4.7) as follows:

- The organization shall review and revise, where necessary, its emergency preparedness and response procedures, in particular, after the occurrence of accidents or emergency situations
- The organization shall also periodically test such procedures where practicable.

An EMS auditor would utilize measures such as those that follow to assess the adequacy of emergency preparedness and response:

- Plans and procedures for potential or actual accidents and emergencies
- Review and revision (if necessary) of emergency procedures following an incident
- Evidence that emergency procedures are periodically tested (if practicable)
- Appropriate training of personnel involved in emergency preparedness and response

FHWA and AASHTO On-Line Clearinghouse for DOT Specifications

FHWA and AASTHO have established an online clearinghouse and electronic library where users can search, review, cross-reference and download current specifications, supplements and related documents from all 50 states, the District of Columbia and Puerto Rico.

DOTs can search any – or all – of the states (and AASHTO) for specifications in main categories or search across all documents for key words included in a specification. Main categories include: Grading, Pavements, Structures, Materials, Traffic control, and Surveying. Links are also provided to transportation related ASTM specifications. An Innovative and Emerging Specifications category can be searched for states specs and background information on design-build, performance related, quality assurance and warranty.

Construction and Maintenance Decision Support Systems

The utility of Environmental Information Management and Decision Support (EIM&DSS) software rests on the existence of well-designed business processes that agencies develop to meet the environmental goals they set. EIM&DSS software provides the technical tools that transportation planners and managers need to make better environmental decisions in the process of doing a DOT's work. Environmental information and decision support systems require data about the environment in which a DOT is operating (environmental requirements and areas requiring special management), and criteria or decision points associated with the various construction or maintenance activities a DOT undertakes.

Decision support systems in maintenance address both the roadway and the roadside. Roadway concerns can be categorized by season. During good weather and/or the construction season, pavement maintenance is the dominant on-road concern; to this end, some states have evolved sophisticated pavement management systems to focus limited maintenance dollars to achieve the maximum system preservation and pavement smoothness. Winter decision support systems have centered around Roadway Weather Information Systems (RWIS) to help guide decisionmaking regarding snow and ice removal and prevention, and accompanying chemical applications. ROW management is in the initial stages of exploration with regard to management via an EIM&DSS.

Environmental Information Management and Decision Support Systems are already in place at many DOTs to support pavement and/or bridge management. Now Environmental Information Management and Decision Support (EIM&DSS) are being developed for other key aspects of construction and maintenance. Practice areas and leaders in the field are noted below:

Maintenance Facilities Management and Auditing

- Texas DOT is undertaking Pollution Prevention Audits of facilities.
- Maine DOT has developed an EMS for all maintenance facilities, associated procedure manuals, and annual audits of all facilities.
- Mass Highway's EMS focuses on hazardous materials and hazardous waste management underground storage tanks, wetlands, water quality, and solid waste. Management System Improvement and Implementation plans are in place for all areas.

Stormwater Facility Evaluation and Prioritization of Improvements

- MDSHA has developed a thorough and duplicable grade-based rating system for stormwater management facilities and has developed an inventory, database, and photo record of all facilities statewide and their maintenance status. Under the rating system, those graded A or B are considered functionally adequate. As of late 2003, between 73 and 75 percent of MDSHA stormwater were functionally adequate (A=everything fine, working fine, no maintenance required, B= minor maintenance, need mowing or trash removal), leaving approximately 25 percent needing maintenance or retrofitting to achieve functional requirements. MDSHA aims to have 80 percent or more of SHA stormwater management facilities rated functionally adequate by 2006, and 95 percent of facilities by 2010.

Culvert and Fish Passage Evaluation and Prioritization of Improvements

- Oregon and Washington DOTs have worked with their state resource agencies to survey culverts statewide and develop systems to identify and prioritize those that need improvement.

Selection of Appropriate Environmental Measures

- NCHRP 25-25(01) is developing a decision support system for selection of water quality control best management practices (BMPs).
- NCHRP 25-27 and current projects underway by the Western Transportation Institute will develop decision support systems for selecting wildlife passage measures.
- NCHRP 24-19 is developing a decision support system for selecting environmentally sensitive bank and erosion control (bioengineering) measures.

Field Compliance Management

- Maryland State Highway Administration tracks NEPA document mitigation and project commitments at the 30 percent, 65 percent, and 90 percent design completion stage or when major design modifications are proposed.
- For large and environmentally controversial projects such as the Woodrow Wilson Bridge, MDSHA has developed a comprehensive tracking system database using

Microsoft Access to track 1200+ ROD commitments and permit special conditions. A 1:400 scale map/plan was developed for each contract depicting permitted impacts. Tracking reports from the database are created for each of 24 construction contracts and compliance is documented in concert with daily compliance inspections. A final compliance tracking report is produced at the close of each contract, complete with a narrative. As part of the final report, MDSHA will show the as-built version of the impacts and compare those to the permitted impacts. The system has also enabled MDSHA to show reductions from anticipated permanent impacts to the environment, due to careful management and minimization efforts throughout each contract. MDSHA is working to create a less labor intensive, statewide system for all NEPA EA and EIS projects.

- To achieve their stewardship planning goal of 100 percent compliance with erosion and sedimentation control requirements on all SHA construction projects, MDSHA is seeking to raise the bar on its past performance measure of ratings of B or better on 90 percent of construction projects annually to achievement of 100 percent compliance in construction. In addition to tracking performance on all construction projects, Maryland is considering certification and recertification of inspectors, contractors, and designers. Certification would require refresher courses and certification that could be lost for poor performance.

Roadside Vegetation Management

- Washington State DOT has a Maintenance Accountability Program and measures performance of both road and roadside maintenance activities.
- WSDOT also has a system for evaluating, monitoring, and addressing Slope Failures and Chronic Environmental Deficiencies in the ROW.
- Oregon DOT has surveyed all state roadsides for environmentally sensitive areas and incorporated that information in a GIS and activity maps for maintenance which indicate what activities are allowed and limitations in place where maintenance activities occur.
- MDSHA and other DOTs are tracking reductions in infestations of noxious weeds, to meet reduction goals.

Winter Operations

Road Weather Information Systems are being tied to increasingly finely tuned anti-icing and salt application strategies. In turn, such systems are being connected to vehicle Geographic Positioning Systems, materials usage, and labor management.

2.5. MEASURING ENVIRONMENTAL PERFORMANCE

The use of performance measures is steadily increasing at the federal and state level.(*76*) Forty percent of the agencies in 39 states responding in a national survey reported that performance measures are being utilized in over half of their department; an additional 33 percent said they employed performance measures agency-wide and planned to increase their use of performance measures in the next one to four years.(*77*) Use of performance measures continues to expand as such measures facilitate evaluation of program effectiveness and communication and decision-making among management.

In his work, *Getting Performance Measures to Measure Up*, Allan Schick says "the great mistake of the performance measurement industry is the notion that an organization can be transformed by measuring its performance….This optimism is not justified, for organizations — public and private alike — can assimilate or deflect data on performance without making significant changes in behavior. Performance information can affect behavior only if it is used, and it is used only when there are opportunities and incentives to do so…(i.e.) organizational change has to precede, not follow, performance measurement."(*78*) Essentially, the "why" must come and sufficient opportunity must arise before "how" comes into play. Strategic planning and quality improvement programs seek to provide the larger context and driver for measurable improvement in performance.

The central function of any performance measurement process is to provide regular, valid data on indicators of performance outcomes; however performance measures should also include information that helps managers measure the incoming workload and gain insight into causes of the outcomes.(*79*) Performance measurement also allows an organization to express the intent of its strategy and how that strategy connects with everyday operations. Such systems create an essential feedback and learning mechanism in support of key management decisions.(*80*)

Special Challenges with Environmental Measures

As noted in the April 2000 GAO Report on *Managing for Results: EPA Faces Challenges in Developing Results-Oriented Performance Goals and Measures*, the limited availability of data on environmental conditions and the effects of pollutants is a major challenge in establishing a relationship between a program's activities and resulting changes in the environment.(*81*) For many DOTs, one of the biggest obstacles is lack of data on the environment and the expense of collecting it, from just knowing what is there to having the resources or incentive to perform water quality monitoring at outfalls. The long-term nature of environmental programs means that data needed to illustrate effectiveness or for annual performance goals and measures is often not available.

While a few DOTs have maintained that it is the resource agency's job to collect this data and make it available, usually DOTs go through an expensive primary data collection process to evaluate impacts, on a project-by-project basis. Some have funded or participated in funding entire statewide data layers for resources of interest, in order to facilitate earlier review and higher-level inferences regarding what resources are present, could be impacted, and should be avoided where possible. According to the author's survey, about one seventh of state transportation agencies have invested in DOT-led identification of high quality natural resources. These states include Kentucky, Louisiana, Minnesota, New Mexico, Ohio, Oregon, and South Carolina. A similar number say they have delineated wetlands programmatically, statewide (Maryland, New Jersey, New York, Ohio, and South Carolina). Florida DOT developed a university partnership to create and manage/maintain data layers of interest to the DOT.(*82*)

Individual Performance Accountability

Performance measures can track what the agency wants and needs from its stakeholders, especially employees. Many DOTs utilize so-called performance measures to indicate whether a specific objective outlined in a quarterly or annual performance plan has been achieved. Often these program outputs are merely whether an action has been performed or not, such as development of an environmental guidebook or procedure. In some cases they involve achievement of a specific level of performance relative to an established benchmark or operational target. More elaborate performance measures are often utilized in new positions funded at resource agencies to account for the effectiveness and worth of the agency's allocation of resources in this new area.(*83*)

NYSDOT established a comprehensive evaluation system for new Construction and Maintenance Environmental Coordinators (see *Staffing* section), to build support for the positions within the agency, ensure that the positions were utilized for the intended purpose, are providing requested services (outputs), and are addressing internal stakeholder needs.

A number of states have incorporated environmental accountability into annual performance evaluation for more than new environmental positions, to add incentive for improved environmental performance and, indirectly, greater satisfaction for external stakeholders. Arizona, Indiana, North Carolina, New Mexico, New York, Pennsylvania, Rhode Island and Utah have indicated they have incorporated environmental performance into annual evaluation of design staff.(*84* Arizona has added environmental performance evaluation for their maintenance staff as well. Indiana, New York, Utah, and Virginia note they do so for both construction and maintenance, while Montana does so for construction staff only.(*85*) A longer list of states do not incorporate environmental outcomes into annual evaluations, but recognize outstanding performance or environmental outcomes where they occur.(*86*)

Table 5: State DOTs Recognizing Outstanding Environmental Work

DOTs providing individual recognition for outstanding environmental work in:	
Planning	CA, DC, DE, FL, IL, IN, MD, MI, NC, OH, PR, TX, WY
Design	CA, CO, DE, FL, IL, IN, MD, MI, MS, NC, NM, NV, NY, OH, PA, UT, WA, WI, and WY
Construction	CO, DE, FL, IL, IN, MD, NM, NY, PA, TX, UT, WA, WI, WY
Maintenance	CO, DE, FL, IL, IN, MD, NY, UT, WI, and WY

Program Measures for DOT Environmental Process Improvement Efforts, EMS, and Strategic Plans

All state transportation agencies, including Puerto Rico and the District of Columbia, have implemented process improvements or new practices designed to enhance environmental performance.(*87*) Half of state transportation agencies have implemented environmental advisory teams—comprised of a combination of partners and stakeholders at federal and state agencies and even consulting firms—to identify opportunities for streamlining and process improvements.(*88*) Often, the process improvement efforts outpace the development of measures to formally track and report progress. However, some of these improvement processes establish objectives that can then be measured or followed to ensure that the desired improvements occur. Some examples follow.

Six Pillars at Oregon DOT

State DOTs often use a method similar to performance evaluation for individuals on a program level; i.e. whether a number of one-time action items are completed during the reporting period and ongoing action items are completed on time and within budget during the reporting period. Stakeholder satisfaction remains an underlying purpose. For example, Oregon DOT will at least partially evaluate the progress of their CETAS/6 Pillars Program on whether desired the desired six programs come into existence, including creation of a habitat bank, implementation of resource mapping, and establishment of a working relationship with Forest Services and BLM.

Phase II of the CETAS process will utilize metrics to analyze a sample of projects with higher potentials for environmental impacts:

- Improving perceptions of people involved in environmental process
- Number of state highway miles with up-to-date natural resource maps relative to total that need mapping
- Number of culverts retrofitted for salmon relative to total needed
- Acres of habitat loss (used as a surrogate for predicted or potential project impacts)
- Predicted avoided, minimized, and mitigated impacts
- Acres of wetlands to be restored (indicating project mitigation and permit conditions)
- Number and acreage of mitigation projects successfully completed
- Actual project impacts
- ODOT and CETAS agency staff perceptions

New York State DOT Initiative Tracking and Participation in State Pollution Prevention Audits

New York State DOT (NYSDOT) has focused on generating buy-in and rapid organizational re-orientation, having made a pronounced, agency-wide commitment to environmental stewardship, protection and enhancement of the environment wherever opportunities exist, rather than just where mitigation is required. As such, NYSDOT has mainstreamed the agency's environmental ethic into a new way of doing business in planning, design, construction, maintenance and operations.

Each of the 11 NYSDOT Regions and most of the Main Office Functional Units have an action plan for their program to track progress toward the Environmental Initiatives' major objectives. The regional and program-specific action plans identify tasks to advance the plan's main objectives, responsible parties, completion dates, and reporting mechanisms. NYSDOT's Environmental Initiative activities are tracked at both the project and program level statewide. Utilizing the Department's automated Project and Program Management Information System (P/PMIS), program managers select Environmental Initiative attributes for any particular project as part of a general work type. This allows for the tracking and management of Environmental Initiative work related to the Department's capital construction program and maintenance activities.(*89*)

In addition to tracking whether opportunities are being captured via the number of partnership projects or degree of partnering that is occurring, whether training and piloting new approaches is occurring and where environmental elements are being incorporated into projects, NYSDOT also participates in state pollution prevention audits. These audits, focused on state laws, primarily track incidents of spills, water quality, and air violations and report performance trends.

NYSDOT has measured the progress they have made toward environmental stewardship by a number of organizational and procedural milestones. These accomplishments have included garnering high level leadership and a mandate, an agency-specific environmental mission, goals and Environmental Stewardship Action plans with monthly progress reports in each unit of the agency. Revised guidance and procedures on implementing environmental stewardship goals, and training and outreach materials on the initiative have also been implemented and tracked.

Maine DOT's EMS Performance Measures

Performance measures currently being tracked for the Maine DOT's EMS include:

- Number of violations of environmental and OSHA standards at MDOT facilities (standard is zero violations).
- Percent closure of corrective actions from audits within 12 months (standard is 100 percent).
- All facilities audited every 3 years.

North Carolina DOT's Delegated Sediment and Erosion Control Program

North Carolina DOT (NCDOT) has its own sediment and erosion control program, with regulation and enforcement delegated by the N.C. Sedimentation Control Committee and Department of Environment and Natural Resources (DENR). NCDOT prepares, reviews, and approves its own sediment and erosion control plans for land-disturbing activities associated with highway construction and maintenance and self-monitors to ensure department compliance with program requirements. NCDOT also evaluates and rates levels of field implementation. NCDOT Roadside Environmental units continuously track field compliance with the delegation agreement, in particular:

- Program outcomes
- Number of Immediate Corrective Actions issued to project staff
- Number of Notices of Violation issued to NCDOT

These measures are of great interest to DENR and the Sediment Control Commission, which review the delegated program on an annual basis. WisDOT is working on a similar continuous improvement process for the state's TRANS 401, which regulates erosion control and stormwater management for WisDOT projects.

New Mexico State Highway and Transportation Department Environmental Measures

The New Mexico State Highway and Transportation Department (NMSHTD) has affirmed a commitment to be environmentally responsible in the agency's vision statement, to be implemented through open, collaborative, ongoing involvement by the public and agencies in the agency's project development process and a commitment to not only protect but to enhance resources and community values. Engineering and environmental staff evaluate each project for which EISs, EAs, or complex categorical exclusions are prepared, on a scale of 1 to 3 for each project (maximum score = 15) once a year. Projects are classified as follows: 13-15 = high, 9 - 12 = medium, 5 - 8 = low. The five criteria are:

1. *Public Involvement*—Was the public involvement program multifaceted, proactive, responsive, and innovative?
2. *Community Impacts*—Were community values enhanced, left whole or reduced?
3. *Resource Impacts and Mitigation*—Were natural and cultural resources enhanced, left whole or reduced?

4. *Agency Coordination*—Was agency coordination multifaceted, proactive, responsive, and innovative?
5. *Decision Process*—Were alternatives considered openly and collaboratively with stakeholders?

NMSHTD tracks the percentage of projects in each category and progress toward raising the bar. The Department has collected information for over four years. The effort is similar to NYSDOT's in that it has been relatively non-threatening to program staff, since they are doing the evaluating. The agency may collect other agency and stakeholder input on performance according to their environmental responsibility goal in the future.

New Brunswick DOT, Canada, Environmental Measures

New Brunswick DOT's Environmental Protection Plan commits the agency to monitor and measure the following few areas:

- The number of employees educated/trained in the protection of the environment and the quality of those initiatives.
- Environmental protection activities at DOT facilities.
- Progress in the implementation of road salt management initiatives.
- Progress in environmental planning for proposed highway projects that fall under environmental impact assessment (EIA) legislation.

Pennsylvania DOT SEMP Maintenance Performance Measures

Pennsylvania DOT (PennDOT)'s goal is that transportation development and operations should be sustainable; i.e. have minimal negative effects on the environment. Supporting that goal, PennDOT is developing and implementing a program to analyze environmental impacts on the corridor level and to integrate, promote, and practice environmental stewardship throughout the Department. PennDOT's general performance indicators include measures of time and cost savings, quality measures of products and services delivered, indicators of greater stakeholder trust, and whether process standardization and delegations of environmental responsibility are achieved. Within Maintenance and where EMSs are in place, PennDOT uses the following performance measures pertaining to the environment.

Example 2: PennDOT Maintenance Performance Measures Pertaining to Environment

Snow Removal	
Salt Usage per Snow Lane Mile (lbs)	250 lbs.
Percent of Material (salt, skid) Deliveries with Penalty	<10%
Highway and Roadside Beautification	
Rest Area and Other QA Results (Avg. Scores)	>4.0
Percent of Interstate Mowing Plan (July 4th) Milestones Met	80-90%
Percent of System Mowing Plan (Aug. 15th) Milestones Met	80-90%
Percent of Weekly Litter & Debris Pick-ups on Interstates and Look-a-Likes Milestones Met	75-90%
Percent of Deer Carcass Pick-ups within 24 hours	70-90%
Stockpile QA Results (Avg. Scores)*	>4.0

Environments/Stewardship

Percent of Projects with No Permit Violations	100%
Percent of District SEMP Milestones Met	70-100%
Percent of SEMP Team's Milestones Milestones Met	80-100%
Number of Counties meeting Stockpile Gold/Silver Award Criteria	5

Total Quality Management

Percent Completion of Business Plan Items	25
Percent of Gap Closure Processes (SAGA/ORP) Milestones Met	80%
# of Process Improvements completed on process maps	80%

*For more on Stockpile quality assurance and associated measures, see the Maintenance Facilities section of this document.

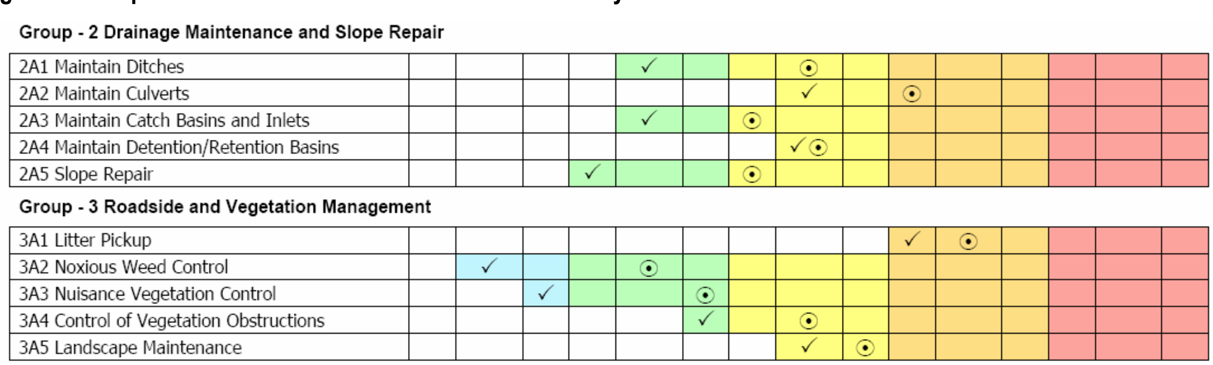
WSDOT's Maintenance Accountability Process and Environmental Factors

WSDOT has developed a Maintenance Accountability Process (MAP) tool and field manual to measure and communicate the outcomes of maintenance activities and to link strategic planning, the budget, and maintenance service delivery. Twice a year, field inspections are made of randomly selected sections of highway. The results are measured, recorded and compared to the MAP criteria to determine the level of service (LOS) delivered.

For example, WSDOT's roadsides are maintained to fulfill highway objectives in four functional categories: operational, environmental, visual and auxiliary. The Operational category includes those functions that provide safe and multi-use roadsides. The Environmental category includes those functions that protect and enhance natural and built surroundings. Visual functions promote a positive quality of life and are integral to the other functions. Auxiliary functions are those that supplement the transportation system, such as safety rest areas. The primary elements of roadside maintenance include, vegetation management, litter control and maintenance of safety rest areas.

Results are summarized annually, such as in the September 2003 Field Data Collection Manual, which includes the following A (blue) through F (red, none) grades for drainage maintenance and slope repair and roadside vegetation management.

Figure 1: Sample WSDOT Annual Maintenance Accountability Process Results



Further details about the methodology of measurement in these areas follow:

Drainage Ditches

Units of Measure: Total linear feet of ditch, per 0.10 mile section; total linear feet of filled ditch, per 0.10 mile section.

Threshold: Count as deficient all ditches which are 50% or more full.

Methodology: Measure all ditches within the section and record the total linear feet of ditches. Measure and record the linear feet of ditch that is 50% or more full of sediment or other material.

For purposes of this survey, to be considered a ditch the structure must be designed and constructed to carry water – not a natural swale, or must be maintained as a ditch by Maintenance.

Comments: Streams adjacent to the roadway are not considered ditches. Standing water (tidal or non-tidal) in ditches is not a deficiency. Vegetation growing in the ditch is not a deficiency. Ditches designed solely to capture rock fall shall not be considered a ditch for this survey.(*90*)

Culverts

Unit of Measure: Total number of culverts, per 0.10 mile section. Total number of culverts greater than or equal to 50% filled or otherwise deficient, per 0.10 mile section.

Threshold: Count as deficient if:

1. Any portion of the culvert is 50% or more filled with sediment or debris, or
2. Any end is significantly crushed or deformed, or
3. The volume of the inflow or outflow is reduced 50% or more by obstructions such as rocks, vegetation, or woody debris, or
4. The pipe is separated 1" or more, or damaged in a way that the function of the culvert is causing significant damage to the roadway prism or adjacent drainage channel.

Methodology: Count and record all culverts within the section. Count and record any culvert that is 50% or greater filled or otherwise deficient. Evaluate only those culverts that cross state highways or county roads at their intersection with state highways. Do not count culverts under private access roads.

Comments: Vegetation obscuring the end of a culvert is not a deficiency unless it obstructs the flow of water. Standing water (tidal or non-tidal) in ditches is not a deficiency. Culverts designed to be half filled with gravel for fish habitat should not be rated as deficient.(*91*)

Catch Basins / Inlets

Inlet Pipe, Outlet Pipe, Flow Line, Elevation, Catch Basin or Grate Inlet, Grate Ground Elevation, Silt Storage, Capacity Varies

Units of Measure: Total number of catch basins and drain inlets, per 0.10 mile section; total number of catch basins and drain inlets that are deficient.

Threshold: Count as deficient any catch basin or drain inlet that has:

1. 50% or more of the inlet grate blocked with debris, or
2. The catch basin has sediment buildup that reaches or exceeds the flow line elevation of the outlet pipe.

Methodology: Count and record the total number of catch basins and drain inlets in the section. Count and record the number of catch basins and drain inlets blocked by debris or catch basins filled with sediment.

Comments: Both catch basins and drain inlets are rated for blockage of the inlet grate. Only catch basins are rated for sediment build-up. A flashlight and/or probe may be needed to determine if the structure is a catch basin (i.e., has silt storage capacity) and whether it is deficient.(*92*)

Slope Failures

Unit of Measure: Total number of slope failures, per 0.10 mile section.

Threshold: Only count as deficient a slide or erosion that is at the time of the inspection:

1. Jeopardizing the structural integrity of the shoulder or traveled lane(s), or
2. Blocking the shoulder or traveled lane(s), or blocking the ditch, or
3. Jeopardizing the structural integrity of guardrail or traffic signs.

Traffic may move slower through the area or lanes may be reduced, causing intermittent stoppages. Erosion or slides not meeting the thresholds above shall not be considered deficient.

Methodology: Determine and record the total number of slope failures found within the survey section. Both fill and cut slopes can be affected.(*93*)

Comments: Chronic or ongoing slope failures that do not meet the criteria listed above at the time of the survey are not to be counted as failures. Edge drop-off is not considered a slope failure.(*94*)

Noxious Weeds - Weed Infestation

Units of Measure: Total square feet of infestation, per 0.10 mile section.

Threshold: Presence of noxious weeds on the roadside.

Methodology: Survey the roadside and determine the presence of any noxious weeds. Measure the square feet of the infestation; the total square feet of infestation should not exceed the total square feet of roadside.

Comments: Identifying noxious weeds can be difficult and is best done by a person trained in weed identification. For assistance in identifying noxious weeds consultation with the area roadside or spray crew is recommended.(*95*)

Nuisance Vegetation - Weed Infestation

Units of Measure: Total square feet of infestation, per 0.10 mile section.

Threshold: Presence of nuisance vegetation on the roadside.

Methodology: Survey the roadside and determine the presence of any nuisance vegetation. Measure the square feet of the infestation; the total square feet of infestation should not exceed the total square feet of roadside.

Comments: Identifying nuisance vegetation can be difficult and is best done by a person trained in weed identification. For assistance in identifying nuisance weeds consultation with the area roadside or spray crew is recommended.(*96*)

Vegetation Obstruction

Unit of Measure: Total number of vegetation obstructions per 0.10 mile section.

Threshold: Vegetation blocking sight distance to guide or regulatory signs, or intersections as seen from the driver's perspective.

Methodology: Measure and record total number of instances where vegetation obstructs sight distance to signs or intersections. For example, if a survey site has two blocked signs and one blocked intersection the surveyor shall record 3 vegetation obstructions on the survey form.

Comments: For the purpose of judging adequate site distance for this survey, signs and intersections should be visible from distances of:

- Freeways 800 feet min.
- Rural roads 500 feet min.
- Urban roads 200 feet min.(*97*)

Litter

Unit of Measure: Total number of litter counted, per 0.10 mile section.

Threshold: Objects approximately 4 inches in any dimension or larger.

Methodology: Observe and record all litter 4 inches and greater.(*98*)

Measuring Environmental Outcomes

Measuring environmental outcomes is a relative rarity at state transportation agencies, partially due to the difficulties with environmental data discussed previously. All state DOTs track the acres of wetlands impacted and acres of compensatory mitigation, to report to FHWA. Some states subdivide this information by type of mitigation, type of wetland, or by watershed.

Washington State DOT's Success Standards for Wetlands Restoration

Washington DOT tracks the number and total acreage of wetland impacts and mitigation projects in the areas of wetland creation, restoration, enhancement, preservation, and upland buffers. Washington State DOT has taken the further step of establishing interim and final success standards for replacement wetlands, including the presence of a functioning hydrological system and saturated soil conditions, vegetation characteristics of native plant species, and wildlife habitat diversity, which will be described in greater detail below. Washington DOT has integrated Environmental Performance reporting into its Quarterly Publication, "The Gray Notebook."

NCDOT's Ecosystem Enhancement Program

NCDOT's Ecosystem Enhancement Program, operated cooperatively with the Department of Environment and Natural Resources, is considering tracking the following environmental outcome measures:

- Number of acres of priority conservation areas acres protected annually by EEP (also contributing to NC's "Million Acres" Program, now "One North Carolina Naturally").
- Amount of watershed improvement achieved after five or more years through appropriate measures.
- Number of acres of wetlands, riparian and non-riparian, and feet of riparian areas (cold, cool, and warm) impacted and replaced.
- Percentage of watersheds enhanced.

- Replacement of all functions lost to impacts from transportation projects (replacement unit less impacted unit is greater than or equal to zero).

Functional replacement will also be assessed and a rapid assessment technique is being developed, to help assess the percentage of successful projects.

Utilizing a Combination of Program and Environmental Indicators

Maryland State Highway Administration Environmental Outcome & Program Performance Measures

MDSHA is using a combination of program measures, outlined in the earlier section on environmental objectives and targets, and environmental outcome measures. Program and process measures which can be expected to yield quantifiable environmental benefits in some cases include MDSHA's targets of meeting 100 percent of environmental commitments on construction projects and achieving 100 percent compliance in implementation of erosion and sedimentation control plans. The agency also has program, progress indicators such as achieving an incompliance rating on their NPDES permit and implementing certain percentages of upgrades in stormwater and industrial facilities by 2006 and 2010.

Washington State DOT's Environmental Indicators and Public Reporting

Washington State DOT is seeking to measure environmental outcomes directly through their wetlands replacement success evaluation effort. In 2000 and 2001 biologists monitored 62 WSDOT project sites ranging from one to eight years in age according to 240 individual measurable standards, including area of buffer width around the entire wetland, whether habitat for target species has been created, species diversity, food chain support, area of stream shaded by vegetation, and area of shrub or forest cover. Such standards are comprised of "an observable or measurable benchmark for a particular performance objective, against which the mitigation project can be compared. If the standards are met, the related performance objectives are considered to have been successfully achieved."(*99*) Contingency measures specify corrective action that will be implemented if a stated standard is not met within a specified period of time. Like most other DOTs, WSDOT also tracks compensatory sites for which monitoring is complete and wetlands that are still being monitored. Of the latter, WSDOT tracks those that are meeting some, all, or no standards at the current time.

WSDOT is also seeking to measure a variety of environmental outcomes along with program outputs and intermediate outcomes. In addition to WSDOT's wetlands replacement success evaluation and cost-benefit efforts discussed earlier, the agency is measuring:

- Construction site erosion control
- Fish passage improvements
    - Number of culverts retrofitted for fish passage improvement
    - Number of barriers removed as a major construction projects
- Recycled materials beneficial use
- Herbicide use
- Environmental documentation process, completion times

- Number of non compliance events (self reported without violations, by regulatory area and activity type) and notices of violations (citations)
- Turbidity upstream and downstream of construction sites (5 pilots)

The agency is also correlating the number of deer killed on state highways (a commonly tracked item at state transportation agencies) with investments in fencing, specialized roadside reflectors, wildlife crossings, and flashing signs to make inferences regarding effectiveness. Progress is reported quarterly in the agency's "Gray Notebook," available on-line.

State Environmental Agency Reporting on the State of the Environment

Several states issue regular reports on the state of their environment, and are using the data contained in those reports to move to a more performance-based system of environmental management. The Florida Department of Environmental Protection is a leader in this area, having issued its first Secretary's Quarterly Performance Report in December 1997. The report divides the department's performance indicators into four tiers:

- Environmental and public health outcome indicators, which measure the effects of the department's action in the real world.
- Behavioral and cultural measures; which measure the department's influence on the actions of the regulated community and the public (such as regulatory compliance).
- Departmental outputs and activities, which measure the actions of the department's employees (such as issuing permits, conducting inspections, etc.).
- Resource efficiency, which measure how efficiently the department uses its budget and manages its employees.

Based on this data, Florida attempts to measure its progress in protecting the environment and identify those areas that need focused attention.

Minnesota and Washington both issued "state of the environment" reports in 2001. Minnesota's section on Land, Air and Water addresses transportation related impacts. Washington State's report addresses Stream Temperatures and Salmon, Air Quality, Hazardous Waste, Solid Waste Disposal, and Spill Prevention, among other areas.

Canada's Sustainable Transportation Indicators

Canada created a definition of a sustainable transportation system that with slight changes has been adopted as a working definition by the Transport Ministers of the 15 countries of the European Union. Their definition of a sustainable transportation system is one that: (*100*)

- Allows the basic access needs of individuals to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

To this end, Canada developed a number of indicators to measure progress toward sustainability. Those include: (*101*)

- **Energy use for transportation** as represented by consumption of non-renewable resources such as fossil fuels. Canada found that energy use for transportation (in petajoules) increased 21.5 percent between 1990 and 2000, even though population growth accounted for only half of that.
- **Greenhouse gas emissions**, (mainly CO_2) which increased by a corresponding level. Transportation was charged with contributing about a third of total emissions directly and much more if its share of emissions from fuel production would have been counted. The most important GHG emitted by transport is carbon dioxide (CO_2), accounting for more than 90 percent of transport's contribution to the greenhouse.
- **Other, more locally acting emissions from transportation including** carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOCs). Transportation's approximate shares of total emissions in Canada are 65 percent for CO, 5 percent for SO2, 57 percent for NOx, and 28 percent for VOCs. The last two combine to form ground level ozone, causing respiratory illness in people and stunting plant growth.

Technological improvements and notably, the introduction in the 1980s of the three-way catalytic converter to reduce emissions from gasoline-fuelled engines, enabled reductions in this category, though particulates were not included in this index, due to unreliable measurement.

- **Safety.** Contributing factors to the declines in road injuries and fatalities were drink-driving laws, seat-belt laws, safety features in vehicles (e.g., airbags and better brakes), and safety features in highway design (e.g., better alignments and signage), along with enforcement of speed restrictions and safe-driving requirements.
- **Movement of people and freight**, both of which increased between 1990 and 2000. Freight movement, with an increase of 37 percent over the decade, more than doubled movement of people.
- **Urban land use and land consumption**. This indicator notes that "widespread ownership of personal vehicles makes development possible at densities too low to justify bus services. People who live in such development need to use their cars for almost all the journeys they make. This leads to more car ownership and use and more sprawl. The result is growth in the use of land for urban purposes (homes, businesses, institutions, etc.) beyond the rate of population growth. In addition, low density development can make rural areas less accessible to urban residents, causing them to travel farther for recreation. Excessive use of land for urban purposes can displace agricultural activity, requiring food to be shipped from greater distances…Between 1971 and 1996, the amount of developed land per urban resident increased by 28.9 percent, from 971 to 1,251 square meters. The total amount of land used for urban purposes increased by 55.7 percent between 1981 and 1996, from 18,015 to 28,045 square kilometers. The increase corresponds to about 1.4 percent of Canada's agricultural land."
- **Household spending on transportation,** which increased from 16.1 percent to 19.2 percent between 1982 and 2000. The increase involved two steep rises: between 1982 and 1986, and between 1998 and 2000. Closer analysis of the household spending data

shows that what increased the most were the costs of car purchase and other fixed costs, e.g., insurance. Real spending on fixed costs—mostly car purchase— increased by 69.2 percent between 1982 and 2000. Real spending on operating costs, mostly fuel, declined by 0.8 percent between 1982 and 2000.

- **Technical performance of road vehicles, specifically how much energy they use**, which provides detail about an aspect of total energy use by transportation. The main contributing factor to these changes were growth throughout the 1990s in the proportion of fuel hungry sport-utility vehicles (SUVs), minivans, and light trucks in the personal vehicle fleet. In the second half of the decade, this factor was offset by reductions in the fuel intensity of other vehicles, notably heavy trucks.
- **Emissions per unit of transport activity.** Substantial improvement in technical performance of vehicles with regard to emission reduction over the decade has largely been offset over the past five years by more vehicles on the road and an increase in vehicle miles traveled.

Environmental Auditing

DOTs have begun to establish programs and procedures for periodic auditing of environmental performance and management systems in order to determine whether planned arrangements are implemented and working.

Environmental audits have been defined as systematic and documented verification processes to objectively obtain and evaluate evidence to determine whether an organization is in conformance or compliance with commitments (legal requirements, internal policies, adopted standards, and defined procedures) and to ensure that necessary corrective actions are made in a timely manner. Audit protocols are often written documents, checklists, procedures or guides used to define the audit scope, to assist the auditor with completing the required elements of the audit plan, and to assist the audit area in preparing for the audit.

New South Wales Construction Auditing Program

Within the New South Wales, Australia, Roads and Traffic Authority (RTA)'s EMS, environmental auditing is one way the RTA assesses its performance in environmental management, identifies areas where improvement is needed, and demonstrates the due diligence of both the RTA organizational management and its employees. The RTA defines environmental auditing as a "systematic, documented verification process of objectively obtaining and evaluating evidence to determine whether specific environmental activities, events, conditions, management systems or information about these matters conform to audit criteria and communicating the results of this process."(*102*)

The NSW RTA established guidelines to provide a structured approach to environmental auditing with risk assessment of projects influencing audit frequency.*103* An environmental audit, which examines the management systems and their implementation through both documentation and reporting and their translation into on-the ground results, can retrospectively examine the performance of the project, and give a context against which to assess the current performance. Records of inspections are brought together as part of the audit documentation for examination. Environmental audit findings enable the RTA to answer the following questions:

- Are RTA's environmental policies, strategies and guidelines being complied with?

- Are environmental goals, objectives, and targets set by the RTA being achieved?
- What opportunities exist to improve environmental performance?
- Are the current environmental management systems and requirements relevant and effective in achieving the RTA's goals?
- Are regulatory requirements being met?
- Is the RTA, through the contractor, meeting its legislative duty of care and exercising due diligence?
- What corrective action should be taken?
- Are regular management reviews conducted to find ways to improve environmental performance?

At the New South Wales, AUS, Roads and Traffic Authority, the assessment and determination of a "generic" or "activity specific" Review of Environmental Factors establishes the environmental measures that are required to be translated into day-to-day construction and maintenance. For construction projects, the RTA notes that its environmental performance hinges on how well environmental safeguards are implemented, maintained, monitored and rectified, and how appropriate follow through occurs, both in construction and in operation and maintenance. The NSW RTA charges project managers with ensuring that conditions of project approval are an integral part of procedures for detailed design, tender documents, tender assessment, construction management, maintenance and auditing. All monitoring requirements arising from source documents are included in Environmental Management Plans (EMP) for projects and sets of maintenance activities. The Contractor's EMP and its implementation are subject to the same quality assurance and audit procedures as other aspects of the project; auditing is undertaken against the conditions of approval and against individual elements of the EMP.

A Verification Report is prepared to establish how well the contractor's performance matches the requirements of the EMP. NSW RTA's "hand off" procedure attempts to "ensure the continuing highest standards of environmental management after completion of construction" by confirming that the environmental undertakings in relation to construction have been completed satisfactorily and passing on to the Maintenance Engineer/Bridge Maintenance Engineer the environmental undertakings in relation to operation and maintenance.

The RTA generally adopts a partnering, non-adversarial approach to contract management. The partnering approach is supported by quality assurance to enhance accountability by the contractor for the delivery of the contract requirements. For the RTA, auditing is an essential component of quality assurance procedures and is the principal method of independently verifying that the contractor is carrying out its responsibilities and is achieving the desired environmental outcomes. The RTA's audits and surveillance of the contractor's activities complements the contractor's monitoring and internal auditing, all of which will demonstrate both the contractor's and RTA's duty of care for environmental issues.

To ensure the environmental issues of a Region or Branch are effectively managed, Region and Branch Environmental Audit Plans are developed. The Plans set directions and document the Environmental Audit Programs for Business Units within the Region or Branch. The Environmental Audit Plan includes:

- A compilation of the Environmental Audit Programs currently being carried out

- The planned Environmental Audit Programs for Business Units
- Identified Business Units that still need to develop an Environmental Audit Program
- The management information required from the programs

The audit program consists of a schedule of audits of the environmental management practices within the Unit. For construction works, the audit program consists of a schedule including:

- Listing of all the project sites.
- Broad risk ranking of all projects to determine the priority and frequency of auditing. Environmental Services Staff often assist in the assessment of environmental impacts and their associated risks. The criteria used to decide this risk ranking includes but is not limited to the:
    - environmental consequences of the activity
    - size and scope of the activity
    - duration of the activity
    - sensitivity of the area affected by the construction
    - demonstrated performance in meeting agreed requirements
    - results of previous audits
    - effectiveness of internal audits

  From this risk ranking a frequency of audits should be established that would ensure the robustness of the environmental management processes.

  Projects of short duration (e.g., up to 3 months and are assessed as low environmental risk) are considered in development of the program, but usually a surveillance program with a checklist against the project or maintenance activity Environmental Management Plan is used instead, and signed off by the work supervisor or lead engineer. Auditing for longer term projects is recommended at least every six months. RTA audits are timed to compliment the contractor's audit plan for the frequency of internal and external audits.

  Audit frequencies may be relaxed if previous audits have identified that systems and procedures are in place and are used diligently on the project. In practice consideration of audit frequencies looks to:
    - Signs of system failure
    - Evidence of adverse environmental effects
    - Major changes to the project or organization
    - Changes in regulations or policy requirements
    - Complaints/concerns from public authorities
    - Identified risk ranking
- Schedule of dates when the audits will be conducted and types of audits
- Identification of resources to complete the program
- Reporting structure

The planning horizon (timeframe) of the program depends on the size of the construction works within the Business Unit; however an annual rolling program that is subordinate to the Business

Plan is recommended, with annual review and reporting and the flexibility to include new projects either planned or underway. After consultation with environmental staff, the final audit program is developed and distributed to the Business Units in the Region or Branch, Project Managers and other relevant staff in the directorate, and the relevant Environmental Services Staff.

New Jersey DOT Construction Audits, Contractor Performance Rating System, and Environmental Factors

NJDOT's Construction and Maintenance Unit conducts audits include but are not limited to environmental issues. Typical findings of these construction and maintenance audits involve sedimentation and erosion control issues. The audits are randomly conducted and primarily serve as part of the construction auditing process, where environmental commitments play an important role.

As part of the New Jersey DOT Contractor Performance Rating System Procedures evaluation of work performed by the Contractor is made to determine the Contractor's performance rating for each contract. The Contractor Performance Rating System generates a Performance Rating of the Prime Contractor, which:

- Provides an objective and consistent method for measuring Contractor performance
- Provides a beneficial effect on Contractor performance
- Increases quality, cost effectiveness and efficiency of the construction process and the finished product
- Provides the Contractor opportunities to improve job performance between rating periods

The ratings provide the Department with essential information to be used to encourage and ensure the best quality product by awarding projects to the lowest responsible bidder that continually provides high quality work. The system is designed to recognize Contractors performing exceptional work, as well as identify Contractors repeatedly failing to perform satisfactory work. Every six months, the Resident Engineer completes Interim Ratings for the project work executed to date and forwards the rating to the Field Manager for concurrence. Interim and Final Ratings are prepared for all projects. Contractors are rated on a 1 to 5 scale, from unacceptable to outstanding performance. Fifty percent of the points are allocated to quality (including earthwork, drainage, and landscaping) and contract compliance. Safety, traffic control, and environmental evaluation comprise another 20 percent of the total. For safety and environmental commitments, a score of 5 translates to 100 percent compliance, without corrective action, a 4 is given for minor non-compliance with no corrective action required. A score of three and minor non-compliance indicates minor corrective action is needed. The lowest two scores are reserved for major non-compliances requiring corrective action and necessary work shut downs.(*104*)

Contractor Performance Checklists are completed by the Resident Engineer and/or project inspection personnel and remain in the project file through completion of the contract. The Contractor Performance Checklists provide detailed information to be used by the Resident Engineer and Contractor in identifying non-compliance in methods, materials or performance that must be improved to provide acceptable quality. The level of importance of issued non-compliance notifications, as well as the frequency and duration of the notices, and resultant scoring of the other items of the checklists are used to determine the Contractor Performance

Rating ratings. To maintain objectivity, the project specific Contractor Performance Checklists are completed by the Resident Engineer and inspection personnel concurrent with the Contractor's execution of the work. Checklists are completed by inspection personnel, as required, for a given work item. Any work item in non-compliance that may negatively impact project cost, schedule or duration will be photographed by inspection personnel and reported to the Resident Engineer. Upon submission of a checklist from inspection personnel indicating non-compliance, the Resident Engineer submits a Notice of Non-Compliance Form and checklist with the noted non-compliance item(s) to the Contractor. A Contractor receiving a Notice of Non-conformance Form may be required to submit a Corrective Action Plan, if noted on the Notice of Non-Compliance Form.(*105*)

New York State DOT Environmental Auditing and Self-Reporting

As a state agency, the DOT is required to audit all its facilities, operations and projects (F/P/Os) (construction contracts) annually for compliance with DEC regulations. This involves a formal assessment in April of the compliance status of the previous fiscal year. The Regional Environmental Audit Coordinator compiles the report for the F/P/Os and in the region and forwards the report to the DOT Environmental Audit Coordinator for final compilation and submission to DEC. The environmental staff can assist in determining compliance issues and the headquarters Environmental Analysis Bureau can provide technical assistance on environmental audit issues.(*106*)

NYSDOT has automated the New York State Department of Environmental Conservation's (NYSDEC) State Environmental Audit System in order to self-report violations of NYSDEC regulations and to report environmental initiative activities. NYSDOT's annual environmental audit relies on many tracking mechanisms that use the NYSDEC automated database. NYSDOT tools for environmental auditing include the ETRACK database, a Microsoft application linked to NYSDOT's Program Support System, which tracks projects and their major milestones. The database details specific aspects of a project, such as environmental, landscape and architecture, and social impacts. The goal of the ETRACK effort is to establish a method to assure consistency in statewide environmental information.

Maine DOT's Environmental Audit Program

Maine DOT (MDOT) has developed an environmental management system for Maintenance and Operations (M&O), Ferry Service, and Laboratories based on the ISO 14001 model. As part of their procedures, MDOT M&O staff conduct periodic environmental audits of Highway Maintenance, Motor Transport Services, Bridge Maintenance, and Traffic Engineering Divisions and all maintenance facilities. The audit systematically documents and verifies whether the divisions and facilities are in conformance or compliance with legal requirements, internal policies, adopted standards, and defined procedures. Gaps are determined and strategies developed to continually improve environmental performance. Corrective actions are tracked, and timely closure of audit findings is an M&O priority.

Cross-functional teams of MDOT employees report their findings to District management and an agency wide Environmental Management Committee that includes the M&O Director. In auditing, the team follows generally accepted guidelines as described in the ISO 14010, 14011, and 14012 or by the American Society for Quality. Audit protocols consist of written documents, checklists, and guides used to define the audit scope. The Environmental

Management Committee monitors completion of the corrective actions in the Corrective Action Plans on a bi-monthly basis and performs follow-up reviews.

MDOT has taken special care to fulfill the EMS objectives of consistency, repeatability, integration of environment into day-to-day activities, measure performance, and ease of understanding. A broad spectrum of employees participated in the efforts to develop relevant, easily understood procedures, processes, and tools for each EMS. These efforts occurred over more than a year and required periodic meetings. Commitment of senior management at the very beginning of the EMS efforts ensured that resources needed for implementation were available, all involved in or affected by an EMS stayed focused on the implementation activities and schedule, and all affected employees understood that they are stewards of the environment. Maine DOT's environmental audit system has the following characteristics:

- Maintenance and Construction projects are inspected by Environmental Office staff that, along with the MDOT Construction manager, are authorized to require changes to address environmental deficiencies on projects.
- All employees are required to be familiar with MDOT's environmental policies and procedures that affect their work, as documented in MDOT's Environmental Policies and Procedures Manuals.
- Management is proactive in all follow-up measures, particularly those that require department-wide policy changes and dedicated funding.
- MDOT Tracks and benchmarks problems and successes through an integrated database.

As a result of using a structured and consistent audit program MDOT compliance in operations and maintenance has substantially improved, according to MDOT's EMS lead staff. Employee "ownership" of and pride in their facilities and actions has also greatly improved. Furthermore, the level of compliance achieved is much higher than with prior initiatives. As a result of the EMS effort, MDOT employees understand that their day-to-day actions can have a positive or negative effect on the environment. Maine DOT's Environmental and Safety Auditing Policy and Procedure is listed in the Appendix. The form MDOT uses to track corrective action requests is also included in the Appendix.

Mass Highway's Compliance Tracking and Self-Audit Programs

Mass Highway tracks compliance through scheduled self-audits, facility inspections and, routine facility observations. Procedures and additional guidance information on inspections can be found in Mass Highway's Facility Environmental Handbook and SOP No. ENV-01-03-1-000; Hazardous Waste Management at Mass Highway Facilities. Procedures and guidance for conducting Self-Audits can be found in Mass Highway Self-Audit Protocol Fieldbook. The Mass Highway Compliance Tracking Methods are included in the Appendix as are the Compliance Tracking Roles and Responsibilities, Self Audit Procedure, and Facility Self Audit Checklist.

PennDOT Stockpile Audits and Award Program

PennDOT audits its stockpile management on a regular basis. Measures are included in the facilities management section. PennDOT's audit system is also used as a basis for an award program for counties maintaining stockpiles. Those that can answer yes to all five measures below are awarded a "gold" award and those that can affirmatively respond to four are given a "silver."

- A four year stockpile needs assessment with spreadsheet is developed in cooperation with Facilities Management and submitted to the District Maintenance office for each facility in the County by June 30th of each year.
- Equipment Managers and Foreman, weekly walk around are documented and charged to coding 822-1201 on payrolls 90 percent to 100 percent of the time.
- A foreman's checklist is completed and submitted to the District Maintenance Office four times per year for each County stockpile. (11/30, 1/31, 3/31,6/30)
- A score of 3.5 or > is received on all model stockpile Quality Assurance evaluations completed.
- All County field and garage employees are presented the Stockpile Academy refresher by April 1, 2002.

For more information see the chapter on Maintenance Facilities under "Land Procurement and Stockpile Development.

Missouri Contractor Performance Measures and Evaluation

Missouri utilizes a project questionnaire in evaluating contractor performance Missouri DOT Past Performance Evaluation Forms. Standard questions based on contract specification requirements are used to evaluate performance in three categories: Quality, Contract Compliance and Prosecution & Progress of work on the project. The evaluation form allocates points for:

- Minimizing disturbance outside the ROW and outside easements.
- Whether necessary salvage and removal was accomplished without damage.
- Drainage items initially installed/constructed in accordance with the plans and specifications.
- Whether embankments were constructed according to designs and specifications.
- Percentage of the sod was living at the end of the initial watering period.
- Soil preparation, lime and fertilizer application in compliance with the contract.
- Initial seed and mulch application in compliance with the contract.
- Acres (hectares) of erodible earth authorized versus that opened at various points.
- Percentage of the required temporary erosion control items were properly installed and maintained.

New Jersey DOT Past Performance Procedures and Evaluation Forms (Word Version). According to a survey by the AASHTO Construction Subcommittee Contract Administration Task Force, performance evaluations directly lead to an adjustment of prequalification capacity rating with the completion of every contract in nine states (FL, IA, IL, MA, MD, ME, MO, NE, VT).(*107*)

Standards and Measures of Environmental Performance Audit Programs

- Audit results should be provided to management and any oversight teams in order to make any needed adjustments to the process.
- The audit program and schedule should be based on the environmental importance of the activity concerned and the results of pervious audits.

- Audit results should be tracked.
- Audit procedures should cover the audit scope, frequency and methodologies, as well as the responsibilities and requirements for conducting audits and reporting results.
- Audits should improve employee awareness, participation and motivation
- Audits should provide the opportunity for continual improvement and improve the confidence and satisfaction of interested parties.
- Improve operational performance.

Standards and Measures for Nonconformance Detection and Corrective and Preventive Action

Ensuring that feedback occurs, procedures are changed if necessary, and environmental outcomes are appropriate or targets are met requires ongoing identification of deviations from expected procedure or performance and follow up by implementing corrective or preventive action.

ISO 14001 identifies standards for nonconformance and corrective and preventive action, which require certified organizations to establish and maintain procedures to ensure this takes place.

- Responsibility and authority are defined for handling and investigating nonconformance, taking action to mitigate any impacts caused, and for initiating and completing corrective and preventive action.
- Any corrective or preventive action taken to eliminate the causes of actual and potential nonconformances should be appropriate to the magnitude of problems and commensurate with the environmental impact encountered.
- The organization should implement and record any changes in the documented procedures resulting from corrective and preventive action.

Thus, in checking for a functional process for identifying nonconformance where it exists and following up with appropriate corrective and preventive action, one may look for the following indicators:

- Process for managing and monitoring nonconformities and noncompliances.
- Records showing timely corrective and preventive action occurred and actions were closed out.

Standards and Performance Evaluation for Monitoring and Measurement

Standards and measures to use or those in place already at DOTs are discussed throughout this document on a subject basis; however, some general measures for a DOT's larger monitoring and measurement effort related to environmental performance are established by ISO 14001 section 4.5.1.

- The organization shall establish and maintain documented procedures to monitor and measure, on a regular basis, the key characteristics of its operations and activities that can have a significant impact on the environment.
- This shall include the recording of information to track performance relevant operational controls and conformance with the organization's environmental objectives and targets.

- Monitoring equipment shall be calibrated and maintained and records of this process shall be retained according to the organization's procedures.
- The organization shall establish and maintain a documented procedure for periodically evaluating compliance with relevant environmental legislation and regulations.

DOTs often maintain documentation when key characteristics of operations are monitored and measured. Most often, such monitoring occurs in response to regulatory requirements or negotiated approvals by regulatory agencies. DOTs maintain calibration records for monitoring equipment and keep records when/that compliance evaluations are periodically conducted. Conformity to a DOT's established environmental objectives and targets also indicate that monitoring, measurement, and feedback (the system) is working.

2.6. Environmental Staffing, Roles, and Responsibilities

An effective environmental management system requires, roles, responsibilities, and authorities to be defined and communicated. Also essential are the necessary resources, including human resources and specialized skills, technology and financial resources, to implement an organization's environmental objectives.

Clarifying Roles and Responsibilities to Ensure Environmental Performance

As part of environmental performance and process improvement efforts, some DOTs have also sought to clarify environmental roles and responsibilities. As of 2002, DOTs that indicated having identified environmental roles across their organizations included: Alabama, Connecticut, Florida, Georgia, Hawaii, Iowa, Kansas, Kentucky, Michigan, Minnesota, North Carolina, New York, Puerto Rico, Texas, Utah, Virginia, and Wisconsin, in addition to the examples which follow. Tables are sometimes used to ensure all responsibilities have been assigned, communication is clear, and no gaps are present.

Mass Highway District Environmental Roles and Responsibilities and Associated Training

Mass Highway's EMS manual describes organizational roles and responsibilities relative to environmental compliance management at Mass Highway facilities. Personnel within the major Organization Offices, Divisions, Districts and Sections that affect compliance with Mass Highway environmental requirements are identified. To "foster the integration of environmental stewardship into facility operations…roles and responsibilities for environmental management have been established and employees shall be educated as how to best carry out their environmental related duties."(33) The sections listed in the Appendix provide an overview of Mass Highway EMS roles and responsibilities for personnel in the Organization Offices, Divisions, Districts and Sections and illustrate the degree to which the success of such an environmental process improvement program depends upon broad involvement and responsibility. These sections are: Mass Highway Environmental Roles and Responsibilities, Section EMS Roles and Responsibilities, Operations Division EMS Roles, and Responsibilities, District EMS Roles and Responsibilities. Training expectations have been tied to each of these roles as well as roles and responsibilities accompanying the training program and are also listed in the Appendix.

The environmental review process encompasses a number of other EMS roles and responsibilities. For example, in that process at Mass Highway, the Chief Engineer assumes ultimate responsibility for ensuring an annual review of the environmental management system is conducted and the Deputy Chief Engineer Environmental assumes responsibility for the EMS Program review, coordinates Senior Management Review and the EMS Task Force reviews. The Deputy Chief engineer also coordinates independent audits and ensures implementation of recommendations from the review. The EMS Supervisor HazMat/HazWaste Unit conducts the annual EMS Task Force review meeting and prepares a summary of EMS Task Force recommendations for the Deputy Chief Engineer, Environmental Section, Chief Engineer, District Highway Directors, Deputy Chiefs, and Department/Section Heads. The EMS Supervisor also participates in the annual Senior Management Review process, represents District/Operation by providing input on current operations and EMS implementation, and reviews bi-annual independent audits and makes recommendations on correction and implementation of audit findings. The EMS Task Force participates in the annual EMS Task Force review process, provides comments on EMS effectiveness and makes recommendations for improvements. An independent EMS reviewer conducts bi-annual EMS program reviews and prepares a summary of findings for submission to the Deputy Chief Engineer.

PennDOT Environmental Role and Responsibility Identification for SEMP Implementation

PennDOT's Engineering & Maintenance District 10 is using the Responsibility Table listed in the Appendix to ensure that responsibilities in delivering its Strategic Environmental Management Program are assigned and carried out. Training requirements to support each position in carrying out their responsibilities are included in the Training Table, also listed in the Appendix.

Caltrans Construction Compliance and Stormwater Roles and Responsibilities

The Caltrans Construction manual specifies that "the district construction deputy director is responsible for ensuring that environmental and permit requirements are enforced. To meet legal requirements, district construction staff must receive appropriate training, possess appropriate skills, and understand their role in successfully carrying out environmental measures. Within the district construction division, appropriate environmental coordinators must be appointed."(*108*) Caltrans extensively delineates roles and responsibilities as part of the agency's Construction Stormwater Coordinator Guidance Manual see pp. 2-8.

Staffing: Environmental Support for Construction & Maintenance

Several state DOTs have added environmental staff devoted to assisting Construction and/or Maintenance staff. In response to the agency's increased focus on environmental sensitivity, Mass Highway established a separate environmental program within its Construction Division. Working with environmental and construction staff in headquarters and District offices, the program provides quality assurance reviews on construction projects, compliance assistance to staff, coordination with regulatory agencies, training and written guidance. NYSDOT and Virginia DOT provide the most far-reaching and staff rich models focused on construction and maintenance. Virginia has placed 29 staff around the state in residencies, primarily to support maintenance operations. Another 19 Environmental Monitors serve as erosion and sedimentation control experts around the state and monitor the full range of environmental commitments. NYSDOT has placed 22 senior environmental specialists in Regions, 11 to support construction and 11 for maintenance.

Mn/DOT and WSDOT Environmental Staff Supporting Maintenance & Operations

Many states have environmental staff in regions or districts that are focused on NEPA compliance and project development and who also provide some support to waste management and environmental compliance/commitment follow-through. Mn/DOT and WSDOT have added environmental staff supporting maintenance and operations. In Washington, assistance is supplied by Regional Maintenance Environmental Coordinator (REMC) who obtains necessary permits and provides on site and telephone consultation.

NCDOT's Environmental Coordinators in the Field

NCDOT has also recently added regional environmental coordinators. Each of North Carolina's 14 statewide transportation divisions employs a Division Environmental Officer to assist, coordinate, and facilitate environmental issues that may occur in the field. The Division Environmental Officer acts as a liaison between field operations and the resource agencies and ensures NCDOT's implementation of environmental commitments.

Indiana DOT's Environmental Compliance Coordinator

Indiana DOT (INDOT) employs an environmental coordinator for non-NEPA compliance in each INDOT district who is responsible for monitoring compliance within INDOT's operations. The position focuses on applicable regulations protecting air, water, soil, and other resources. The Environmental Coordinator is responsible for training construction and maintenance personnel on environmental permitting, regulations, and methodologies to ensure that highways are environmentally "friendly" and conform to all laws and regulations. Likewise, the environmental coordinators assist in developing and undertaking environmental research projects, best management practices, and the establishment of environmental policy. They are also responsible for inspecting construction sites to ensure compliance with permits and mitigation.

Virginia DOT's Residency Environmental Specialists for Maintenance

Virginia DOT (VDOT)'s 29 Residency Environmental Specialists (RESs) cover 45 residencies, with the objective of facilitating delivery of the transportation program by providing regulatory compliance, leadership, management, and accountability, primarily for maintenance. The positions provide daily guidance, assistance, and leadership to residency and field personnel to ensure that their operations are performed in compliance with regulations and best management practice. The RESs also serve as liaisons between the residency office and the district environmental staff. RESs advise staff on the need for permits and reviews and assist with training of staff and planning of operations. The RES determines whether permits are needed, assists in the development of permits and erosion control plans, and reviews and approves borrow pit and disposal areas for maintenance and operations. The RES reviews environmental commitments with the project manager and/or Residency Engineer prior to commencement of operations to ensure compliance with best practices and permit requirements, and provides periodic review of controls. The RES also works with district environmental staff to develop training needs assessments for the residency and formulate training modules to keep staff up to date with environmental changes that affect the residency.

In addition to basic knowledge of environmental laws and regulations, permit requirements, erosion control issues, and wetland identification, the RESs require skills working with people of a variety of educational levels, planning and directing environmentally compliant operations, and working to develop an environmental ethic with regard to transportation operations. VDOT has developed a training program and manual for the RESs, specifically focused on erosion control and water-related issues. While Resident Engineers were initially skeptical about placing what they viewed as auditors in their residencies, the RESs were quickly seen as indispensable additions who greatly reduced environmental risks and liabilities for Resident Engineers individually and for the agency as a whole. Unlike NYSDOT's program a description of which follows, VDOT designed their RES program to have entry level personnel who were then trained and could serve as an RES feeder program for more senior level headquarters environmental staff.

NYSDOT Construction & Maintenance Environmental Coordinators

NYSDOT's investment in new senior environmental coordinators for Construction and Maintenance Districts has been significant considering that the department is downsizing overall. As previously mentioned, NYSDOT hired 11 environmental coordinators (ECs) to support Construction and the same number to support Maintenance. These 22 environmental coordinators are senior NYSDOT staff selected by upper management to focus on regional priorities while providing oversight, quality assurance, and technical advice. This program is designed to minimize permitting problems and inconsistencies in overall regional approaches, including meeting environmental commitments throughout the project development lifetime. NYSDOT decided to place the ECs directly into Regional Construction and Maintenance Groups in order to address specific areas for department-wide environmental improvement in Construction and Maintenance, as follows: 1) increased environmental field presence; 2) increased familiarity with maintenance staff, activities and issues; 3) improved responsiveness to maintenance environmental needs; 4) greater leadership and follow-through on priority environmental issues in maintenance; 5) improved environmental training for maintenance staff; and 6.) improved intra-regional communication on environmental issues.

Upon hiring, the ECs were directed to spend about 50 percent of their time "in the field" observing, learning, advising and proactively identifying environmental stewardship opportunities.(*109*) Maintenance forces in particular are often called upon to react immediately to a safety situation due to storms, accidents, etc. and need timely environmental advice and recommendations. As the first point of contact, the Maintenance Environmental Coordinator (MEC) helps bring about improved coordination and faster response to environmental needs. By focusing solely on environmental issues in maintenance, the MECs are also able to learn what issues are priorities and commonplace and then prepare regional guidance and training to address these areas in a proactive and programmatic manner. Furthermore, through their sole focus on maintenance issues, MECs have the support, time and ability to identify and coordinate the follow-through on environmental stewardship opportunities, many of which may have been missed in the past.

So that the ECs could "hit the ground running, learn as a group and be integrated with other department programs, a system was set-up immediately upon their hiring that: 1.) provided a clear description of the EC role and responsibilities; 2.) provided comprehensive training in priority environmental areas; 3.) provided bi-annual statewide EC coordination meetings; and 4.) provided for each EC to submit a monthly activity report.(*110*) These activities have been intended to improve EC effectiveness through direction, knowledge, shared experience and communication.

Table 6: NYSDOT Sample Performance Program for Environmental Support Staff in Construction

TASKS AND OBJECTIVES	PERFORMANCE STANDARDS
Ensure that constructability issues regarding environmental impacts are understood by designers and appropriately incorporated into projects.	1A. Represent regional construction group at meetings during all phases of project development, e.g. pre-scoping, scoping, etc., and provide recommendations regarding constructability issues related to environmental impacts. 1B. Review project plans at Preliminary and Advanced Detail Plan stage to ensure that constructability issues relating to environmental impacts are adequately addressed. 1C. Assist in development of ECOPAC materials during project development. 1D. Review project materials, including ECOPAC, at final Plans, Specifications and Estimates stage to ensure that constructability issues related to environmental impacts are adequately addressed.
Ensure that Regional Construction staff, Contractors and Consultants are thoroughly familiar with the environmental context and requirements of projects.	2A. Attend Preconstruction and Get Start meetings and take lead in discussion of environmental issues using ECOPAC and applicable plan sheets, specifications, notes, etc.
Provide Quality Assurance services to ensure that environmental commitments and obligations are fully implemented during project construction activities.	3A. Assist with development and implementation of necessary and desirable project modifications that may affect environmental impacts. 3B. Ensure that an adequate level of environmental monitoring occurs at critical project stages, e.g. wetland construction. 3C. Ensure appropriate notification, coordination and documentation of environmental obligations during project construction, e.g. update SPPP.
Provide Support Services to ensure that policies, procedures and training contribute to improved environmental performance in construction.	4A. Review , revise and generate procedures, guidance and specifications, as appropriate, to ensure full consideration of environmental issues and opportunities during project construction . 4B. Identify and provide/coordinate appropriate environmental training to construction staff in a timely and efficient manner.
Serve as Regional Construction Coordinator for Erosion and Sediment Control issues.	5A. Provide early and continuous input to design staff regarding erosion and sediment control plan development. 5B. Review final erosion and sediment control plan and provide recommendation prior to construction sign-off. 5C. Discuss Erosion and Sediment Control Plan with Construction staff, Contractor and Consultants prior to construction activities. 5D. Review Contractors required written Erosion/Sed. Control Plan and provide recommendation prior to EIC approval. 5E. Review necessary modifications to original Erosion and Sediment Control Plan that occur during project construction and provide recommendation prior to EIC approval 5F. Ensure that required Erosion and Sediment Control records are maintained in the project file.
Serve as Regional Construction Coordinator for Department Environmental Ethic and Stewardship Programs.	6A. Proactively identify and implement programmatic and project specific opportunities to incorporate environmental betterments into construction projects and activities. 6B. Provide/coordinate timely and appropriate environmental

	awareness training for construction staff.
Provide liaison between Regional Construction Unit and Regional Landscape Architecture/ Environmental Services Unit, The Environmental Analysis Bureau and Regulatory Agencies.	7A. Attend RLAES Unit staff meetings and provide feedback regarding construction/environmental issues and activities. 7B. Attend statewide Construction/Environmental Coordination Meetings to exchange information with other regions and EAB Coordinator. 7C. Attend annual NYSDOT Environmental Conference. 7D. Serve as general point of contact regarding environmental issues during project construction by directly providing technical and procedural advice to construction staff or coordinating same with RLAES Unit, external groups and agencies, as appropriate.
Assist with conduct of Regional Environmental Audit.	8A. Ensure that Environmental Audit materials relating to construction activities are completed in a timely, thorough and accurate manner. 8B. Provide annual Environmental Audit Training for responsible Regional Construction staff.

To share experiences, establish priorities, identify issues of common concern, and increase knowledge and awareness within the larger agency, NYSDOT Construction Environmental Coordinators and Maintenance Environmental Coordinators submit brief monthly reports on activities in the following ten core areas.

Quality Assurance

- Review Preliminary, Advanced Detail and Final Plans for Constructability (Erosion and Sediment Control, etc.)
- Inventory/Disposal of Residency Hazardous Materials
- Review Department Practices and Operations (Salt Storage/Handling, Bridge Washing, Herbicide Applications, Mowing, Ditch Cleaning, etc.)
- Review ECOPAC
- Attend Preconstruction and Get Start Meetings
- Compliance with Permit Conditions and Regulations
- Review Staging, Spoil, Borrow and Field Office Locations
- Attend Scoping Meetings

Environmental Stewardship

- Specific Projects (Nest Boxes, etc.)
- General Environmental Awareness

Liaison

- Attend RLAES Unit Staff Meetings
- Meet with RLAEM
- Meet with Regulatory and Resource Agencies
- Meet with Environmental Groups

- Attend Regional Committee Meetings (Environmental Initiative, etc.)
- Respond to Public Inquiries, Complaints, etc.
- Attend Statewide Operations Environmental Coordinator Meetings

Technical Advice

- Provide Informal Technical Advice to Field Staff
- Residency Visits
- Project Visits

Training

- Prepare Training Materials and Conduct Training Classes
- Coordinate Training Classes

Permitting

- Prepare, Review, Coordinate Permit Materials
- Develop Programmatic Agreements
- NPDES Phase 2 Compliance
- Review Highway Work Permit Applications

Programmatic Guidance

- Prepare written Guidance/Procedures
- Prepare or Revise Specifications

Assistance to Other Units

- Design, Construction, Maintenance, and Main Office

Environmental Audit

- Prepare or Advise on Audit Reports and Follow-up on Audit Violations

Personal Development

- Attend Training Courses and Attend Conferences/Seminars
- Miscellaneous
- Salt Contamination Investigation
- GIS
- SPDES

This information and an estimated ratio of percent of time spent in the field vs. in the office is tracked by a headquarters program coordinator to ensure that field staff receive further guidance, support, or training as needed. The Main Office Coordinator meets biweekly with representatives from the Main Office Construction, Maintenance and Design Divisions and regularly travels to meeting with regional maintenance and construction staff and environmental groups. Regions regularly introduce new and innovative environmental practices in construction and maintenance activities, which are communicated to other regions to ensure statewide benefit.

2.7. Environmental Training and Certification

If an organization is expected to succeed in its environmental objectives, it must develop the capabilities to support it. These capabilities reside in the staff a DOT employs and the training, awareness, and the cultivation of competence it requires and supplies.

Competency-Based Training Systems

NCHRP Report 360, "Professional Development of Maintenance Engineers and Managers," took a first shot at identifying and describing common responsibilities and knowledge requirements for professionals involved in highway-maintenance engineering and management and developed a classification structure of education and training needs for highway-maintenance engineering and management professionals.   Some transportation agencies have developed their own competency-based approaches to assessing and addressing the training needs of their own workforces.

PennDOT's Transportation University

PennDOT created a Center for Performance Excellence (CPE) for managing employee development and linking education to strategic goals.(*111*) One of CPE's main programs is PennDOT's Transportation University, a virtual university on the corporate learning model. Its as lead positions are filled by senior DOT staff, Bureau Directors, and Deputy Secretaries. Experts throughout the agency provide most of the instruction. The Transportation University is focused on competency-based training and employees' professional growth. Necessary tasks, skills, and competencies for each job classification are identified by a team of top performers in each job class, and training has been structured around those competencies. The CPE works with instructors, training coordinators and subject matter experts to develop the courses and tracks associated with particular knowledge. PennDOT feels this approach ensures maximum return on invested training monies by focusing on relevant competencies and required skills for advancement of the trainee.

Specialized schools and colleges cover various areas of expertise, and are supported by a team of volunteer experts from throughout the Department. Each school has an operating committee of agency leaders and volunteers that meets three times a year to develop and align needed learning experiences to identified competency needs and ensure that courses are evaluated at the appropriate level. Non-traditional learning approaches such as on-the-job training and combination approaches supplement traditional training courses.   For example, the School of Transportation Professions is looking at giving credit for winter operations preparation such as the winter dry run.

Of particular interest to construction and maintenance professionals is PennDOT's College of Transportation Professions, which serves the Design, Operations, and Construction communities as and includes a School of Technical Specialties and a School of Workforce Development. The College of Transportation Trades includes Schools of Equipment Repair, Graphic Design, Motorcarrier Enforcement, and Specialty Trades. Other Colleges address Human & Organizational Development, Information Systems & Technology, Leadership & Executive

Management, Professional Administration, Administrative Support, and Customer & Partner Services. More information on PennDOT's Transportation University may be found online.

PennDOT is developing Position Analysis Workbooks for 90 percent of the positions in the agency. The Position Analysis Workbooks detail all the job duties and tasks, and the skills, knowledge, and competencies required to perform them. Tasks and competencies are also linked to courses that PennDOT has available and courses that need to be developed. The workbooks are used by the Transportation University and training committees as a guide for developing educational opportunities targeted to workplace needs. Training and other learning experiences are also required to support agency strategic objectives. Employees are able to use the workbooks as a planning tool for their own professional development, cross-training experiences and promotional opportunities. Supervisors, mentors and coaches can use the workbooks to orient new employees and to ensure employees receive appropriate learning experiences. Position analyses have already been developed for Assistant Maintenance Managers, Diesel Mechanics, Transportation Equipment Operators, and Quality Coordinators. Position analysis workbooks will be available over the next year for the following professions of potential interest to Construction and Maintenance managers: Training Coordinators, District Safety Coordinators, Construction Inspectors, Equipment Operators A, Equipment Operators B, Highway Maintenance Worker, Laborer, Semi-Skilled Laborer, Equipment Operator Trainee, Equipment Operator Instructor, Automotive Mechanic, Tradesman Helper, Motor Carrier Enforcement Officer, Highway Foremen, Receptionists, Clerks-various categories, Welders, Customer Service Leadership, Managing Partners, Tunnel Maintainer, Maintenance Repairman (includes Building Trades — Carpenter, Electrician, Mason, Painter), District Equipment Managers, County Equipment Managers, and Equipment Body Repairer & Painter.

PennDOT also developed an internet-based learning management system that provides an online resource for employee training records, official transcripts, course and program catalogues, out service and on-the-job training information, class schedules and current enrollments. Working with their supervisors, employees are able to schedule training courses as part of their individual development plans using this tool, which the agency calls Training Partner 2000.

Caltrans Work Breakdown System

Caltrans has also taken a work competency approach to designing training for employees, but only in particular areas of the agency. In 1994, Caltrans issued the first version of the Department's Capital Outlay Support (COS) Standard Work Breakdown Structure (WBS). The Capital Project Skill Development Plan originated with Caltrans' 1998 Strategic Plan and is modeled on a similar workforce development plan at the Oracle Corporation. Caltrans' structure breaks down the content of capital project work into 491 discreet products and activities (or deliverables) and the roles necessary to complete those activities. A task force of subject matter experts specified the 'roles' that employees play in producing the particular deliverable. Caltrans assessed the knowledge, skills, tools and competencies necessary to achieve those deliverables and fill identified roles.

Caltrans also developed estimates of the number of current employees who play each role and the degree to which they needed training in the knowledge, tools, and skill areas. Caltrans quantified needs via a gap analysis by comparing the needed knowledge and skills with the actual workforce capabilities. They further identified those employees who urgently needed specific training and those having a moderate need. Task force members identified specific classes to teach the required knowledge and skills. Caltrans initiated a Long-Term Training Plan, a re-defined and re-focused blueprint for ensuring its 11,000+ capital projects employees can accomplish the 491 WBS deliverables.

Courses designed to support the competencies list learning outcomes, WBS deliverables, types of employees needing each course, and estimated audience size. By focusing on roles rather than job classification, Caltrans used a bottom-up approach that enabled the task force to specifically describe the skills necessary for each role. The group designed 579 courses to support the 491 deliverables. Of those, 337 courses were already available, and 242 needed to be developed. Additionally, the task force prepared cost estimates to develop and implement each course.

Once program managers approved and prioritized the courses for each functional area, they developed a funding plan for FY 2000-2001. The plan identified high-priority training needs based on currently available courses and those to be developed. The California Legislature committed $15.1 million to Capital Project skill development for each year from 2000 to 2003. The range of courses available through the program covers the gamut from a 2-hour course on Engineering Service Center Outreach to the 8-week Bridge Design Academy. Caltrans also uses a blended approach to training, incorporating internet- and computer-based training, classroom sessions, and self-study. Classes are taught by Caltrans staff, contract trainers, and vendor-generated materials. The Capital Project Program is currently the only Caltrans program using the WBS, but the Department is exploring additional use of the process. (*112*)

Train the Trainer Programs

Professional training by private providers can be expensive and time-consuming to give to entire teams. Train-the-trainer approaches train just one, two, or a few individuals in formal classroom settings, then arrange for them to train other team members in either classroom or on-the-job training sessions. As a result, training costs can be contained, and what is learned by the few is leveraged to train the many. DOTs typically rely on in-house trainers.

PennDOT's Instructor Development Program for Internal Subject Experts

PennDOT is one of the many state DOTs where over 90 percent of training is offered in-house, which has created substantial demand for on-staff (volunteer) trainers and train-the-trainer programs. PennDOT's Transportation University is supported by a team of hundreds of volunteer experts from throughout the Department. The bulk of TU's instructors are equipment operators. Center for Performance Excellence Transportation University support staff provide instructor development courses, including classroom skills and how to use visual aids.

NYSDOT's Training Pipeline for Environmental Coordinators, Construction, & Maintenance Staff

NYSDOT's 22 Construction Environmental Coordinators and Maintenance Environmental Coordinators are thoroughly trained and then in turn deliver a variety of training courses on the Regional level. Headquarters specialists at the Environmental Analysis Bureau deliver much of the initial training to CECs and MECs, who serve as trainers in the Regions and also receive some of the regular training for Construction and Operations staff, such as the agency's Paving and Snow Universities. Consultants assist in offering advanced courses in wetland identification and stream channel design, elements of which CECs and MECs can then teach to construction and maintenance staff on the job or in other training settings.

Table 7: NYSDOT Maintenance and Construction Environmental Coordinators Recommended Training Priorities

Course Topic		Source/Instructor
General Environmental Overview Regulations/Agencies/Issues Water/Ecology Hazardous Waste Cultural Resources SEQR/NEPA Air/Asbestos Noise ECOPAC Environmental Audit	1 Day	Environmental Analysis Bureau (EAB)
Operations Handbook: Application to Maintenance BMPs	1 Day	EAB & Maint.
Operations Handbook: Application to Construction Specifications Waste Disposal BMPs	1 Day	Construction and EAB
Erosion and Sediment Control Design Considerations Regulations/Specifications Implementation/BMPs	2 Days	Don Lake et. Al.
NHI Hazardous Bridge Coatings Lead Health and Safety Air Quality Monitoring/Lead Dust Hazardous Materials Manifests Painting, etc.	5 Days	NHI and EAB
Snow University	2 Days	Operations
Health and Safety Awareness Inspection Module/MURK 1C/Handbook/Lessons Learned Haz Comm Manual	1 Day	Construction coor. With B. Gibney
Earthwork School	2 Days	Geotech. Engineering Bureau
Ad Hoc Inspector Modules/OJT	Variable	Regional Construction Group
ROW Herbicide Applicator Certification Regulations Products Applicator Safety Environmental Considerations Techniques/Equipment	3 Days	Operations and DEC
Intro to Wetland Identification/Delineation Intro - Wetland Identification 3 Parameter Method	1 - 2 Day(s)	EAB
Intro to Stream Restoration (Classification, Assessment, Restoration)	1 - 2 Day(s)	EAB and Greene Co.
Paving School	5 Days	Operations
Advanced Wetland Delineation	4 Days	EAB

Wetland Identification/Function Hydric Soils Hydrophytic Vegetation Hydrology 3 Parameter Method		(Consultant)
Advanced Stream Restoration Stream Types/Functions Classification System Assessment Methods Restoration Techniques	3 Days	EAB (Consultant)
Asbestos Inspector Certification	3 Days	EAB/(Consultant)
Haz Waste Operations & Emergency Response	5 Days	EAB/(Consultant)
GIS Introduction to Software Maintenance Program	1 Day	EAB
Stormwater Management Regulations/Policies/Procedures Site Considerations Facility Design Maintenance and Operation	2 Days	Don Lake et.al.

The CECs and MECs, trained as outlined above, then take the leading in developing training tailored to different audiences (e.g. inspectors, construction staff, and contractors) and opportunities for outreach. An example of a Training Schedule is listed in the Appendix of the training occurring in each of NYSDOT's Regions, frequency, audience and size, and how training is altered for different audiences and topics related to Construction and Environment.

Maintenance Environmental Coordinators offer a variety of training on the Regional level as well, to residency staff, inspectors, contractors, and sometimes even local watershed groups. In some cases, the Department of Environmental Conservation assists in teaching the course. MEC training offerings for Maintenance for 2003 included:

- Environmental Initiatives for 2003 - Nest Boxes, Mowing, Web, etc.
- Environmental Handbook (for different audiences) and GIS Applications
- Hazard Tree Awareness, Identification & Management
- Spring Herbicide Kick-Off Meeting
- Deer Composting
- Living Snow Fences
- Erosion and Sediment Control
- Watershed Approach, GIS, Natural Stream Design, Wetlands
- General Environmental Sensitivity-2003 Herbicide Contract and Site Specific Environmental Sensitivity - 2003 Herbicide Contract
- Annual Asbestos Awareness.

Available NYSDOT training presentations may be found at the sites for Training and Presentation Slides and at NYSDOT Training. In addition to several leadership and supervisory resources, including NHI's "Tools for Peak Performance: Motivating Maintenance Workers to Do Their Very Best," NYSDOT has the following training presentations available on-line at the time of this writing include the following:(*113*)

- Stormwater Management: New SPDES Phase 2 Regulations.
- Soil Bioengineering/Biotechnical Workshop.
- Best Management Practices — Disposal of Surplus Material, Engineer In Charge Training.
- Erosion and Sediment Control, Presented at AGC/DOT Technical Conference.
- Construction Regional Environmental Training.Region 3.
- Erosion and Sediment Control for Maintenance, Region 8.
- Stormwater presentation at DOT's 11/14/02 Stormwater Training for Designers.
- NYSDOT Stormwater Management Program Presentation
- Environmental Training Documents for Maintenance and Constructions.
- Air Quality Training slides.
- New York City Watershed Presentation Slides.

NYSDOT has also produced Equipment Training: Evaluation Guides for Skills Demonstrations - 4th Edition for skill demonstration on all categories of NYSDOT heavy equipment. NYSDOT awards certificates for internal NYSDOT purposes only. The points covered are also the teaching points used by the Equipment Operator Instructors who prepare employees for their skills demonstrations. In addition to teaching materials, the files contain maintenance checklists for each piece of equipment.

Qualities to Consider in Identifying and Growing Good Instructors

Subject matter experts that are already on-staff and frequently approached by other staff members for their advice are then tapped as potential trainers for others. Train the trainer approaches require careful selection of employee-instructors, preferably supported by growth and development opportunities. The Transportation Association of Canada recommends looking for the following additional qualities: (*114*)

- Is accessible for questions
- Knows how to give feedback - always positive and never uses sarcasm or ridicule
- Holds respect for his colleagues and is respected by them
- Can summarize ideas in a clear and precise way
- Listens to the opinions of others and seeks their recommendations
- Facilitates ideas and the sharing of new concepts or work methods
- Is current on new methods and procedures

The LTAP program notes that instructors are often the most important variable for success in training. A good instructor can help participants leave with valuable knowledge, increased skills, and motivation to put the knowledge and skills into action when they get back to the job. LTAP offers the following suggestions to "help grow good instructors." (*115*)

- Start by selecting subject matter experts. If experts are not experienced trainers, provide them with training on how to conduct training (train the trainer). The Nebraska LTAP Center has had much success with training motor grader operators to train other operators.
- Keep the trainers up-to-date with the latest technology and training techniques. They can do this by reading journal and newsletter articles, attending LTAP meetings, participating in train-the-trainer sessions and practicing with new training techniques.
- Involve instructors in workshop development. Instructors can bring real training experience, as well as knowledge of the target audience to workshop development.
- Share training resources, such as videos, manuals and instructor's guides.
- Show instructors they are appreciated. Honor volunteers.

Environmental Training for Construction and Maintenance

In a 2002 survey by the author, almost of half of the 50 state transportation agencies indicated they have begun to train maintenance staff on environmental regulations, issues, and BMPs. As one example, the Colorado DOT new orientation and refresher training for maintenance staff includes a brief overview of environmental and water quality issues in maintenance. In 2002, twenty-four state DOTs reported performing general natural resources sensitivity and/or regulatory training for engineers and/or construction. Contacts can be found by clicking [see contacts]. Approximately 60 percent offered engineers and construction staff general training in NEPA, public involvement, the DOT's environmental process, and BMP maintenance and water quality considerations. At NYSDOT, for example, Engineers in Charge (EICs) receive training from lead construction and environmental staff in environmental considerations in construction, along with other supervisory topics. Just Connecticut, Florida, South Carolina, Utah, and Washington reported offering training on environmental stewardship/enhancement projects for engineers [see contacts]. While almost half of state DOTs introduce engineers to context sensitive design or context sensitive solutions (CSD or CSS), Delaware, Indiana, Kentucky, Maryland, Nevada, New Jersey, Pennsylvania, and Utah were able to boast having trained over 90 percent of their engineers in context sensitive design [see contacts]. North Carolina has recently undertaken similar training in CSD for engineers conducted by the Center for Transportation and the Environment.

Environmental training for construction staff is receiving attention as well. Mass Highway's new environmental compliance program within Construction offers an environmental component in each district's winter training program. Annual training to all construction field personnel covers environmental regulations and permits, erosion and stormwater control, contractor responsibilities, and pre-construction meetings. Utah DOT's training for Construction Environmental Control Supervisors is described in the section below, as it was combined with training for contractors.

Contractor Outreach and Training

Utah DOT Joint Training for Contractors and Construction Environmental Supervisors and Maintenance Staff

In the mid 1990s the Utah DOT (UDOT) decided the agency needed to try to enhance contractors' understanding of environmental issues in construction. UDOT put together a two-day class on temporary erosion and sedimentation control and other environmental issues that may arise in construction. UDOT has now condensed the class to one day. The class includes an overview of UDOT's environmental process and Clean Water Act and water quality regulations in particular. UDOT introduces contractor to erosion and sediment control basics and the standard drawings and BMPs UDOT has available, as well as the agency's erosion and sediment control manual. Contractors practice developing their own SWMPP and review inspection points.

While the class spends the most time on water quality, it also addresses, NEPA, threatened and endangered species issues, and what to do if the contractor encounters a cultural resource. Archaeological and prehistoric sites, cultural and paleontological clearances are covered. Contactors and staff are familiarized with the 18 species on Utah's noxious weed list and expectations to minimize disturbance, reseed all disturbed areas promptly, regrading, and weed spraying. These requirements and commitments are now contained in NEPA documents as well. UDOT also reviews hazardous materials practices, fuel storage, waste oil handling and environmental clearances required for off-site work proposed by the contractor but not included in the contract. The latter section addresses environmental permitting concerns for off-site contractor needs such as for material sites, staging areas, office sites, water lines, holding ponds, stockpile locations, slope flattening, etc. Floodplain, farmland, and air quality clearances are among those reviewed.

Contractors and UDOT construction crew inspectors are invited to attend the course, as are UDOT designers and maintenance staff. The contractor designates one person to be called an Environmental Control Supervisor and the UDOT crew designates one as well. Jointly, these supervisors discuss environmental issues on-site, and decide inspection schedules, changes, and needed clearances on additional sites. UDOT's ECS is responsible for:

- Inspecting the project site for compliance with UPDES and other environmental permits.
- Ensuring that environmental protection measures in the plans are implemented on the project.
- Maintaining temporary erosion and sediment control measures.
- Modifying the Stormwater Pollution Prevention Plan as required.
- Obtaining additional environmental clearances for off-site work.
- Coordinating with the UDOT construction crew's ECS.
- Ensuring that all environmental mitigation commitments are followed on the project.

Further information on the program, slides, and hand-outs are available.(*116*)

NJDOT and NJ Associated General Contractors Partner to Convey Stewardship Practices

NJDOT is currently developing contractor training and meetings with its contractors to discuss good stewardship practices. The New Jersey Associated General Contractors has become an active participant in the Federal Highway Administration's National Quality Initiative program, signing quality initiative partnering agreements with the New Jersey Department of Transportation (NJDOT) and the New Jersey Department of Environmental Protection (NJDEP) with the goal of keeping transportation projects environmentally friendly and obtaining timely environmental permits. The AGC founded the Construction Industry Advancement Program to educate contractors about business issues, including designing environmentally friendly projects.(*117*)

Mass Highway Communicates Standards and Expectations to Contractors

Like NJDOT, Mass Highway has been reaching out to contractors to communicate standards and expectations. With recent years' changes to NPDES, EPA Region 1, the Massachusetts Department of Environmental Protection (DEP) and Mass Highway are providing a workshop on the NPDES Construction General Permit, regulatory requirements and DOT expectations for contractors. The workshop is being presented to Construction Industries of Massachusetts (CIM), an advocacy organization of construction contractors in Massachusetts. Like NYSDOT, Mass Highway is also reaching out to local organizations. Mass Highway has presented workshops at meetings of the Massachusetts Association of Conservation Commissions (local wetlands regulators), identifying construction issues, methods, requirements, and successful erosion control BMPs in order to familiarize local regulators with Mass Highway work, so that permit conditions can meet both construction and environmental needs.

AGC and Illinois DOT Reach Out to Contractors on Erosion & Sediment Control

The Associated General Contractors of Illinois (AGCI) and the Illinois Department of Transportation (IDOT) worked together in developing a seminar series on erosion and sediment control. The seminar was aimed at helping highway contractors and government employees understand the effects of the EPA's Phase II Stormwater Regulations. A total of ten one-day seminars were held, with over 1,400 people attending. The seminar series was especially effective because it tailored information to Illinois geography and IDOT best practices. Co-training highway construction contractors and state government employees in the same forum ensured that everyone heard the same message. Workbooks were developed for all participants with information from the presentations. This seminar series is one of several joint public/private training efforts undertaken by AGCI and IDOT.(*118*)

Pre-Construction Meetings

Mass Highway, New Jersey DOT (NJDOT) and Texas DOT (TxDOT) are among the many DOTs that now conduct pre-construction informational meetings covering environmental matters. TxDOT's pre-construction meetings with contractors sometimes include training on specific topics pertinent to the project at hand.

KYTC Environmental Leadership Training

The Kentucky Transportation Cabinet (KYTC) has been using a three-day Environmental Leadership Workshop (developed by the FHWA Southern Resource Center) to train staff to address environmental issues of all activities. Secretary Codell has led a corresponding series of "culture talks" in conjunction with its own one-day environmental leadership training course for all employees. KYTC has also become a national leader in CSS/CSD training, which the agency has incorporated into its construction activities.

Oregon DOT Environmental Outreach and Training for Maintenance Staff

ODOT has an extensive outreach/training program for its maintenance personnel on environmental issues. Elements of this program include environmental orientation for new employees, monthly/quarterly manager team meetings, winter pass foremen annual meetings, annual field visits, hazardous materials training, erosion and sediment control training, fish passage training, and training on ODOT's Resource and Restricted Activities Zone maps for district roads. The department also relies on participation in professional symposiums/conferences and videos it has developed, including "Road to Recovery: Transportation Related Activities and Impacts on Salmon," and a new video being made on calcium magnesium acetate (CMA): "CMA: A valuable tool for winter operations and total storm management." ODOT also trains staff through continuing education classes and systematic trials of new products.

Caltrans Environmental & Equipment Training for Construction and Maintenance

Caltrans has developed the following environmental training modules and resources for construction personnel, focused on minimizing stormwater impacts:

- Water Pollution Controls While You Work: Temporary BMPs on Highway Construction Sites 23 minute Video Presentation (47.5 mb)
- Field Application Training for Erosion and Sediment Control BMPs Powerpoint Presentation
  Erosion Control BMP Implementation Powerpoint Presentation Part A
  Sediment Control BMP's Powerpoint Presentation Part B
  Field Application Training Class Exercises Powerpoint Presentation exercises
- SWPPP and WPCP Preparation Workshop
- Water Pollution Control - Compliance for Construction Sites for Resident Engineers
- Inspecting for Water Pollution Control on Construction Sites
- Water Quality Sampling and Analysis on Construction Sites Part 1
  Water Quality Sampling and Analysis on Construction Sites Part 2
- Management of Construction Site Dewatering Operations
- Introduction to Construction (Boot Camp) - Stormwater Module 1 hour
- Introduction to Construction (Boot Camp) - Stormwater Module 2 hours
- Introduction to Construction (Boot Camp) - Stormwater Module 4 hours
- Introduction to Construction (Boot Camp) - Stormwater Module 6 hours

Caltrans also tracks and provides information on continuing education courses available at universities and community colleges around the state, that are recommended for staff; these include: Erosion & Sediment Control, Water Pollution Control, Regulations, Asbestos/Lead Abatement, Water & Natural Resources Management, Land Use Management, Water Quality Sampling, Hazardous Materials Management, and Emergency Response.(119)

Caltrans includes some environmental training in classes for maintenance forces, which include orientation, a variety of Hazardous Materials handling courses, Lead Paint Removal and Abatement, Herbicide/Pesticide safety, Stormwater Pollution Prevention Plans, and Water Treatment Certification. Of particular interest to other DOTs may be Caltrans' Equipment

Management Responsibility course, taught as part of Caltrans' Maintenance Equipment Training Academy (META) to maintenance leadworkers, with an expanded version for supervisors and superintendents. Caltrans Maintenance Equipment Training Simulator (CMETS) program is offered on a traveling basis in an 18-wheeler statewide. CMETS was developed in an effort to reduce vehicle accidents, extend equipment life (and thus reduce resource usage), and enhance the overall safety of field maintenance employees. The primary target audience consists of new-hires with little truck driving experience, although experience has shown that employees from all skill levels can be challenged in the simulator. CMETS can simulate almost any engine and transmission combination found in the Caltrans fleet, with truck types including 5- and 10-yd dump trucks, and tractor-trailer combinations. Road types include city streets, freeways, secondary roads, dirt and gravel roads, as well as snow covered roads. Instructor controlled inputs include volume and behavior of autonomous traffic, day or night, clear or fog, wind gust, ice patches, and specific autonomous vehicle behavior. Simulated failures to own equipment include tire blowout, loss of oil or air pressure. Driving parameters that are measured and recorded for each student include number of gear shifts, number of gear grinds, number of transmission failures, speed control, following too close, brake temperature, riding the clutch, turns or lane changes without signaling, collisions, and others. Caltrans hoped that the use of simulation in the initial stages of training would reduce the frequency and severity of repairs attributed to poor shifting technique as well as operator induced repairs in general. Of note, since the inception of simulator training, no transmissions have been damaged during subsequent META training in Sacramento, saving significant resources.(*120*)

Recommended Practices in Implementing Adult Learning Programs that Benefit Construction and Maintenance

Adults bring their own experience to the learning process. This 'frame of reference' provides the basis from which they relate to and gauge the value of all new things. As a result, adult learners have particular needs. It has been said that adults retain 10 percent of what they read, 20 percent of what they hear, 30 percent of what they see, 50 percent of what they see and hear, 70 percent of what they talk over with others, 80 percent of what they use and do in real life, and 95 percent of what they teach someone else to do.(*121*) Many of the recommended practices below are adapted from LTAP Training Tools and a best practice overview by the Transportation Association of Canada.(*122*) According to recommended practice, training methods should:

Identifying Employees' Needs and Expectations

- **Address "what's in it for the employees," their needs and expectations.** Jobs with motivating potential are meaningful/will make a difference to others, require a variety of skills, have responsibility and autonomy to make decisions about how to carry out the work, and involve feedback and learning about performance, preferably from doing the work itself.
- **Relate to learners' experience.** Adult learners bring a wealth of experience to training. They want to relate the training to what they experience in their lives. They also come in a wide range of ages, backgrounds, interests, abilities, and learning styles. This characteristic can be useful because it allows trainers to tap into this diversity and depth of experience by allowing participants to share, analyze and learn from both their own and other's experiences. This characteristic can also be detrimental to trainers, as some participants do not go beyond their own experiences, becoming less enthusiastic about

new ways of doing things. A creative and motivating organizational context entails a continuous dynamic between the expertise, skills, and creativity of individuals and teams and the management practices, resources, innovation, and organizational motivation of the larger organization/work environment.(*123*)

- **Tailor training to the needs of various staff groups.** Accommodate their level of experience in classroom learning situations. The amount of training and the level of detail of training that is required by specific personnel will vary. For example, managers may not need to know how to calibrate a spreader or to plow a road in order to carry out their responsibilities. They should however understand the importance of an effective calibration program and what equipment is needed to optimize salt use. Operators that do not make salt application decisions may not have to understand much about the decision-support systems. However, they need to understand salt application policies, the chemistry and application of salt, the environmental issues, good housekeeping practices at maintenance yards, record keeping, equipment operation and relevant decision-support information. Workers at snow disposal sites that do not operate spreaders will need to be trained in snow disposal site operating procedures, the chemistry of salt, environmental issues and relevant equipment operations, but may not need a detailed understanding of decision-support systems for snow and ice-control.
- **Identify and seek to change existing workplace value systems where necessary.** Apart from the cultural attitudes in the workplace each individual operator will have a perception of his/her role within the operations. Some will hold the view that acquiring knowledge of new systems or technologies is not their responsibility and they do not get paid to think about such things. They may perceive their role as followers of instructions. Their 'locus of control' is 'external' and they rely on others, such as their supervisor, to provide the appropriate conditions/features for them to carry out their work. The challenge for the trainer is to convince these individuals that there is something in it for them and to try to 'internalize' their locus of control by stressing how important each individual's contribution is to the overall success of the initiative. External influences are too remote to make the best decision under the circumstance and their judgment is valued as the best available given their training, experience and local knowledge.

  For many operators who have been involved in winter control operations for more than the last few years, the standard of a job well done has been to see how much salt they can put down during their shift. Their value system said "More is Better" or "When In Doubt — Put It Out". Then along comes an initiative to optimize the amount of salt being used and the value system is changed to "Just the Right Amount and No More." The trainer should take the approach that operators have options to consider which only they as operators are in a position to make.

  Be aware of fears of the learner. Emphasize what is in it for them. It is important to get the "what's in it for me" issue on the table right away and for good answers to be provided. New York State DOT has tried to build on employee's positive impulses and concerns for the environment and has tried to keep messages simple and memorable. One example for maintenance staff has been: "Save Birds, Mow Less."

Engaging Employees in the Learning Process

- **Accommodate self-directed learners**. Adults often want to learn what they want to learn at their own pace. They want to be involved in the training process, learning from activities and sharing their knowledge with others. They learn best when they voluntarily choose to learn.
- **Present material in a variety of ways, and enable learning by doing whenever possible.** Include a combination of verbal and visual aids, group discussion and practical application.
- **Address immediate problems and concerns.** Adults are motivated to learn if they think the new information or skills will help them solve the problems and challenges they encounter in their jobs.
- **Take advantage of any opportunity to have immediate and automatic feedback** on whether the learner's actions are consistent with the learning goals. The more immediate the feedback, the more likely the learner will begin to self evaluate. They will begin to correct themselves once they recognize the gap between the stated objectives and their knowledge. It is estimated that 40 percent of skills learned in training are lost immediately, 25 percent remains after six months and only 15 percent remains after one year.

Packaging Materials Effectively

- **Provide opportunities to integrate new concepts immediately.** Adults want to use the information presented now, or at least tomorrow, on the job.
- **Time training close to when learning can be implemented.** For example, salt management trainings should be scheduled for each fall, close to the onset of the snow and ice control season.
- **Ensure training of all personnel who can affect the environment and the DOT's reputation.** This often includes seasonal and contracted personnel. If the DOT is not going to provide such training, training requirements may be included in contracts.
- **Trainers should assemble a bank of local case studies, photos, and examples.** Local examples bring the lessons home and reinforce learning goals.
- **Deliver training on location in different areas and take advantage of available down-times.** Training opportunities should not be limited to formal classroom settings. Trainers should be aware of the workplace schedules, inclement weather policies, shift changes and shift downtime, for example, and take advantage of these windows of opportunity to present training modules. Depending on the regular duties of the staff there are also opportunities to provide training in informal tailgate sessions or in post-storm debriefing sessions.

Assessment and Learning Objectives

- **Verify minimum competency levels through assessment and certification.** Some transportation agencies have included testing and a minimum passing grade in their training programs. In the absence of any industry certification standards, this type of internal agency certification may be advantageous to those transportation agencies wanting to provide an assurance of minimum competency levels.

- **Assess needs and develop learning objectives.** Needs assessment helps ensure that training is targeted where it is needed. Learning objectives focus the training on what employees and contractors need to learn.
- **Identify second language/literacy skills issues and plan accordingly.** It will be important that the trainer identifies those learners who may not be native English speakers and modifies the training and evaluation to accommodate their needs. When dealing with these learners the trainers should try not to bring undue attention to them in a classroom setting. It is advisable to ask their supervisors prior to the training if there are learners with these challenges.
- **Increase retention** by incorporating as many of the following strategies as possible into the lesson:
    a. Use realistic examples of how skills can be used.
    b. Give learners real life context for the application of concepts rather than presenting theory without a practical association.
    c. Use rich analogies.
    d. Include practice of skills.
    e. Use clear and effective visual aids.
    f. Consider pre-training assignments.
    g. Keep skills and concepts close to the work generally done by participants in the normal jobs.
    h. Use post-training follow-ups.
    i. Encourage sharing of anecdotal experiences through discussion sessions.
    j. Utilize informal leaders and the natural culture of the workplace to the extent possible in delivering the message of the training.

  This reinforces the need for refresher training. Trainers should make available easy access to reference materials to permit the learners to refresh their knowledge in a comfortable, non-threatening way. Again, periodic tailgate sessions help to reinforce the learning goals.
- **Use reminders.** The success of the training is the level of knowledge retained by the learner. Putting the key learning points in front of the learners in the workplace can enhance the level of retention and the rate of change in values. Key messages such as using the right material in the right amount in the right place at the right time can be promoted in the workplace. For example the application rates or spreader control settings can be posted in an area where the learners congregate such as lunchrooms or staging areas. Similarly, reminder signs with this information can be displayed in the truck cabs adjacent to the vehicle controls.

Gathering Feedback

- **Use feedback mechanisms.** Statistical data can be used to provide regular feedback. If work management software systems are available in the workplace then year-to-year or year-to-date comparison information of salt use or salt costs can be posted or distributed so the operators can see what impact they have on the financial side of the operations as well as environmental impacts.

- **Informal sessions** can help to reinforce the training especially if there is an opportunity for the internal champions to relate their experience with the equipment, the conditions and the decisions they made based on what they encountered.
- **Evaluate the training**. PennDOT's Center for Performance Excellence makes suggestions for improving courses and trainers based on student feedback and environmental measures. Templates and reports are provided so that evaluations are performed in a standardized manner. This process includes gathering trainee reactions and opinions, measuring new knowledge through testing, surveying the effects on job performance within 60 to 90 days, and determining the training's return on investment.
- **Monitor the extent to which staff is performing with respect to expected learning goals.** This should be done on an ongoing basis through observations of staff behavior. Any deficiencies in behavior should be identified and a plan developed to re-train in the appropriate areas.
- **Maintain up-to-date files of the training provided to each member of staff.** It is advisable to include any certification and course description in the file to maintain a record of the worker's competency. The records should include the date, time, duration and subject of the training, as well as the source of the training and trainers. Records should be maintained summarizing the percentage of staff trained in target areas at each level of the organization.

A series of benchmarking teleconferences conducted by the author for the AASHTO Center for Environmental Excellence and the Kentucky Transportation Cabinet culminated in the following recommendations from participating states to better support construction and maintenance staff in delivering environmental performance improvements:

- Identify who within agency (usually environmental staff) can provide such technical assistance. Make sure their phone numbers are easily available to staff.
- Have technical assistance staff take advantage of existing seasonal and annual meetings to let maintenance staff know they are out there and available to help.
- Develop trust between the trainer and training participants. If maintenance staff feel they know the trainer, they will be more willing to call for help when needed.
- Ensure maintenance staff is provided training on the necessary equipment.
- Arrange for Designers to rotate into maintenance annually (suggestion was one month per year). Implementation of this suggestion has resulted in a variety of improvements, including maintenance getting access ledges for stormwater ponds. In contrast, recommending solutions without field assistance can lead to failures and higher expense.
- Host a Design Academy once a year to train mid-level designers.
- Work with project engineers on a project-by-project basis to design roadsides appropriately.

- Reach out to/facilitate further training of Landscape Architects in DOT Regions or Districts, so they are on board with integrated vegetation management approaches and can assist with outreach to engineers.
- Develop technical guides for Maintenance Operations, synthesized from construction manuals, specs, field manuals, manufacturers' guides, etc.
- Develop and use a Product Acceptability List such as WisDOT's PAL, which is connected to specs and helps staff navigate unwieldy spec books. It is searchable on the web and streamlines and standardizes use of these materials.

Tailgate Resources: Pocket Guides and Bulletins

Fully half of all state DOTs report having developed simple field guides on BMP maintenance and water quality considerations for engineers and/or construction [see contacts], though many are out of print. Pocket guides are small, portable, and accessible to both DOT field staff and contractors, and are easy to carry on-site. Some examples include the following:

- Caltrans Stormwater Pollution Prevention Bulletins for Construction, Post-Construction, and Maintenance are short, two-page resources covering commonly arising issues and can be used easily as field references.
- Mn/DOT's Inspector's Job Guide for Construction includes guidelines for inspecting erosion control compliance, tree protection, disposal of wastes, culvert and storm sewer installation, seeding and finishing, and a variety of other construction activities.
- Colorado DOT's 2002 Erosion Control and Stormwater Quality guide is a 40-page pocketbook that helps construction and maintenance workers adhere to CDOT's Erosion Control and Stormwater Quality Guidelines by providing details and diagrams on implementing and maintaining water quality Best Management Practices (BMPs).
- Mass Highway is developing an Erosion and Stormwater Control Field Guide for Resident Engineers, due summer 2004, to accompany their NPDES Stormwater Pollution Prevention Plan Template and Guidance manual.
- NJDOT's Environmental Management Practices Construction Industry Pocket Field Guide for Environmental Stewardship in New Jersey was drafted by the Construction Industry Advancement Program of New Jersey (CIAP). It is provided to all NJDOT construction personnel. The 34-page field guide highlights common construction activities and identifies related environmental issues and contacts for additional information.
- TxDOT has developed pocket field guides for both projects and facilities addressing environmental compliance issues that may be encountered and how to address them, including contacts for more information. Scenarios include finding archeological evidence during construction or having a chemical spill at facilities.

California, Florida, New Hampshire, North Carolina, Ohio and Texas offer newsletters or internal bulletins addressing water quality considerations in construction or maintenance [see contacts]. In addition to Caltrans' notable stormwater pollution prevention bulletins for construction, post-construction, and maintenance, the agency offers a weekly one page newsletter on water quality issues located at Caltrans' on-line stormwater publications page.

Standards and Measures for Training, Awareness, and Competency Programs

The simplest and most common way that DOTs assess their performance with regard to staff training and competency is through accounting for attendance in various training programs. Training pre- and post-tests are also commonly used to test knowledge acquisition. A few state DOT programs, including PennDOT's Transportation University, are exploring re-evaluation months later to see if knowledge is retained and personnel can show competency.

ISO 14001 outlines several standards for organizations undertaking training related to environmental process improvement:

- The organization identifies training needs relative to environmental commitments, objectives, and targets.
- All personnel whose work may create a significant impact upon the environment have received appropriate training. This information is usually tracked in training records.
- The organization establishes and maintains procedures to make the employees or members at each relevant function and level aware of:
    - The importance of conformance with the environmental policy and procedures and with the requirements of the environmental management system.
    - The significant environmental impacts, actual or potential, of their work activities and the environmental benefits of improved personal performance.
    - Their roles and responsibilities in achieving conformance with the environmental policy and procedures and with the requirements of the environmental management system, including emergency preparedness and response requirements.
    - The potential consequences of departure from specified operating procedures.
- Personnel performing the tasks which can cause significant environmental impacts are competent on the basis of appropriate education, training and/or experience.
- The organization has defined competency and is maintaining it through various means.

On the Job Training—Promoting Continuous Learning in the Workplace

Researchers estimate that training provides 20 percent of the critical skills required to do a job and the remaining 80 percent is learned on the job. This implies that regardless of the effectiveness of the lesson plan, most of the learning will take place on the job outside the classroom setting. Fostering a workplace where operators are encouraged to share information, experiment with new concepts, and challenge old ideas is essential to change the approaches and behaviors targeted by more formal training methods. If the behavior has not changed, additional or follow up re-training is required. On-the job training is part of the mix of training offered by many DOTs, whether informally or more formally for credit, as PennDOT's Transportation University offers, for example.

On-the-job training for construction crews at the Wyoming DOT (WYDOT) is supplemented by a video presentation on environmental compliance and awareness that stresses avoidance and minimization of environmental impacts. The training emphasizes WYDOT's mission statement and environmental policy and includes a statement by the Wyoming Contractors Association on the importance of environmental sensitivity during construction.

Contractor Certification Programs

Due to the rapid influx of advanced technologies and the increasing reliance of DOTs on consultants and contractors for their engineering and technical services, state DOTs and professional organizations within the transportation industry are trying to provide assurance of professional competency.(*124*)

Some state environmental agencies are running contractor certification programs in erosion control inspection, with DOT participation. Contractor certification programs for Underground Storage Tank testing and removal are also among the more common.

Virginia DOT Specification and Certification for Erosion Control Contractors

In accordance with VDOT Road and Bridge Specification §107.14 (a), land disturbing activity which occurs within the VDOT right-of-way must be supervised by a certified Erosion and Sediment Control (ESC) Contractor, who is required to be on-site at all times during that land-disturbing activity. Until 2001, the Virginia Department of Conservation and Recreation (DCR) and VDOT sponsored a cooperative training for ESC Contractors. This training program was entitled DCR's Erosion and Sediment Control Contractor Certificate of Completion (DCR's Contractor Certificate) program. The former DCR Contractor Certificate program included a one-day training course followed by a one-hour examination.(*125*)

VDOT environmental monitor reports showed increases in project compliance levels from 30 percent in 1999 to 93 percent in 2001.(*126*) Likewise, VDOT's Construction Quality Improvement Program (CQIP) noted significant environmental compliance rating increases from 88.0 percent in fiscal year 1998/1999 to 93.4 percent in fiscal year 2000/2001.(*127*) VDOT believes the DCR Contractor Certificate program provided a key contribution to VDOT's project environmental compliance level. A new version of the program is administered by the Virginia Road and Transportation Builders Association (VRTBA) with VDOT providing the instructors and copies of the VDOT-developed manual. The goal of the course is to demonstrate to the contractor how implementation of VDOT's specifications and standards ensure compliance with environmental and property protection related laws and regulations and, synonymously, are critical elements of the quality and the economic integrity of road building/maintenance practices. The course introduces contactors to the Erosion and Sedimentation Control program, state and federal laws, the erosion process, minimum standards, vegetative practices, VDOT specs and standards, and VDOT contract enforcement. A certification exam proctored by the VRTBA enables those who pass to become certified to comply with VDOT Specification §107.14 (a), which stipulates that inspection for proper installation and deficiencies immediately after each rainfall, at least daily during prolonged rainfall and weekly when no rainfall occurs.(*128*)

Maine's Voluntary Contractor Certification Program

The Maine Department of Environmental Protection (DEP) has developed a non-regulatory, incentive-driven program to broaden the use of effective erosion control techniques. The DEP administers a voluntary contractor certification program to prevent nonpoint source pollution from construction activity by creating an incentive for Maine contractors to become educated on erosion and sedimentation control best management practices. The Voluntary Contractor Certification Program (VCCP) is coordinated by DEP's Nonpoint Source Training and Resource Center. The program requires attendance at two 6-hour training courses and the successful completion of a construction site evaluation during the construction season by local soil and water conservation district personnel. To maintain certification, a minimum of one 4-hour continuing education course within every two-year period after initial certification is required.

The certification entitles the holder to forgo the 14-day waiting period for Soil Disturbance and Stream Crossing Projects under the Department's Permit-by-Rule program, allowing certified individuals to start work on such projects earlier than contractors who are not certified. Certification also enables a contractor to advertise as a "DEP Certified Contractor," and DEP maintains a list of certified contractors that is posted on the agency's web site. This list is available for distribution to the general public, state agencies and other interested persons. All certified individuals can also obtain any publication from the Nonpoint Source Training and Resource Center Library at no charge. Under certain circumstances, certifications can be revoked. Revocation is likely if a formal enforcement action is taken against a certified contractor whose failure to employ satisfactory erosion and sediment control practices results in sedimentation of waterbodies or wetlands.

Tennessee DOT Erosion Prevention and Sediment Control Training and Certification Program

Tennessee DOT has funded a research project to develop an Erosion Prevention and Sediment Control Training and Certification Program consisting of three training courses: the Fundamentals of Erosion Prevention; the Design of Vegetative and Structural Measures for Erosion and Sediment Control; and a Train-the-Trainer Workshop.(*129*)

WSDOT Partnership with AGC to Deliver Statewide Training and Certification

The Washington State Department of Transportation (WSDOT) requires contractors to participate in erosion control training. Restrictions by the Washington State Department of Ecology (DOE) requiring erosion and spill control lead certification and triggered an increased demand for erosion control training. To meet this demand, WSDOT partnered with the education foundation of the Associated General Contractors of Washington to deliver a statewide training program for contractors and staff from federal, state and local agencies. An already-ambitious statewide program of 18 training events for 600 students was doubled due to high demand. The 12-Hour Certification course is taught to non-WSDOT parties through training partners and WSDOT only recognizes certificates provided through the organizations listed below:

- AGC of Washington Education Foundation
- Northwest Laborers Employers Training Trust Fund
- Inland NW AGC

WSDOT's on-line resources for WSDOT staff include:

- Certification in Construction Site Erosion and Sedimentation Control for WSDOT Personnel
- Certification Course Manual
- Erosion Control Design Course Manual
- 2-Hour Class for WSDOT Designers

New DOE requirements for written stormwater pollution prevention plans led to the addition of further courses. These programs have raised the construction industry's environmental awareness and helped protect the Washington environment.(*130*) Currently, WSDOT has made courses in Erosion and Sediment Control and Spill Prevention available, with classes in NEPA and Endangered Species Act applications on the way.

Iowa DOT Certification for Construction Inspection, Material Testing, and Spill Prevention

The Iowa Department of Transportation Technical Training and Certification Program is responsible for ensuring that all technicians who perform material testing, hazardous spill prevention, construction inspection, and grade inspection and erosion control on construction projects in Iowa are qualified. Over 200 classes are held annually with approximately 3,000 individuals participating. The program is working toward reciprocity of technician certification between states, regional material development, uniform test procedures, and coordinated exchange of state information. The Iowa DOT also is using a new approach to dealing with a downsized workforce by using maintenance equipment operators to perform testing/inspection duties and construction, and materials inspectors to perform maintenance duties in their respective off-seasons, requiring additional of cross-training.(*131*) For maintenance employees, IDOT also offers training in roadside vegetation management and a certification program for herbicide application.

Certifications Provided by Private Associations

The Manitoba, Canada Heavy Construction Association (MHCA) developed and implemented a Safety, Health, and Environment certification program. The Certificate of Recognition (COR) program is a comprehensive approach to reducing human, financial and environmental costs of accidents and involves education, training, and implementation of standard safety, health, and environmental practices.(*132*)

The Safety, Health and Environment program was developed and implemented by the Manitoba Heavy Construction Association (MHCA). The program provides a Certificate of Recognition (COR) and a comprehensive approach to reducing human, financial and environmental costs of accidents. It involves education, training, and implementation of standard safety, health, and environmental practices.

National Institute for Certification in Engineering Technologies

National Institute for Certification in Engineering Technologies (NICET) certification takes some of the guesswork out of applicant screening by identifying those technicians who have acquired a minimum amount of relevant work experience and who have demonstrated their knowledge by meeting a rigorous exam requirement. NICET tools can also be used to diagnose staff training needs, by measuring skills and knowledge against an objective national standard.

For example, the Highway Maintenance certification program was designed for engineering technicians involved in the inspection/supervision of street and highway maintenance activities. It covers all aspects of routine roadway and right-of-way maintenance, including interpretation of plans and specifications; scheduling of projects and personnel; recordkeeping; knowledge of materials (asphaltic concrete, Portland cement concrete, soils, herbicides, etc.) and techniques for their proper use; familiarity with equipment and proper use of equipment and associated safety features; and traffic safety during maintenance operations.(*133*)

NICET offers four levels of certification for Highway Maintenance. The typical job duties and associated responsibilities of highway maintenance engineering technicians are broken down into discrete work elements which form the basis for an evaluation of the candidate's knowledge. Level I is designed for trainees and entry-level technicians who perform limited job tasks under frequent supervision, Level II is for technicians who perform routine tasks under general daily supervision, Level III is for intermediate-level technicians who, under little or no daily supervision, work with standards, plans, specifications, and instructions, and Level IV is for independent, senior-level technicians whose work includes supervising others. Certification at Levels II, III, and IV does not require prior certification at the lower level, but it does require meeting the certification requirements of the lower levels.(*134*)

Requirements for certification, the program detail manual, and applications are available for Bridge Safety Inspection, Highway Design, Highway Construction, Highway Materials, Highway Surveys, Traffic Operations, and Erosion & Sediment Control as well as Maintenance. Overviews of various NICET certification programs are available online.

Society for Protective Coatings Certification Programs

The SSPC Protective Coatings Specialist Certification (PCS) contractor certification program is based on consensus standards developed by industry professionals and is recognized as an independent contractor evaluation program, as well as a pre-qualification tool for facility owners. Each program reviews the industrial painting contractor's primary ability to provide quality work in accordance with applicable safety, health and environmental compliance standards. The program is divided into the following categories:

- QP 1 evaluates contractors who perform surface preparation and industrial coating application on steel structures in the field.
- QP 2 is a supplement to QP 1 that evaluates the contractor's ability to perform industrial hazardous paint removal in a field operation. Two categories of certification are available based on the type of equipment and containment.
- QP 3 evaluates a contracting company's ability to perform surface preparation and protective coating application in a fixed shop facility. SSPC issues three categories of shop certification: enclosed shop, covered shop, and open shop; a certification for Inspection Companies whose focus is the industrial painting industry.
- QP 5 evaluates an inspection company's ability to provide consistent quality inspection of coatings & linings for its clients.

Sources of Training, Materials, and Information

Budget constraints are pressing states to design necessary training as efficiently as possible, while tailoring training to the needs of employees and state-specific conditions. As noted by AASHTO's Stewardship Demonstration Project, transportation agencies may look to adapting training from other states or national courses to their own needs, thereby reducing development costs, to initiating joint training efforts with other agencies and neighboring states, or to developing internal mentor-based on-the-job training programs. States also may find that non-traditional training approaches, such as distance learning, can provide the learning experience needed while minimizing costs in terms of staff time and travel expenses. LTAP facilitates sharing of a large collection of informational videos and other resources.

Many training resources are already available to maintenance and highway managers nationwide. To avoid "re-creating the wheel" in the development of training resources for environmental aspects of construction and maintenance, managers may want to contact some of the entities mentioned in the sections below.

State Transportation Agency Training Programs

Some state transportation agencies have developed extensive training programs. For example, PennDOT's Transportation University offers over 300 courses and CALTRANS offers over 400. Some DOTs have developed extensive training programs on selected areas. For example, extensive erosion control and drainage channel maintenance materials have already developed by Mn/DOT's Dwayne Stenlund. Both the U.S. Forest Service and the Penn State Center for Dirt & Gravel Roads have developed a training program for maintenance of non paved roads. AASHTO's Stewardship Demonstration project website profiles training developed by WisDOT, NCDOT, and UDOT:(*135*)

- Wisconsin Department of Transportation (WisDOT) partnered with the Wisconsin Department of Natural Resources to train staff, consultants, contractors, and utilities prior to the 2002 construction season on erosion control and stormwater management. The training objective is to help trainees develop and use more effective strategies for erosion control and stormwater management during and after construction. WisDOT continues to update and refine the training based on feedback from the course attendees.
- North Carolina, Colorado, Pennsylvania, Utah and Wisconsin are training their staff in context sensitive solutions (CSS). A number of states, including Wisconsin and Kentucky, have made the training effort a part of a larger CSS program.

Contact any of the above agencies or DOTs in adjacent states for assistance. Public agencies are usually willing to share materials.

Pooled Fund Cooperative (SICOP) and On-Line Programs

One of the most widely known pooled fund cooperative programs in construction and maintenance is SICOP, the Snow and Ice Pooled Fund Cooperative Program. It was developed by AASHTO (The American Association of State Highway and Transportation Officials) under AASHTO Administrative Resolution 3-94. Training for supervisors and field operators in understanding the new processes and equipment used in these proactive snow and ice control techniques has been slow in developing; as a result lack of effective and scientifically based training has hampered progress in the implementation of anti-icing (AI) and road weather information system (RWIS) technologies from the SHRP and International Scanning Tours.(*136*) Nearly all of the snow-belt states and the American Public Works Association (APWA) and the National Association of County Engineers (NACE) contributed to this pooled fund. SICOP promulgates the Winter Maintenance Program, the goals of which are to 1) sustain or improve levels of winter maintenance service with significant benefit/cost improvements, 2) provide an enhanced level of environmental protection, and 3) place technology in service on operational maintenance sections within two winter seasons.(*137*)

The need for the development of an interactive computer-based, stand-alone, training program was identified during the AASHTO/Federal Highway Administration/Strategic Highway Research Program (SHRP) Implementation Program by the Lead States Team for the implementation of advanced AI and proactive snow and ice control technology. This task was subsequently handed off to SICOP. A Technical Working Group nominated by participating state DOTs was organized to guide development of the training program, which contains an online encyclopedia related to AI/RWIS. The RWIS/AI Computer-Based training utilizes a series of realistic scenario-based exercises and has been built as a self-paced, interactive, stand-alone, computer-based training program. SICOP intends for the program to be sufficiently flexible to provide training to equipment operators, first-line supervisors, and middle managers. To facilitate wide distribution, the program will use open-systems architecture and open standards for hardware and software. Generic training packages will be available for purchase from AASHTO. One of SICOP's prototype training package resembles a video game where equipment operators mix salt brine.

Another video-based training program was produced by a team of researchers at the University of Washington and funded by Transportation Northwest (TransNow), to teach basic rolling principles, techniques, and considerations without tying up equipment. A 3-D hot-mix asphalt compaction trainer, the program allows its user to train for the industry by playing a video game. Users experience simulated construction environments and receive real-time feedback based on their commands. It is adaptable to a variety of training situations, since instructors can set paving conditions and then guide students through interactive environments. The Xpactor can be downloaded for free at TransNow's Website.(*138*)

Transportation Curriculum Coordination Council

The Transportation Curriculum Coordination Council (TCCC) is a partnership of government and industry that is drawing on training resources nationwide to support training and certification of highway construction inspectors, technicians, and engineers—while minimizing duplication of effort and helping public agencies to maximize their training dollars. This partnership includes the Federal Highway Administration (FHWA) and its National Highway Institute (NHI), three American Association of Highway and Transportation Officials (AASHTO) Subcommittees, and five Regional Training and Certification Groups (the New England Transportation Technician Certification Program, Mid-Atlantic Regional Training and Certification Program, Southeast Task Force for Technician Training and Qualification, Multi Regional Training and Certification, and Western Alliance for Quality Transportation Construction) representing 46 State transportation agencies. Through these web links, the reader/user can access construction and maintenance certification courses that are available across the country.

TCCC works closely with the National Highway Institute, proposing new classes to develop and identifying existing resources. For example, a new NHI Bridge Construction Inspection course recommended by the TCCC draws upon two state resources, the New Mexico Quality Bridge Deck Workshop and the MDSHA "in-house" Bridge Construction Manual and identifies related NHI training materials that have already been developed.

National Highway Institute

The National Highway Institute (NHI) in FHWA's Office of Professional Development, trains current employees, nurtures some potential employees, and provides outreach and information exchange services. Students represent federal and state transportation agencies and private-sector groups. Last year, NHI presented more than 550 courses to 16,000 individuals. In an effort to improve its outreach and course delivery, NHI is also piloting Web-based distance learning courses. A complete list of NHI courses may be found on-line.

Environmental aspects are being incorporated into many of these courses. Focusing on the FHWA vision to "improve transportation for a strong America," NHI has placed particular emphasis on delivering courses to advance Administrator's "vital few" goals of safety, congestion mitigation and environmental stewardship and streamlining. Specifically, these courses advance current practices, incorporate new technologies, and keep abreast of current federal policies. This CD-ROM provides information about current training courses in structures, materials and pavements, design of traffic operations, construction and maintenance, hydraulics, ITS, financial management, civil rights, highway safety and other related topics, and the environment.

Local Technology Assistance Centers

There are 57 Local Technical Assistance Program (LTAP) centers: one in each state, Puerto Rico, and six regional centers serving American Indian tribal governments. The centers are located at universities or state highway agencies and are funded in part by federal LTAP funds, state DOTs, the Bureau of Indian Affairs, universities, local agencies, and by state legislatures. The LTAP centers were established to provide the flexibility needed to tailor programs to meet the varied needs of the local transportation work force. LTAP centers increase the skills and knowledge of local providers through training, technical assistance, and technology transfer, including program-building activities. The LTAP Clearinghouse Information Resources contains a searchable database with information on local roads resources, LTAP centers, and training resources.(*139*)

University Transportation Research Centers

The Transportation Equity Act for the 21st Century (TEA-21) established 13 new university transportation centers (UTC), and reauthorized 14 existing UTC and 6 centers previously designated as university research institutes. The latter were originally funded under the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). TEA-21 also added education as another primary objective of the UTC Program in addition to transportation research and technology transfer, which were established as primary objectives in ISTEA. A complete listing of the UTCs is available at the Council of University Transportation Centers (CUTC).(*140*)

Listservs

Technology transfer has been significantly enhanced by the use of computers. A snow and ice mailing list (snow-ice@list.uiowa.edu) has several hundred subscribers from around the world and provides a forum for the discussion of topics related to winter maintenance. Users state that it is a quick and easy way to find expertise in almost any area of winter maintenance or to find that the area of interest is one in which little or nothing is known.

The Center for Transportation and the Environment maintains a listserv on wildlife crossing concerns and issues. The Wildlife, Fisheries and Transportation Web Gateway contains information about best practices, policy issues, searchable databases, and related listservs.(*141*) FHWA maintains a listserv, called Re: NEPA - Federal Highway Administration, on which users can ask and have answered a variety of highway and environmental questions.

CHAPTER 3: DESIGNING FOR ENVIRONMENTAL STEWARDSHIP IN CONSTRUCTION & MAINTENANCE

State transportation agencies have been devoting increasing attention to the relation of design considerations to DOTs' ability to effectively steward the environment in construction and maintenance. Raising the bar on environmental performance in construction and maintenance requires cooperation with design and attention to a host of factors at an early stage in the process (planning or design) when appropriate design changes can be made and increased funding may be sought. State DOTs increasing emphasis on and guidance for designers is evident in the proliferation of design manuals that are available. AASHTO maintains a list of links to state DOT manuals on their website, at design.transportation.org. Almost every DOT has a manual for drainage and water quality considerations in design. The most widely available guidance is not duplicated here. Rather, this section focuses on more recent and emerging stewardship practices in design that assist construction and maintenance staff in delivering positive environmental outcomes.

3.1. BEYOND MITIGATION: PROJECTS TO ACHIEVE ENVIRONMENTAL GOALS

As part of their stewardship commitments, environmental planning, or process improvement efforts, some state DOTs have begun to systematically encourage and include non-compliance-related enhancements in project design and construction.

Environmental Betterments and Dual Purpose Projects

Dual Purpose Projects at Caltrans

Caltrans has explored "dual purpose" projects to achieve both environmental and transportation objectives. To further explore opportunities for enhancement as well as avoidance and minimization of environmental impacts, Caltrans is working with The Nature Conservancy of California to overlay the road network with priority habitat conservation areas statewide. A previous effort co-sponsored by Caltrans examined statewide wildlife habitat connectivity needs and associated opportunity areas for conservation. Caltrans has pursued other types of "dual purpose" community and environmental benefit projects where opportunities arose.

NYSDOT's Guidelines and Procedures for Environmental Betterments

NYSDOT's environmental initiative guidelines and procedures encourage DOT Regional Design Groups to look for opportunities for joint development with municipalities, other agencies, and private developers whereby design, construction, land acquisition and maintenance responsibilities can be mutually and equitably shared, while accomplishing community goals. The guidelines allow specific environmental elements or facilities requested and funded by others (e.g., municipalities, other agencies, and environmental groups) to be incorporated in DOT capital and maintenance projects as "Environmental Betterments," wherever practicable. Such elements or facilities include landscaping, park amenities, historic building preservation, noise barriers, created wetlands, stream restorations, stormwater basins, habitat improvements, and new municipal sanitary sewer lines, storm sewer lines and water mains that provide an environmental benefit. Such “ environmental betterments” are intended to benefit from the “economies of scale” possible on large public works projects and the particular equipment and skilled personnel available in such cases, that could cost sponsors and stakeholders less than individual projects designed, constructed, and let by themselves. NYSDOT’s Stewardship Initiative calls for the following practices or features to be incorporated into DOT capital and maintenance projects, as appropriate: (*142*)

- Practice of context sensitive design.
- Street ambience enhancements (e.g., benches, decorative paving, bollards, period lighting fixtures).
- Restoration of historic highway related features (e.g., historic lighting fixtures, stone walls, guiderails).
- Measures to retain the integrity of historic parkways and bridges.
- Increased wild flower plantings.
- Additional landscaping to enhance the appearance of noise barriers.
- Increased landscape plantings to improve roadside appearance and streetscapes.
- New or rehabilitated fishing access and trail head parking areas.
- New or rehabilitated boat and canoe launch sites.
- New or rehabilitated historic markers and interpretive signing.
- Increased signing of important waterways and watersheds.
- New or rehabilitated scenic overlooks.
- Retrofits of existing highway drainage systems with created wetlands and stormwater management facilities.
- Soil bio-engineered stream banks.
- Plantings, boulders, deflectors and other techniques to improve fisheries habitat.
- Culverts for wildlife crossings.
- New or rehabilitated wildlife viewing sites.
- Wildlife habitat improvements.
- Mitigation and enhancement for past wetland impacts.
- Restored and enhanced wetlands.
- Acquisition of endangered species habitat.
- Acquisition for preservation of regionally important wetlands and upland habitat.
- Acquisition of scenic easements.
- Improvements to highway entrances of public parks, wildlife management areas, and historic sites.
- Replacement of fixed-time traffic signals with vehicle activated signals.

As part of NYSDOT's proactive outreach effort, Regional Design offices have invited local municipalities, environmental groups and agencies to combine their funded and designed environmental elements or facilities with ongoing DOT projects. In some cases, NYSDOT has provided added design services to assure that the community's "environmental betterment" work is appropriately integrated into the transportation project plans and specifications. NYSDOT can also provide contract letting and construction inspection of the Environmental Betterment work at no charge to the municipality, other agency or environmental group.

Since NYSDOT's Environmental Initiative is a component of the Department's Capital Program Update process, Regional Planning and Program Managers are required to include Environmental Initiative projects on their updated program. Regions identify those projects that have environmental or context sensitive design work which goes above and beyond regular mitigation or permit requirements and track those elements as a project attribute in the Department's Project and Program Management Information System (P/PMIS). Various work types allow environmental initiative projects to be grouped by a specific activity, as outlined in NYSDOT's Environmental Initiative Statement and description of the Dedicated Environmental Benefit Projects. This overview also outlines NYSDOT's further rationale for investment in such public goods: (*143*)

Example 3: NYSDOT Initiative - Environmental Benefit Projects

NYSDOT will fund and implement a number of environmental benefit projects that are well-suited to the Department's mission and capabilities. To program environmental enhancements on property owned by the New York State Department of Transportation will be a simple, straightforward and visible demonstration of environmental commitment. These projects will be designed to:

Improve water quality because studies done by the New York State Department of Environmental Conservation (DEC) have shown that non-point source runoff is now the major cause of water pollution. Non-point source pollution enters a water body from diffuse origins on the watershed and does not result from discernible, confined or discrete convergences such as a pipe or ditch. NYSDOT, with its extensive network of state highways, is in an excellent position to assist in improving New York's water quality. Since, non-point source water pollution control is most practically achieved through the construction of stormwater control measures that NYSDOT routinely incorporates into its projects. NYSDOT will also retrofit existing highway drainage systems by designing and building:

- Created wetland and stormwater management structures
- Bioengineered streambanks.
- Specialized water quality inlet structures

Restore wetlands because the initial construction of New York State's transportation infrastructure caused negative impacts on wetland acreage, function and value. During the last two decades, the New York State Department of Transportation has gained extensive experience both in delineating state and federal wetlands and in avoiding, minimizing and mitigating adverse impacts to wetlands. NYSDOT will continue to use this new knowledge to go beyond regulatory state and federal no-net-loss goals by helping to increase New York State's wetland acreage and function by:

- Improving or restoring wetlands affected by federal-aid highway projects that were done before regulatory mitigation was required.
- Constructing additional wetland acreage in projects beyond that required for state and federal wetland permits.
- Working cooperatively with The Nature Conservancy and the resource agencies to preserve important existing wetland sites.
- Creating new wetlands to control non-point source pollution as well as to provide other wetland functions, such as wildlife habitat.

Protect fish and wildlife because fisheries habitat in New York State has been degraded by the channelization and siltation of state waterways, and DOT has the capability to deliver restoration measures in an efficient and practical manner. The New York

State Department of Transportation will protect wildlife by planting specialized food and cover crops along state highway rights-of-way and by providing more and safer wildlife crossings under state and local highways. For example, NYSDOT will design and install:

- Boulders and stone weirs to improve fisheries habitat
- Culverts for wildlife crossings
- Plantings for wildlife habitat

Promote eco-tourism because people travel on state highways. And, through access to nature, people develop a deeper sense of why the environment warrants protection. Eco-tourism is a growing and sustainable part of New York State's economy. Because a large part of the eco-tourism experience depends on the appearance of state roadsides as well as access to natural features, the New York State Department of Transportation will develop:

- New or rehabilitated fishing access and trailhead parking areas
- Historic markers and other interpretive signing
- Improved bikeway and pedestrian facilities
- New scenic overlooks

Enhance transportation corridors because as a state agency, the New York State Department of Transportation's customers include the traveling public and the people who live and work in New York State's transportation corridors. They deserve improvements in the quality of their lives that can be achieved through:

- Providing streetscape amenities
- Wild flower plantings
- Landscaping to enhance the appearance of noise barriers
- Reestablishing street trees in historic districts
- Rehabilitating comfort stations and rest areas

The New York State Department of Transportation will continue to make every effort to:

Reduce environmental toxins by:

- Using salt and sand for highway anti-icing and de-icing as judiciously as possible
- Sweeping roadsides better and more often
- Reducing herbicide applications
- Cleaning up wastes previously generated on NYSDOT projects and at NYSDOT facilities

Improve air quality because up to half of the air pollutants emitted in New York State are emitted by single occupancy vehicles; that is, by cars with only a driver. To reduce these emissions, the New York State Department of Transportation will:

- Implement Transportation Demand Management practices
- Encourage alternatives to single-occupancy vehicle commuting
- Expand Ozone Alert Day initiatives
- Promote the use of alternative fueled vehicles
- Provide facilities for pedestrians and bicyclists
- Support mass transit

Increase the use of recycled materials because New York State's environmental policy calls for recycling as the first choice in dealing with solid waste. As a leader in this policy initiative, the New York State Department of Transportation will pilot and promote the use of recycled:

- Tires in highway embankments

- Glass, plastics, and aggregate in pavement mixes
- Plastic, rubber, and aggregate in noise walls

Preserve and enhance our New York State heritage because our historic and our natural heritage belongs to all New Yorkers. Because of the nature of its work, NYSDOT is in a unique position to enhance this heritage by:

- Preserving historic structures
- Promoting state bike routes and greenways
- Increasing highway tree plantings and other landscaping
- Providing streetscape amenities
- Increasing roadside plantings and maintenance for aesthetic improvement

Through active integration of environmental concerns into the Department's daily operations and coordination with regulatory agencies, environmental groups, municipalities and concerned citizens, the Initiative will attain the goals set forth above.

Maintaining or Improving the Natural Environment as Transportation is Built

An increasing number of DOTs are incorporating ecosystem conservation into their planning processes; the General Accounting Office noted that DOTs in Oregon, South Dakota, Colorado, and North Carolina "reported extensively considering ecosystem conservation in transportation planning using several approaches. The Oregon Department of Transportation has included a policy in its long-range plan to, among other things, maintain or improve the natural and built environment, including fish passage and habitat, wildlife habitat and migration routes, vegetation, and wetlands. The long-range transportation plans of Colorado and North Carolina each contain specific references to goals or policies to conserve ecosystems, while South Dakota's plan contains a more common, less specific goal aimed at protecting the environment."(*144*)

Cultural Resource Enhancement Efforts

Cultural resource improvement efforts are included as a part of Context Sensitive Design/Solutions initiatives at state DOTs and often include such environmental stewardship practices and improvements to cultural resources as:

- Extending trails or sidewalks
- Visual screening
- Scenic easements
- Special signage design/placement
- Preservation of historic context

AASHTO's Environmental Stewardship Demonstration Program profiles these and other project and programmatic cultural resource stewardship projects, about which further information is available on-line: (*145*)

- Bell Farm Bridge (KY)
- Pioneer Street Bridge (VT)
- Bridge Over Virgin River, East of Hurricane (UT)
- WV Route 9 Environmental Commitments (WV)

- AHTD Historic Bridge Management System (AR)
- Section 106 Programmatic Agreement (VT)
- Section 106 Programmatic Agreement (DL)
- Farmland Mitigation (CA)
- Community Sensitive Design Development (WI)
- Connecticut Farm Map (CT)
- Cultural Resource Partnership with Indiana University (PN)
- Section 106 and 4(f) Programmatic Agreements for Historic Canal Bridges (NY)

AASHTO's Center for Environmental Excellence maintains background information about information about Section 106 of the National Historic Preservation Act and Section 4(f) of the Department of Transportation Act on-line along with Recent Developments, Documents and Reports, Success Stories, and Related Links. A notable practice and use as a design resource in the state of Minnesota is MN/Model - A Predictive Model of Precontact Archaeological Site Location for Minnesota.

Often cultural resources enhancements are included in general project costs. Other times, such enhancements are funded as separate Transportation Enhancements (TE) activities, which are federally funded, community-based projects that expand travel choices and enhance the transportation experience by improving the cultural, historic, aesthetic and environmental aspects of transportation infrastructure. Transportation Enhancement funds are apportioned to the state DOTs through a minimum 10 percent set aside of each state's STP funds. TE projects must be one of 12 eligible activities and must relate to surface transportation. For example, projects can include creation of bicycle and pedestrian facilities, streetscape improvements, refurbishment of historic transportation facilities, and other investments that enhance communities and access. The National Transportation Enhancements Clearinghouse contains descriptions and photos for a full range of such efforts, as well as links to learn the basics of the TE program, view a Guide to Transportation Enhancements, access state-specific information, order free documents, or assistance. Federal legislation related to TE is accessible through the Federal Highway Administration (FHWA) TE Web site. In addition to a project list, NTEC maintains a state program policy and procedures database that is updated periodically as changes occur.(*146*) Some state DOTs are more active in implementing the TE program and using TE dollars than other states. Several states, including Wisconsin, Massachusetts, and Alaska, have funded numerous TE-eligible projects using funding sources other than the TE set aside.(*147*) The following trail extension project profiled by NTEC is a prime example of a cultural resource enhancement project, in the sidewalk/trail extension category, undertaken with DOT support:

New Hampshire Lincoln-White Mountain Trail

New Hampshire DOT facilitated construction of over 2.5 miles of sidewalk and multi-use path through what was once an ailing mill town in New Hampshire's majestic White Mountains. The town of Lincoln now bustles year round with tourists bound for hiking, biking or skiing, after town officials recognized its strategic importance as a gateway to the White

Figure 2: Lincoln, NH White Mountain Trail

Mountains, and focused efforts on better connecting the community with recreational opportunities in the area. The path was built over the former site of a penstock, a sluice used to transport water to the mill, between the Pemigewasset River and Route 112. Residents of the town can now safely travel adjacent to Route 112 by foot, and bikers coming down from the Noon Mountain ski area or through Franconia Notch can use the path to enter town. Parts of the path abut the White Mountain National Forest, where walkers and bikers can take in the beauty of the mountain scenery and, in the autumn, enjoy the region's spectacularly colored foliage.(*148*)

Figure 3: NH White Mountain Trail Bridge

3.2. CONTEXT SENSITIVE DESIGN/SOLUTIONS

The Context Sensitive Design (CSD) process, also called Context Sensitive Solutions (CSS), identifies the physical, visual, and social context in which a project is situated. Establishing the existing context is done through observation and analysis along with interviews and discussion. CSD/CSS fosters the use of:

- Strong stakeholder involvement programs.
- Collaborative and interdisciplinary approaches to decision-making.
- Understanding of the aesthetic and other contexts within which transportation occurs.
- Consideration of human and natural environmental effects of transportation.
- Selection of design criteria appropriate to a specific project's safety, operational, and environmental needs.

The American Society of Civil Engineers (ASCE) defines CSS as "a collaborative, interdisciplinary approach, involving all stakeholders to ensure that transportation projects are in harmony with communities and preserve environmental, scenic, aesthetic, and historic resources while maintaining safety and mobility."(*149*) In sum, a CSD project is highly responsive to the environmental conditions, both cultural and natural, in which it occurs.

As noted by the TxDOT/Texas Transportation Institute project, "Guidelines for Aesthetic Design in Highway Corridors: Tools and Treatments for Texas Highways," the goal of aesthetics design in the highway environment is to create a pleasurable experience for the user and a positive contribution to the visual character of the community, while attending to safety and efficiency needs.(*150*) This can be approached through visual quality and four related information factors: complexity, coherency, legibility, and anticipation.(*151*)

Context sensitive solutions also minimize impacts to sensitive areas during design. Ideally, the highway project is planned to fit the particular topography, soils, drainage patterns, and natural vegetation as much as practicable. To this end, designers collect information and/or map surface waters, natural drainage ways, and direction of drainage patterns. Examples of stewardship practices DOTs have taken in design to avoid environmental impacts include:

- Asymmetrical widening to avoid wetlands, critical slopes, active slide areas, or the locations of endangered plant species.

- Alignment or profile shifts.
- Design deviations
- Installing guardrails to avoid slope flattening that will encroach upon sensitive areas.
- Building retaining walls to minimize the fill footprint.
- Minimizing clearing limits to avoid impacting buffers.
- Reuse of existing bridge abutments to help avoid disturbance to native vegetation and endangered species.
- Use of materials that blend with the natural setting of the area.
- Use of timber bridge rail, timber guardrail, and timber handrail in some cases rather than guardrail and concrete barrier walls.

The 1998 State DOT "Thinking Beyond the Pavement Workshop," identified the following recommended actions for states which may be considered practices that achieve environmental stewardship: (*152*)

- Adopt Federal language from 23 U.S.C. 109 in their own policies to include environmental, scenic, aesthetic, historic, community, and preservation criteria in projects, along with safety and mobility.
- Advance the philosophy of context sensitive design in the strategic plans of AASHTO committees.
- Review procedures, organizational structure, and staffing to encourage and institutionalize context sensitive design.
- Develop educational programs for staff and consultants that develop the necessary attitudes and skills to carry out context sensitive design, including highway design, communication skills, and process improvements.
- Provide the tools necessary for context sensitive design, including 3D presentation tools.

AASHTO Environmental Stewardship Demonstration projects highlight success stories in implementation of CSS/CSD initiatives in Kentucky, Utah, North Carolina, and Wisconsin.(*153*)

State DOT CSD/CSS Policies, Plans, Guidelines, Agreements, Training, and Examples

Caltrans' Context Sensitive Design approach implements the Director's Policy on Context Sensitive Solutions and the Deputy Directive on Accommodating Non-Motorized Travel. Caltrans' Highway Design Manual Philosophy and Application of Standards provide for the use of nonstandard design when such use best satisfies the concerns of a given situation through an exception process. Practices and design opportunities for downtown areas are included in the agency's booklet on Main Streets: Flexibility in Design and Operations. Caltrans has also produced internal articles on "Innovation: Context Sensitive Solutions" and Context Sensitive Design Powerpoint Presentation and case studies on U.S. Hwy. 50 Operational Improvements Project in Placerville and The Donner Park Overcrossing.

Connecticut DOT has promoted context sensitive design through statewide awareness training, training courses for its managers, and development of an ongoing training course for engineers through collaboration with the University of Connecticut's Engineering Department. ConnDOT sponsored a regional context sensitive design workshop with CSS leaders and 300 participants from 18 states and the District of Columbia, comprised of 85 percent transportation professionals and with 15 percent representing stakeholder interests outside transportation. An Executive Summary is available on-line. ConnDOT also is utilizing a Connecticut Farm Map in CSD/CSS.

Florida DOT's Public Involvement Handbook, updated in 2003, addresses CSD/CSS issues.

The Kentucky Transportation Cabinet has held extensive training workshops in context sensitive design, geared toward all participants in the project development phases. The Kentucky Transportation Center maintains CSD/CSS case studies, and the KYTC Context Sensitive Design Workshop is available on-line as is Kentucky Streetscape Design Guidelines for Historic Commercial Districts. KYTC's premier CSD/CSS project is the Paris Pike which created a 4 lane road with curvilinear alignment, timber guardrails, grass shoulders, large trees and rock fences retained along roadside, and stone veneer on headwalls and bridges. KYTC stripped, stockpiled, and returned the silt loam topsoil to its original thickness after grade and drain work was completed.

The Maryland State Highway Administration developed a "Thinking Beyond the Pavement" strategic plan to guide CSD/CSS implementation, conducted charettes to identify project development process strengths, designed a project evaluation instrument, and established teams to review and implement project improvement strategies. MDSHA developed a process to move beyond a "traditional" engineering approach to transportation projects and developed a new means of roadway improvement design that captures the broader effects of transportation safety and mobility decisions on 1) specific community needs, 2) on the land use decisions that are likely to follow, and 3) the cumulative impact on air/water quality and quality of life. The result of this mission was a new planning/design process subsequently used in scores of projects and communities and published in When Main Street is a State Highway. SHA replaced what they called a "cookie-cutter" approach to roadway design work with a method that better reflected each community's unique character and living environment. Participating communities are given a clear understanding of the choices involved and the information necessary to make effective, long-term decisions. The approach has now been used in over 50 constructed projects and no project has had to be redesigned because of opposition or lack of understanding for its need.

The process has also formed the basis for organization-wide training whereby highway engineers have been empowered to go beyond "standards-driven" design solutions. MDSHA has been called upon to deliver training using this approach to other DOTs and to partners in Architecture, Planning, Urban Design and Historic Preservation nationally. MDSHA has developed an internal orientation course for CSD/CSS and MSHA's project development process, a Resource/Reference Guide for project managers, introductory and advanced-level project management courses, and advanced level, topic-specific project management courses, as well as a support system for project managers that include mentors and other resources.

In support of CSS/CSD and the governor's Smart Growth Initiative, MDSHA's Neighborhood Conservation Program (NCP) provides funding for projects that stimulate growth and investment in older communities. The NCP projects are initiated by a community contact to SHA requesting assistance in addressing traffic issues with regard to pedestrians, transit riders, bicyclists and motorists. The program gives priority to improvements along state highways located within designated neighborhoods and part of Priority Funding Areas where the improvement will ignite economic growth, contribute to other revitalization efforts and promote neighborhood conservation. A key component of the NCP is total participation throughout the process by the affected community. The community and SHA form a partnership to gather information, define the concerns to be addressed through the project, and then create viable alternatives. SHA provides the technical expertise while community representatives assure that the functioning needs of the town are met through design plans and implementation. Working together, the team develops plans for improvement that will create more livable, convenient and enjoyable communities. More than $124 million is funded for NCP projects through fiscal year 2006 for improvements such as roadway reconstruction, roadway signing, lighting and traffic controls, constructing curb and gutter, sidewalks and transit shelters, improvements to existing storm drainage lines, streetscape design, and pedestrian and bicycle accommodations and safety.(*154*)

Mn/DOT's policy is to use a "Context Sensitive" approach to create excellence in transportation project development—an approach that incorporates design standards, safety measures, environmental stewardship, aesthetics, and community sensitive planning and design. Mn/DOT Technical Memorandum No. 00-24-TS-03 outlines the department's commitment to CSD. Mn/DOT is incorporating context sensitive design into all aspects of transportation project development—planning, design, construction, and operations through new policies, extensive research, and training programs. Mn/DOT has developed many implementation resources, including the use of visualization technologies to support CSD. Mn/DOT produced Context Sensitive Design, the Road Best Traveled and an Executive Summary that serves as a good introduction to CSD principles and design practices. Also, Mn/DOT's entire CSD/CSS workshop is available on-line, addressing CSS issues in sessions as follows:

- Session 2: Mn/DOT Introduction
- Session 3: What is Context?
- Session 4: Introduction to Design Workshop
- Session 5: Design Workshop Session A: Defining the Context
- Session 6: District Engineers Panel
- Session 7: The "Think" Method of Design
- Session 8: Design Workshop Session B
- Session 9: Walking Tour of Excelsior Boulevard
- Session 10: Creative Engineering
- Session 11: Design Workshop Session B Continued
- Session 12: Edge and System Relationships
- Session 13: Aesthetics and Landscaping
- Session 14: Design Workshop Session C
- Session 15: Public Involvement
- Session 16: Putting It All Together
- Session 17: Design Workshop Session D
- Session 18: Getting It Built
- Session 19: Presentation of Working Case Studies
- Session 20: Closing Comments

- Resource Case Studies
- Glossary
- Bibliography

One of Mn/DOT's premier CSD/CSS examples is the 47-mile Minnesota Highway 38 Edge of the Wilderness National Scenic Byway, which offers a winding route around lakes and wetlands. The project involved partnerships with federal, state and local parties to guide the design process. More than 90 percent of the highway would have been altered to increase the design speed to 55 miles per hour, which would have required some cut and fillsover 25 feet high and clearing limits as great as 190 feet. It was agreed that the existing horizontal and vertical alignment would be maintained as much as possible unless spot upgrading could significantly improve safety. Six foot paved shoulders with a continuous rumble strip to lessen the roadway footprint on the land, and guardrails occasionally extended to further protect in-place resources. Additional design flexibility included shallow ditch bottoms at higher vertical alignment points and increasing the back-slope steepness to minimize vegetation and visual impacts. Special care was taken to choose appropriate native turf establishment. Roadside maintenance practices have encouraged the re-establishment of native vegetation. Under the direction of a Leadership Board, the corridor continues to be maintained, redesigned, and reconstructed following best-practice environmental design principles.

A recently completed University of Minnesota research project, entitled Attributes and Amenities of Minnesota's Highway Systems that are Important to Tourists, studied eleven scenic byways in Minnesota, including Highway 38. The research examined user preferences for physical characteristics, aesthetics, and amenities of each roadway segment. Early focus groups provided a framework for the study and results revealed that road travelers are able to differentiate between physical and socially derived attributes and amenities, roads do have strong character and can strongly influence user trip satisfaction.(155)

The **Montana Department of Transportation** (**MDT**) and the Western Transportation Institute hosted a Context Sensitive Design Workshop with attendees from 38 states and South Africa. MDT's premier CSS project is Highway 93, which will include 42 wildlife crossings, including culverts, bridges, and two overpasses. The Memorandum of Agreement (US Highway 93 from Evaro to Polson) MTDOT, FHWA, and the Confederated Salish and Kootenai Tribes is available on-line.

Utah committed to a culture change process as part of implementing Context Sensitive Solutions at UDOT. The effort is focused on addressing the transportation need and being an asset to the community that is compatible with the natural and built environment. UDOT provides guidance for implementing these principles on their website. The initiative has focused on community outreach and project development and includes assessment of stakeholder attitudes and internal practices, an implementation and staff training plan, and post-implementation assessment. UDOT also created a Directorate position for Context Sensitive Solutions, to provide leadership and coordination for the agency's CSS Program. Other position responsibilities include development of long-range plans for the CSS Program.

Nevada's Governor stated "because [highways] affect our ecosystems and the way our neighborhoods and places of business connect to each other, they influence the quality of life of every citizen in the state;" in response Nevada DOT (NDOT) developed a Pattern and Palette of Place: A Landscape and Aesthetic Master Plan for the Nevada State Highway System that provides guidance for aesthetic treatments for city streets, rural roads, gateways, rest areas, and various other circumstances. In many cases it also provides guidance through examples of various levels of aesthetic treatments, from no cost to high cost. The document also discusses the process of developing a project that is aesthetically pleasing and fits into the context of its environment.

New Jersey DOT has implemented a training program for highway engineers and other transportation professionals, along with stakeholders in New Jersey host communities, to ensure Context Sensitive Design Awareness in New Jersey. This program emphasizes the use of effective public involvement techniques, implementation of design flexibility, and the concept and importance of "Placemaking." NJDOT's premier CSD/CSS project is Route 35 Coopers Bridge over the Navesink River between Red Bank and Middletown, which was dedicated in 2000 after five years of planning and redesign by a partnership between the communities and NJDOT.

New York DOT gives internal awards for Context Sensitive Solutions. The agency's philosophy aims for projects that are in harmony with the social and natural environment and community needs, and show measurable success in improving the community's environmental, scenic, aesthetic, historic, and natural resources, above and beyond mitigation requirements. To that end, NYSDOT has developed a number of resources to implement CSD/CSS including: NYSDOT Engineering Instruction 01-020, NYSDOT CSS Implementation Plan, and a review of Context Sensitive Solutions in New York Construction News. NYSDOT also provides its staff a Place Audit: An Assessment Exercise from the Project for Public Spaces to help assess a site's current and potential performance.

North Carolina DOT worked with the Center for Transportation and the Environment to develop CSD/CSS Presentations used in training NCDOT engineers and project managers. Also, the University of North Carolina Highway Research Center developed a document entitled Visualization: Guidance for the Project Engineer, which provides an overview of visualization capabilities and techniques, a discussion of cost benefits and development time, and a survey of the state-of-practice of state DOT visualization techniques.

Oregon DOT developed CSD/CSS guidelines for Historic Downtown Main Streets: Strategies for Compatible Streetscape Design. The Portland, Oregon Traffic Calming Program is also available on-line. Context sensitive design guidance for natural resources is under development; ODOT plans to apply such practices and standards programmatically in rehabilitation of Oregon bridges.

Texas DOT developed a Landscape and Aesthetic Design Manual, which provides in-depth information and guidance on landscape and aesthetic design and includes details about selecting and using specific aesthetic treatments, as well as design planning and evaluation for common structural elements as well as common transportation features like interchanges, highway corridors, entrance and exit ramps, and more. Complimenting the Landscapes and Aesthetic Design Manual, TxDOT and the Texas Transportation Institute developed Guidelines for Aesthetic Design in Highway Corridors: Tools and Treatments for Texas Highways, a reference to assist TxDOT designers and consultants in selecting and specifying appropriate aesthetic treatments for transportation projects. The project developed Technical Data Descriptions with fundamental information about the character, advantages, disadvantages, costs, and maintenance implications of aesthetic treatments or elements designers may consider for use on highway projects. The aesthetic treatments or elements addressed in the Technical Data Descriptions include: (*156*)

Example 4: Aesthetic Treatments Discussed in TxDOT Guidelines for Aesthetic Design - Site Amenities & Public Art

Concrete (Poured-in-Place) - Coatings and Coloring

- Sealer Stains
- Acid Stains
- Integral Color
- Color-Hardened Concrete
- Thin-Set Surface Coatings

Concrete (Poured-in-Place) - Textures

- Sandblasting
- Colored, textured Concrete
- Form Liner Finishes

Veneers

- Brick and Stone
- Tile

Concrete (Modular) - Walls

- Concrete Masonry Units
- Modular Block

Paving

- Brick and Concrete Pavers

Traffic Barriers

- Movable Concrete
- Interior Planter Support System

Asphalt - Textures

- Patterned Asphalt

Asphalt - Color

- Surface-Coated
- Integral Color

Pedestrian Barriers

- Railings
- Fences

Lighting

- Accent Lighting
- Fiber-Optic Lighting
- Specialty Street Lighting

VTrans or the Vermont Transportation Agency has focused the agency's CSD/CSS efforts on Historic Bridge Program, Danville Project, the Shelburne Road Project, and Vermont Byways. The Danville Transportation Enhancement Project is a partnership among VTrans, the Vermont Arts Council and the Town of Danville, Vermont to integrate artistic enhancements into the redevelopment of a portion of U.S. Highway Route 2 through the village center, to "enhance the essence of a small, close-knit rural community by providing a safe, attractive and comfortable pedestrian environment in the Village of Danville while celebrating its unique historic, built and natural features." The project provided better sight lines and improved vehicular and pedestrian safety while respecting the aesthetic and socio-economic fabric of the community. VTrans is also in the process of developing a statewide layer of critical wildlife corridors, the first products of which will be developed by late 2004, in addition to undertaking research to minimize human and beaver conflicts.(157)

Washington State DOT's approach to CSD/CSS helps implement the WSDOT Livable Communities Policy. WSDOT Roadside and Site Development and WSDOT Design Visualization Services provide implementation tools. WSDOT has emphasized learning from others both nationally and internationally, through sponsorship of a 2002 Regional US-Canadian CSD Workshop and the CSD-100 International Symposium Main Street America Meets Main Street Europe. The agency provides Geometric Design Practices for European Roads on the WSDOT Context Sensitive Design website. In 2003 WSDOT published "Building Projects that Build Better Communities - Recommended Best Practices."

WSDOT's Roadside Manual includes guidance on "Design Enhancements," which WSDOT defines as "the incorporation of manmade elements in the landscape to accomplish goals such as expression of community character, marking a community entrance, providing corridor continuity on a scenic or recreational highway, and as mitigation for visual impacts."(*158*) Examples of such enhancements occur on tunnel portals, bridges, noise walls, community entrances, rest areas, and park and ride lots and may consist of a landform, water feature, wall or barrier texture, color, pavement type, brick variation, site furnishings, or a combination of elements, including incorporation of impressions into a wall, barrier, or bridge structure.

WSDOT's Washington State Roadside Manual also calls for the following questions to be answered at the 30 percent review point: (*159*)

- What is the purpose of design enhancement?
- What is the community character?
- What is the historical significance?
- What is the cultural significance?
- How does enhancement contribute to corridor continuity?
- Who is the audience?
    - Driver & passengers
    - Transit and rail users
    - Pedestrian or recreational users
    - Community/neighborhood residents
- How long will the design enhancement be viewed?
    - Is it on a bridge portal that is seen for long moments on approach?
    - Is it on the side of the road and seen only briefly?
    - Is it at an intersection where drivers will be stopped at a light?
    - Is it at a park and ride lot or safety rest area?
- Is the design enhancement in a publicly accessible area (such as a viewpoint, park, or plaza)?
- How great is the potential for vandalism on the site?
- Will the design enhancement create a distraction or act as a fixed object that can be a hazard?
- Will the design enhancement block sight lines (to signs, merging traffic, etc.) or infringe on safety?
- Will the design enhancement be lighted?
- Will lighting create a distraction or glare problem?
- Can the lighting be developed to enhance visibility for both road users and pedestrians?
- How high is the chance that the design could become an attractive nuisance?
- What are the dimensions of the design enhancement?
- Does its scale relate to its context?

Incorporation of art into the design of a facility is an option for some projects, including a repeating element or pattern along the length of a corridor, which can include wall textures, luminaire design, railing design, or site furnishings such as bicycle racks, street tree grates, trashcans, or benches. The WSDOT Traffic Manual, "Signs" has a section on Community Entrance Markers (under "Miscellaneous Signing") that provides guidelines on these elements.

WisDOT's Community Sensitive Design Development has resulted in a Policy/Philsophy Statement for CSD in WisDOT, revision of the WisDOT Facilities Development Process to include public involvement opportunities earlier and more often, development of policy and guidance on formats for Public Involvement meetings and coordination and extensive outreach to internal and external stakeholders in the development of policy changes. Design criteria tables and guidance were expanded to incorporate the full range of flexibility provided in the AASHTO "Green Book" guidance.(*160*) Whereas WisDOT FDM design criteria formerly fell in the middle to upper range of the AASHTO design criteria, the revised design criteria include AASHTO minimum design criteria available with justification addressing safety, traffic operations and social and environmental effects of a project. Design Standards and Planting and Aesthetic Design components of the manual received particular attention. The WisDOT Local Cost Share Policy is being revised to incorporate more aesthetic elements into projects by expanding the list of eligible items to include low cost treatments such as textured and colored concretes and to incorporate budgets that can be used to fund "non-standard" treatments outside the list of eligible items.

WisDOT has developed CSD training workshops for over 400 WisDOT staff and other stakeholders. Outreach has included such groups as local government officials, environmental groups, state and federal agencies, Wisconsin Transportation Builders Association, Wisconsin Association of Consulting Engineers, and special interest groups. At the training sessions, attendees are provided with a CSD training manual and copies of the WisDOT FDM revisions, developed by WisDOT Roadway Development Engineers. They also receive a copy of the FHWA publication "Flexibility In Highway Design." To support CSD/CSS work in each district, WisDOT also established "aesthetic contacts," given more in-depth training by WisDOT landscape architects. The aesthetic contacts assist district engineers in refining visual impact ratings, determining aesthetic budget estimates, and developing aesthetic design treatments.(*161*)

WisDOT has also assembled resources on context sensitive solutions that are available to state transportation agencies on-line, or are in process.(*162*)

Roadway Aesthetic Treatments Photo Album Workbook - Federal Lands Highway

The Federal Lands Highway Divisions have extensive experience with aesthetic treatments on highway projects. In an effort to document innovative practices being applied across the nation, a Technology Deployment project was initiated to collect information about aesthetic treatments used in highway construction. The product of this effort is a compact disc with approximately 200 examples of innovative aesthetic treatments. The Roadway Aesthetic Treatments Photo Album Workbook. The workbook has been showcased at previous annual meetings of the American Association of State and Transportation Highway Officials and the Transportation Research Board.

The Aesthetic Treatments Photo Album was produced during FY 2000 and updated in FY 2002, providing an extensive reference guide of innovative aesthetic treatments that have been applied on transportation projects nationwide for bridges, walls, barriers, soil and rock cut and fill slopes with a focus on roadway case studies. For each aesthetic treatment example as much of the following information as possible is included:(*163*)

- Agency Name
- Brief Project and Aesthetic Treatment Description
- Reason (s) Aesthetic Treatment Used
- Contact Person Name and Address
- Color Photographs
- Contract Document Plan Sheets
- Construction Specification
- Bid Price Cost Data
- Maintenance Requirements (if any)

Example 5: Federal Lands Highway Special Aesthetic Treatment Categories

1 - Rock Cut Slope
Rock staining

Rock sculpting

Fresh and weathered

Half casts

2 - Soil Cut Slope
Serrated Soil

Creation of natural looking land forms

Special vegetative treatments

3 - Fill Slopes
Rock 1.25H : 1V

Re-vegetated

Reinforced slopes

4 - Retaining Walls
Form liner treatments

Painted or stained face

Natural stone facing

Simulated stone facing

Custom treatments

Bush Hammer finished concrete

Vegetation planted facing

Shotcrete facing

MSE w/Precast Facings

Segmental block walls

Welded wire faced

Timber faced

5 - Rockfall- Barriers, Fences, Draped Mesh
Weathering steel guardrail

Steel backed timber

Stone masonry or simulated stone

Concrete core w/stone or timber facade

Gabion Barriers

GM rail w/aesthetic treatment

Brugg or other proprietary fence

DOT's own fence

Colored vinyl coated chain link or gabion mesh fences or slope screening

6 - Bridges
Colored or stained concrete

Stone masonry or simulated stone

Form liner treatments

Custom treatments

Timber

7 - Bioengineering Treatments
Waddles

Bio-logs

Live stakes and Live planted walls

Logs and boulders on slope

Bounded fiber matrix

Organic based fertilizer

Riprap barbs

Matings

Context Sensitive Design/Solutions References and Resources

State products for developing Context Sensitive Solutions are listed within state initiatives under Context Sensitive Solutions. The following technical assistance and guidance is available on a national basis.

Flexibility in Highway Design (FHWA Pub. No. FHWA-PD-97-062). In an effort to highlight Flexibility in Highway Design for the environment, FHWA produced this document which includes an Overview of the Highway Planning and Development Process as well as the following design guidelines: Highway Design Standards, Functional Classification, Design Controls, Horizontal and Vertical Alignment, Cross-Section Elements, Bridges and Other Major Structures, and Intersections.

- Federal Highways Traffic Calming Website is dedicated to all the known and electronically publicized transportation programs and studies that pertain to traffic calming. As traffic calming needs often differ, techniques include police enforcement and public education only in some areas. In others, it means the employment of speed humps while in others it means the possible use of a wide array of techniques and devices. This web site is dedicated to all the known and electronically publicized transportation programs and studies that pertain to traffic calming. FHWA Community Impact Assessment Quick Reference for Transportation from the Federal Highway Administration. Also, FHWA - Citizen's Guide to Transportation Decision Making.
- The National Transportation Enhancements Clearinghouse is an information service sponsored by the Federal Highway Administration and the Rails-to-Trails Conservancy. Transportation Enhancements are community-focused activities related to surface transportation that involve consideration of environmental, cultural, economic, and social conditions. The site provides an explanation of the Transportation Enhancements program (a federal-aid reimbursement program) and how it is implemented at the state level.It provides professionals, policy makers and citizens with timely and accurate information necessary to make well-informed decisions about transportation enhancements, including landscaping and scenic beautification. The site includes a compilation of Web sites, virtual libraries, databases and other Internet resources that provide information on contacts, reports, legislation, policies, implementation or other issues relating to activities that can be funded as Transportation Enhancements.
- Thinking Beyond the Pavement: A National Workshop on Integrating Highway Development with Communication and the Environment, University of Maryland.
- A Policy on Geometric Design of Highways and Streets, AASHTO.

International Scanning Tour on Highway Geometric Design Practices for European Roads. (FHWA-PL-01-026) The objective of this scanning tour in June, 2000 was to review and document procedures and practices in highway geometric design and context sensitive design in several European countries. This "Report" gives a brief discussion on practices the scan tour participants found most significant.

- A Guide to Best Practices for Achieving Context Sensitive Solutions, Transportation Research Board. NCHRP 20-07, Task 128 identified, described, and disseminated information on the best examples of highway projects contributing to enhanced community livability. The final report was published by AASHTO and is entitled, How

Transportation and Community Partnerships Are Shaping America Part II: Streets and Roads. The publication is out of print but black and white copies are available from AASHTO. NCHRP Project 16-04 on Design Guidelines for Safe and Aesthetic Roadside Treatments in Urban Areas is due to be completed in late 2005. Objectives of the project are to develop 1) design guidelines for safe and aesthetic roadside treatments in urban areas and 2) a toolbox of effective roadside treatments that balance pedestrian, bicyclist, and motorist safety and mobility and accommodate community values. The guidelines will be based on an evaluation of the effects of treatments such as trees, landscaping, and other roadside features on vehicle speed and overall safety. The guidelines will generally focus on arterial and collector-type facilities in urban areas with speed limits between 25-50 mph.

- Project for Public Spaces, Context Sensitive Solutions has published Getting Back to Place: Using Streets to Rebuild Communities.
- Building Roads in Sync with Community Values, Public Roads Magazine.
- Getting it Right in the Right-of-Way: Citizen Participation in Context Sensitive Highway Design, Scenic America.
- Traditional Neighborhood Development: Street Design Guidelines, Institute of Transportation Engineers, 1999.(*164*)
- The National Main Street Program is designed to improve all aspects of the downtown or central business district, producing both tangible and intangible benefits. Improving economic management, strengthening public participation, and making downtown a fun place to visit are as critical to Main Street's future as recruiting new businesses, rehabilitating buildings, and expanding parking. Building on downtown's inherent assets — rich architecture, personal service and traditional values and most of all, a sense of place — the Main Street approach has rekindled entrepreneurship, downtown cooperation, and civic concern.
- National Park Service–Rivers, Trails and Conservation Assistance Program (RTCA), is a community resource of the National Park Service and works in urban, rural, and suburban communities with the goal of helping communities achieve on-the-ground conservation successes for their projects. They help communities help themselves by providing expertise and experience from around the nation. From urban promenades to trails along abandoned railroad rights-of-way to wildlife corridors, their assistance in greenway efforts is wide ranging. Similarly, their assistance in river conservation spans downtown riverfronts to regional water trails to streams.
- Walkable Communities
- Traffic Calming.org
- Context Sensitive Design for Major Urban Thoroughfares, a joint project of the Institute of Transportation Engineers and the Congress for the New Urbanism begun in 2003 will: 1) Present a new design framework developed in this effort specifically for use in urban projects, 2) Detail a design process to implement that framework based on current AASHTO, FHWA, ITE, and other design standards, criteria, and practices, 3) Incorporate optimal existing guidelines for the total public right-of-way, including but not limited to

the pedestrian realm, intersections, bicycle facilities, transit, access management, and on-street parking. The project has received support from EPA and FHWA as well.

3.3. AVOIDING IMPACTS TO ARCHAEOLOGICAL OR HISTORIC SITES

Prior to construction, any potential cultural resources should be identified in compliance with Section 106 of the National Historic Preservation Act. An archaeological record search should be conducted during the planning process in accordance with the State Historic Preservation Officer (SHPO).

AASHTO and NCHRP 8-40 sponsored a study in 2001 focusing on "the improvement of existing procedures for evaluating cultural resource significance through the use of information technology." The first phase of the study involved the collection of information on how state DOTs and SHPOs use (or do not use) information technology in making decisions on resource significance. The study found that: (*165*)

- Most SHPOs and DOTs have not completed a standard set of historic contexts for their states; and, if the contexts exist, they exist only on paper.
- Many SHPOs and DOTs do not have their resource inventories in a computer database.
- There are competing state, regional, and national efforts in terms of computerized cultural resource database development.
- When databases do exist, they were not developed to be used as a tool for evaluating significance. Rather, the majority is used to describe and locate resources on the landscape regardless of whether or not they are listed in or eligible for listing in the National Register.
- The majority of the DOT and SHPO staffs rarely use their cultural resource inventories or historic contexts to evaluate cultural resources. Rather, they rely on their own personal experiences and knowledge, and those of their cultural resource consultants.
- DOT and SHPO staff are generally not satisfied with the tools that they have to make and justify their decisions on resource significance, and they would like to see increased sharing of information and approaches among agencies and states.

Archaeological Sites

- The following recommendations have been developed with regard to stewardship of archaeological sites, objects, and districts or complexes on construction sites: (*166*)
- Utilize covenants and easements to ensure avoidance, where possible. Donation can occur as a part of avoidance strategy where preservation responsibility is assumed by a third party. For example, by preserving nearly 12 acres of archaeological site within the ADOT right-of-way, it is estimated that ADOT saved $2 million in excavation costs. The preserved site areas will be available for future archaeological researchers. ADOT has partnered with the City of Tucson, South Tucson, Pima County, the Tohono O'odham Nation, and the Yaqui Tribe to seek funding that will allow expansion of this preserve and its incorporation into a cultural and natural resource park (a grant application is pending).(*167*)

- Establish a buffer zone of at least 50 feet between the edge of the construction zone and the edge of the archaeological resource to ensure avoidance. Fencing, earthen berms, or other permanent barriers can be used to ensure avoidance in conjunction with a buffer zone.
- Add 12-24 inches of topsoil to "cap" the resource by intentional burial. Archaeological testing must be conducted prior to capping.

Treatment options and design recommendations include: (*168*)

- Avoidance
- Redesign
- Realignment
- Inclusion of a buffer zone of 50 feet minimum between the edge of the construction zone and the edge of the resources to ensure avoidance.
- Adaptive Reuse
- Relocation or removal of historic resource from project area as an alternative to demolition. Requires design input for site of relocation.
- Incorporation of historic elements into new design
- Retention of historic setting
- Mitigation of road noise
- Reduction in traffic speeds.
- Retention of historic elevations, lane widths, shoulders and road curvature.
- Avoidance of new visual elements, such as curbing, lighting, or signage, that may detract from historic character.
- Landscaping to preserve rural feeling and association where appropriate.
- Recording/Research, which may include: drawings, photography, records research, and informant interview
- Placing information kiosks/signage in highly visible areas with roadside turnoffs to provide public access. Use in conjunction with recordation and research.

Historic Resources

Historic resources can include buildings, structures, objects, districts, and landscapes. Roads may be deemed historic for aesthetic, engineered, or cultural values. Although states often catalog thousands of archaeological sites, there are many problems with these databases for building statewide predictive models. In addition to lack of computerized data and wide variations in the comprehensiveness and intensity of survey in different parts of the state, data is often incomplete or unreliable for particular sites and inventory typically only where researchers expect sites to be, leading to under-representation in less known areas. These problems complicate and in some cases prohibit the development of predictive site location models that could assist in design for avoidance of likely sites and minimize accidental finds during construction.(*169*)

Nevertheless, DOTs have developed a variety of ways to steward cultural resources and historic sites in the course of design and construction:

- When more burials than anticipated were discovered on TxDOT Mission Refugio project, TxDOT expanded the scope of its public involvement process and contacted other possible stakeholders, including the Refugio county judge, Refugio government officials, a local history museum, and community members. Many of these stakeholders helped TxDOT identify historic features and artifacts.(*170*)
- When the Arkansas State Highway and Department of Transportation (AHDT) took on the expansion of a one-lane bridge over the Mulberry River in the Ozark National Forest, they chose to construct a rock retaining wall, made with native stone quarried from near the construction site. Using local stone to build the structure was lower in cost than some traditional systems, and was much cheaper than a masonry face. It also enabled the wall to fit in with the natural surroundings. The team chose a mechanically stabilized earth (MSE) wall system, using geogrid reinforcements for the taller walls, covered by the locally quarried stone. It required no special equipment or labor, and provided more flexibility without distress. AHDT widened the existing gravel road to two travel lanes with shoulders; constructed a bridge over Indian Creek; developed drainage improvements; and designed functional, yet aesthetic, retaining walls for the project. Native stone also provided natural water drainage. Concrete would have enabled water to seep into the walls when the Mulberry River flooded, causing a buildup of hydrostatic pressure through water retention. Retaining walls are now free-draining, eliminating the need for a human-engineered drainage system.(*171*)

Figure 4: Arkansas SHDT Historic Bridge and Native Stone Retaining Wall

- NHDOT continues to maintain just over 50 covered bridges. Hundreds more used to exist and the rebuilding effort began with the passage of a new law that allowed New Hampshire to use State Bridge Aid money to rebuild former covered bridges. With an 80 percent share from the state and 20 percent from the town, each new covered bridge had would have to meet legal load and height standards. The $3 million Smith Millennium Covered Bridge (Long Truss with integrated arches spans 163 feet over the Baker River in Plymouth) can handle two 18-wheel tractor-trailer trucks passing each other. It combines the historically proven qualities of a wooden covered bridge with more modern amenities, such as a fire detection system, lighting for the interior travel way and an exterior sidewalk. A picture is included to the right. This and other new covered bridges in New Hampshire are the result of state and community partnerships that

Figure 5: NHDOT Smith Millennium Covered Bridge

led to the rebuilding of local landmarks, thus restoring part of the state's heritage that are also highly functional parts of the state's transportation system. They are structures that both honor the past and look to the future.(*172*)

3.4. HABITAT CONNECTIVITY AND WILDLIFE CROSSINGS

Wildlife issues are on the rise for state DOTs. Wildlife related concerns include habitat fragmentation and connectivity for wildlife, loss of habitat, increasing numbers of threatened and endangered species, and secondary and cumulative impacts.

The federal Endangered Species Act prohibits harm to or take of any listed species or adverse modification of designated critical habitat. Some of the existing regulations can be reviewed at the Overview of the U.S. Fish and Wildlife Service and recent developments at AASHTO's Center for Environmental Excellence website. Other sites which provide regulatory information include the USFWS' Digest of Federal Resource Laws of Interest to the U.S. Fish and Wildlife Service, Executive Orders, FHWA's Summary of Environmental Legislation Affecting Transportation, December 1998 and the Center for Wildlife Law' Federal Wildlife and Related Laws Handbook, Statute Summaries. Maintenance and construction staff are responsible for ensuring that no threatened or endangered species within areas they are working are injured or destroyed or their habitat impacted without proper permits. DOTs are implementing stewardship practices specific to certain threatened and endangered species as well as practices designed to benefit wider groups of species and ecosystems more proactively. This sections specifically focuses on what DOTs are doing to improve habitat connectivity and the ability of wildlife to safely cross roads.

State transportation agencies currently employ a mix of underpasses, bridge extensions, culvert installations, and culvert modifications, and associated fencing and ecowalls to facilitate wildlife movement. Effective wildlife fencing and crossing structures can significantly reduce many harmful impacts of roads on wildlife populations, though such measures can contribute to habitat fragmentation. More and more DOTs are exploring wildlife passages and culvert retrofits as means to enhance wildlife passage. In a few cases overpasses are being built. From a wildlife conservation perspective, the impacts addressed by these stewardship measures include habitat loss, habitat fragmentation, degradation of habitat quality, road avoidance zones, increased human activities, direct mortality, reduced biodiversity, genetic isolation, chemical contamination, changed hydrology for fisheries, reduced access to vital habitat, disruption of processes important to animal life cycles, and disruption of the food chain. Rigorous evaluation of the success of these measures has been implemented more slowly as funding for such work after the conclusion of construction is harder to find and frequently involves partnerships with others. In a 2002 survey by the author, 17 of 50 state DOTs said they were beginning to systematically incorporate wildlife crossings into roadway designs, but only a couple state DOTs had wildlife crossing policies, and only two states reported they had prioritized barriers for correction based on benefit evaluation.(*173*)

NCHRP 25-27, starting in 2004 and concluding in 2007, will investigate what guidelines are currently used by DOTs to determine wildlife crossing dimensions or design, the decision process, and any tools or aids that are used in that process. As of early 2002, only five state DOTs reported providing some direction to designers in this regard. In dissecting existing decision processes, NCHRP 25-27 will seek to understand the various factors used to decide what type of crossing will be employed as well as the extent to which long-term maintenance costs (annuities) of a highway structure guide selection (e.g. steel arch culvert vs. precast concrete girders with concrete deck). Ultimately the project will produce design guidance and a decision support tool for DOTs, as well as measures of cost and effectiveness.(*174*)

Identifying Locations for Wildlife Crossings

The locations of wildlife crossings and/or problem areas are critical for effective mitigation of the barrier effect caused by highways; however, few methodological approaches to identify and prioritize these key areas have been explored. Only three state DOTs reported using modelling tools to identify habitat linkages as of 2002, and only one state did so for a large number of species on a statewide basis.(*175*) Six states had embarked on or participated in statewide efforts to determine connectivity needs as of early 2002.(*176*) Several more have begun to do so over the past two years.

Planning for wildlife crossings can be very involved; however, much can be accomplished using rapid assessment techniques, available information, and expert panels. The Forest Service's national expert on wildlife crossings advocates a simple rapid assessment approach that has proven effective in a variety of circumstances, is fast, and affordable: (*177*)

- Select highways to be examined.
- Select species for analysis
- Use available, spatially specific information, especially that available digitally in geographic information systems (GIS).
- Use a team of local biologists. Teams can often examine 100 miles/day.

DOTs, resource agencies, universities and non-governmental organizations such as The Nature Conservancy, American Wildlands, and the Rocky Mountain Elk Foundation have attempted to fill this gap by conducting workshops, often with DOT sponsorship. Biologists, researchers, and regulatory specialists come together in a workshop setting to make decisions on conservation and connectivity needs based on analysis of best available environmental data. With recent requirements of all states to identify priority conservation areas, new opportunities for interagency identification and prioritization of wildlife crossing needs are emerging.

NCHRP 25-27 will survey state transportation agencies to determine what information is used to determine location and number of wildlife crossings on planned sections of highway-improvement project, whether models are developed around political, project, or ecological boundaries, and whether connectivity needs are assessed at the project level, political/statewide level, or the level of ecoregions surpassing political boundaries.

Monitoring Wildlife Crossings

Performance evaluation of crossing structure depends upon adequate monitoring. Future design benefits from such information as well. Most monitoring efforts to evaluate wildlife crossings have been short-term and focused on discerning whether target species are using the crossings. Monitoring programs have largely been aimed at single-species or have been confined to certain taxonomic groups; consequently, such programs may fail to recognize the requirements of other non-target species and ecological processes. Further, studies have generally failed to address the need for wildlife adaptation to environmental change. How well crossings ultimately perform depends on how well they accommodate changes in wildlife species distributions, abundance and behavioral profiles. Wildlife crossings are expensive measures, but a large void exists in devising cost-effective designs based on ecological and engineering criteria. Also, the current information base on wildlife crossing performance is geographically limited.

While nine of 50 state transportation had modified culverts for enhancement of connectivity across roads as of 2002, only four of these monitored such crossings with feedback to DOT designers and/or the state or federal wildlife agency.(*178*) Eight of 50 state DOTs reported monitoring specially constructed wildlife underpasses, with feedback to design and wildlife agencies.(*179*) Though DOTs more commonly employed bridge extensions to facilitate wildlife passage, usage by wildlife was much less frequently monitored than with other crossing technologies.(*180*)

According to research by the Western Transportation Institute, evaluation of a wildlife crossing structure installation may involve consideration of the following issues: (*181*)

- Motorist safety and animal-vehicle collisions
- Ecological impacts of mortalities and the "barrier effect" due to roads and traffic on individual animals, on a specific species, on populations of animals, on ecological communities and biodiversity, or on ecosystem processes and functional landscape integrity.

NCHRP 25-27 will add to this knowledge base by collecting details about types and methods of wildlife crossing monitoring in use, how often monitoring occurs, and the length of time for which it has occurred. The project will seek to detail the ecological criteria currently used to judge whether wildlife crossings are functional or effective, whether targets are established in advance, criteria are based on single target species, observed frequency of use by target or multiple species, population- or ecosystem-level data collection and analysis, or accident reduction.

Wildlife Crossing Techniques, Research, and Resources

This section reviews environmental stewardship practices and features that are being incorporated in many transportation projects across the country, including the restoration or preservation of habitat as mitigation and the addition of wildlife underpasses, overpasses, bridge extensions, enlarged culverts, and fencing by many states dealing with the realities of wildlife conservation and motorist safety. These practices were initially presented in NCHRP Report 305 and are summarized herein. Habitat-related mitigation and conservation measures are some of the most effective measures and are used to address the broader ecological concerns associated with reductions in habitat and wildlife connectivity. Model stewardship practices in this area will also be briefly reviewed.

Existing crossing techniques can also be view at the Wildlife Crossing Toolkit developed by the U.S. Forest Service. Their website offers a searchable database of case histories from a wide variety of locations, time periods and wildlife species where people have attempted to solve issues resulting from wildlife/highway interactions.(*182*)

Research by the Western Transportation Institute found that the physical dimensions of the underpasses had little effect on passage because animals in the Banff National Park in Canada may have adapted to the 12-year old underpasses; however, structural attributes were more important on newer structures. Furthermore, the level of human activity in the vicinity was an important factor suggesting that mitigation strategies need to be proactive at the site and landscape level to ensure that crossing structures remain functional over time, including human use management.(*183*) The Western Transportation Institute is developing a vehicle-animal collision "toolbox" of countermeasures, which will provide detailed information to support application choices and decisions, and performance measurement.(*184*)

The remainder of this section consists of summary excerpts from NCHRP Synthesis Report 305 and practices adapted from that discussion with regard to wildlife crossings, except where otherwise noted.(*185*)

Fencing

Fencing is a common practice used throughout the world to keep animals off highways. Twenty-eight states report using fencing to protect wildlife. The most frequent application is to keep deer off of roads. Deer are locally overabundant in a number of states, and fencing has proven to be an effective way to keep deer off the roads. Clevenger (*186*) reported an 80 percent reduction in ungulate-vehicle collisions on the Trans-Canada Highway in Banff National Park after fencing.(*187*)

- **Design fencing applications for target species.** Typical fencing applications are rectangular mesh or chain link fence from 2.6 to 3.0 m (8.5-10 ft) high. Florida and some European countries use strands of barbed wire along the top of the fence to discourage animals from climbing over the fence. Also used is finer mesh wire of from 2 x 2 cm (0.78 in.) to 4 x 4 cm (1.57 in.) buried 20 to 40 cm (7.87-15.75 in.) with a height extending from the ground of from 0.5 to 1 m (1.64-3.28 ft).
- **Keep local wildlife interactions in mind when designing fences.** For example, in California fencing application in areas with kit fox and coyotes provide a gap under the fence just large enough for the kit fox to negotiate at full run so that the latter can escape predators such as the coyote.
- **For reptiles and amphibians, bend the upper edge of the finer mesh at a 90-degree angle to provide a lip to prevent animals from climbing over** the fence. In Waterton Park, Canada, a temporary silt barrier type fence was used to direct frogs into polyvinyl chloride (PVC) drop traps so that volunteers could move them across the highway to a pond during the few-week-long migration period. Europeans have used a PVC barrier with an angled lip to keep reptiles and amphibians off the highways as well as a fabricated galvanized steel rail with a barrier lip along the upper edge. Iowa DOT has placed finer mesh fence at the bottom of regular fence to prevent smaller wildlife such as turtles, snakes and other small animals from getting on the Eddyville Bypass and Highway 63 at the Bremer-Chicksaw county line. This fencing approach has been commonly used in Europe to keep smaller animals off highways.
- **Bury fine-meshed fencing at the bottom in use with pipe culverts for small animal connectivity or in association with other ROW fences.** This practice has been successfully used under highways in Europe in culvert pipes with diameters approximately 0.4 m to 2.0 m (1.31-6.56 ft). California used a unique fencing application for desert tortoise approximately 6 km (3.7 mi) east of Kramer Junction on Highway 58 in San Bernardino County. A finer [1.27 cm (0.5 in.)] mesh section of wire fence, approximately 50.8 cm (20 in.) in height, was installed along the bottom of a typical 1.22-m (4-ft) right-of-way fence. The finer mesh fence was buried approximately 15 cm (5.9 in.) to prevent animals from going under. This portion of the fence was held in place

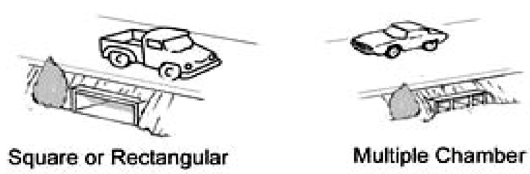
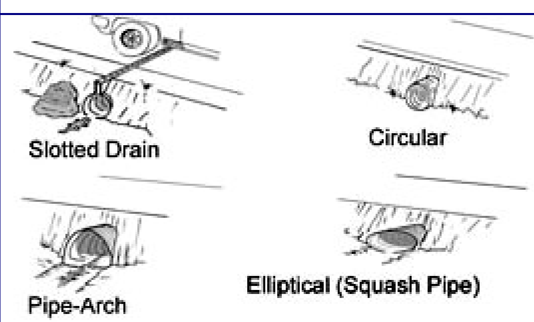
using three strands of wire. The fencing application was done on an approximately 35.42- km (22-mi) section of four-lane highway. The fencing angled into the road at a series of culverts and bridges that were constructed for wildlife connectivity.

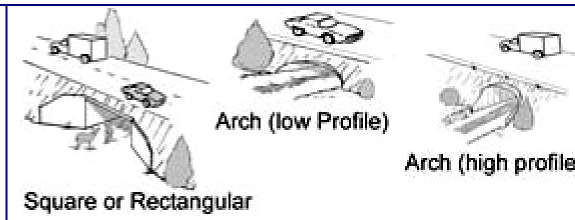
- **Fence installation decisions should account for the potential for wildlife to be trapped between the fences should they find a way to enter the rights-of-way under, over, or around the fence ends.** Because fencing is not totally exclusionary, Bissonette and Hammer studied two highway sites in Utah to compare the use of one-way gates and earthen ramps. They found that earthen ramps were used from 8 to 11 times more than one-way gates. Irrespective of the species, fencing without provisions for movement across the road can cause disruption of connectivity resulting in isolation of populations. This can be especially problematic for species with low populations, where the possibility of extinction can result.

Culverts

Properly designed culverts can enable wildlife to cross roadways by passing under an intersecting roadway through a culvert. A culvert is a conduit covered with embankment around the entire perimeter. It may or may not convey water. Small conduits for amphibians are sometimes called tunnels. The following table is from the U.S. Forest Service on-line Wildlife Crossing Toolkit.(*188*)

Table 8: U.S. Forest Service Wildlife Crossing Toolkit Guide to Culverts

Category	Definition	Shape	Typical Material
Box Culvert	Culvert has four sides, including bottom. Sometimes square or rectangular corrugated metal pipe culverts without bottoms are called box culverts, but in this toolkit they are referred to as bottomless culverts. Box culverts may be arranged in a horizontal series of small culverts to form multiple chambers.		Precast concrete Cast-in-place concrete Wood
Culvert (Continuous)	Culvert is continuous in circumference. The lower portion may or may not be buried. Sometimes simply called *pipe*. European badger culverts are sometimes called *ecopipes*. Slotted drain culverts are continuous except for a break in the upper portion.		Corrugated metal pipe Metal plate Cast-in-place concrete Precast concrete Wood

Bottomless Culvert	Culvert is discontinuous in circumference with rounded or square top and natural surface bottom. Also called *open-bottom culvert*.		Corrugated metal pipe Metal plate Precast concrete Cast-in-place concrete Wood

From Forest Service Wildlife Crossings Toolkit on-line at http://www.wildlifecrossings.info/cst2.htm

Modified Drainage Culverts

Drainage culverts can be modified to accommodate wildlife, a practice increasingly implemented by state DOTs and for which the Netherlands is reknowned. Small mammals and amphibians are able to move through the culverts on shelves and floating docks or through wildlife tunnels built parallel to the wet culvert. NCHRP Synthesis Report 305 identifies the following stewardship practices with regard to modified drainage culverts: (*189*)

- **Addition of a 0.46 m wide × 0.30 m high (18 in. × 12 in.) elevated concrete walkway can allow animals to move through a culvert even when water is present.** Such modified culverts were successfully tried on US-98 in Texas for bobcats.
- **A central "sacrificial" culvert with other culverts placed on both sides but at a higher elevation for drainage and connectivity can diminish blockage by beavers**, which attempt to block the lower culvert, and the adjacent culverts at higher elevation remain open. Beaver-exclusion devices, including fencing, perforated pipe, or a combination of the two have been successfully used throughout the United States to reduce impounding of water behind road fills and for wetland mitigation and habitat preservation.

Drainage Culverts

NCHRP Synthesis Report 305 reports a number of states are using culverts in different applications for a variety of species. Florida, Montana, New Hampshire, Texas, and Wisconsin are using culverts for reptiles and amphibians. Nebraska and South Dakota are using them for turtles. (*190*)

Culverts with dual drainage and wildlife crossing purposes have proven successful in accommodating both terrestrial and aquatic organisms depending on water levels in the area of the culverts. When placed at the proper elevation, they can serve both types of organisms. Drainage culverts are typically used where highway causeways or fill sections transverse wetlands with fluctuating water levels such as wet prairies and marsh. They are also used on intermittent streams and floodplain areas that may inundate during wet periods. Aquatic species such amphibians and fish use them when they are wet and terrestrial species including reptiles and small mammals use them when they are dry. Thus,

Pictures of Florida DOT drainage/wildlife culverts, Massachusetts amphibian tunnels, Dutch structures, and wildlife using the culverts mentioned above, as well as other projects around the world can be seen at FHWA's wildlife crossings website; however, Evink notes that few states have researched the effectiveness of these structures.(*191*) Nevertheless, it is known that

- Culverts should be sized for use by multiple species, wherever possible.

Stream Culverts and Bridges

Like drainage culverts in upland areas, oversized culverts can be designed and placed at the proper elevation over waterways to provide passage for a large number of aquatic and terrestrial species. (*192*)

- **Use the natural stream bottom rather than a concrete or metal bottom.**
- **Provide shallow water or even dry edges along the stream edge in the culvert or bridge to allow the greatest number of species to move through**.
- **Allow extra height for larger mammals, such as deer, bear, and other species** that ordinarily follow riparian corridors for movement and pass safely under roads. A wide variety of designs are possible depending on the site-specific construction environment – concrete box culverts, and round, oval, and elliptical pipe culverts.
- **Provide cover as well as substrate on the inside of the culvert, similar to that of the exposed stream, to expand utility of the culvert**. Proper sizing of the culvert depends on site-specific considerations and hydraulics, but including the natural streambed and as much adjacent upland as possible proves most successful.

Wildlife Underpass Bridges and Dry Culverts

Upland culverts are one of the most frequently used structures for wildlife crossings and have proven successful for accommodating a wide variety of species. Pipe culverts and box culverts have proven effective for small animals. California is using culverts for San Joaquin kit fox. Illinois, Kansas, Montana, New Hampshire, New Jersey, Oregon, Texas, Utah, and Virginia are using culverts for other small mammals. Arkansas, Colorado, Wyoming, Utah, Michigan, Maine, Washington, and Kansas report using larger culverts for deer and other wildlife.(*193*)

- **A range of culvert sizes, from 1.22 m × 1.22 m (4 ft × 4 ft) in Arkansas up to 2.44 m × 7.32 m (8 ft × 24 ft) in Florida and from 1.5 to 10 m (4.92–32.81 ft) in New South Wales, Australia,** have been successfully used for various species of terrestrial mammals and reptiles.
- **Use frequently placed culverts [150–300 m (492.13–984.25 ft)] of varying size in close proximity to shrub or tree cover.** Clevenger and Waltho found that for a variety of culvert sizes for small and medium-sized mammals, passage was positively correlated with traffic density, road width, road clearance, and culvert length. They also found that all species with the exception of coyotes and shrews preferred small culverts with low openness ratios. There appeared to be some evidence of predation at crossings so the thought was that the smaller culverts provided comfort to the prey species. Weasels and shrews preferred culverts with nearby cover. The researchers felt that drainage culverts could be used to mitigate the harmful effects of high-speed roads.(*194*)

Wildlife underpasses are bridges and/or large culverts over dry land and sometimes land and water, constructed expressly to facilitate wildlife movement in important corridor areas. The length and height of these large culverts or bridges varies with the wildlife expected to use them. Twenty-three states report using underpasses for wildlife. The Western Transportation Institute is cataloging existing uses of and research on underpasses and culverts to provide further guidance to DOTs on stewardship practice in this area.(*195*)

Extended Bridges and Existing Structures

One of the most successful and cost-effective means of providing for wildlife movement down riparian corridors is the extended bridge. Twenty-four states report using extended bridges for wildlife movement and wetland protection.(*196*)

- **Provide adequate area for both water movement with associated organisms and dry habitat for terrestrial species movement.**
- **Consider the characteristics of the area when trying to determine the appropriate length of the bridge.** In cases where there is an important corridor for movement of rare or protected wildlife species, bridging the entire floodplain may be necessary. At the other end of the spectrum, where the floodplain is being used by habitat-limited species, a combination of smaller structures and fences may be possible.
- **When choosing a combination of bridge and fill, consider what reptile and amphibian species will likely move up the fill slope onto the road.** Standard fencing will not stop this movement so that very expensive barrier walls and associated guard rails may be necessary to prevent significant kills of these species during periods of the year when they are moving around in large groups.
- **Consider the cost of mitigation for wetland takings by opting for a fill section.** By the time the costs of shorter bridges or culverts, fill acquisition, barrier walls for reptiles and amphibians, guardrails, and fencing are factored in, along with the cost of wetland mitigation, the cost of a more substantial bridge, preferred for habitat connectivity, may already have been approached.

Viaducts

Viaducts are a potential solution for the entire spectrum of species moving through an area, as these long bridges can leave wetlands, rivers, and variable topography and geology below largely intact. Typically, this approach is most cost-effective where there is topographic relief, such as in mountainous areas, is sufficient to make bridging necessary for a significant span of a waterway, canyon, or valley; use of spanned lands by wildlife is typically a secondary benefit. (*197*) Design of viaducts for wildlife connectivity and habitat enhancement is increasing, especially in Europe.

Wildlife Overpasses

Although wildlife overpasses are largely a European phenomenon, Florida, Hawaii, New Jersey, and Utah reported overpasses being used by wildlife and the Montana Department of Transportation and the Connecticut DOT are installing wildlife overpasses on Highway 93 and Route 6, respectively. The New Jersey overpasses, among the first in the United States, were completed in 1985 at a cost of $12 million. The two overpasses were designed to provide connectivity across I-78 (a six-lane highway) at an approximately 2-mile stretch that crossed the Watchung Reservation in Union County. The Utah overpass was constructed principally for deer. The Florida overpass on I-75 in Marion County just north of County Road 484 is a multi-use overpass designed to accommodate a recreational and equestrian trail, as well as for wildlife use. Two overpasses were built over the Trans-Canada Highway in Banff National Park and are being used by a variety of wildlife.(*198*)

- **Allow the widest width possible.** Wildlife overpasses can vary in width from 3.4 m (11.15 ft) to 870 m (2,853.6 ft). Wider passages are more effective at allowing animals to cross and animal behavior on wider structures is more normal than on narrower ones.
- **Establish or preserve suitable habitat at and leading to the overpasses.** Where this has been accomplished, it has been found that the overpasses were effective for a wide variety of animals including invertebrates.

Other Structural and Non-Structural Measures for Wildlife

Signage and deer reflectors are common approaches to informing motorists when they are entering an area where the danger of wildlife collision is high, though the effectiveness of these methods has not been demonstrated. However, a few methods have been documented to work: (*199*)

- **Use a series of solar-powered, battery-operated, motion sensors to determine animal presence and trigger low-voltage, LED-illuminated warning signs that reduce the posted speed limit to 40 km/h** and alert motorists to the presence of approaching wildlife. This method has been successfully used in Switzerland, though the location on the road was also adjacent to a large wildlife overpass over a major nearby freeway.
- **Install vertical pipes perpendicular to bridge railings to keep bird flight patterns above the elevation of traffic.** Florida reported installing PVC pipe approximately 3 m (9.84 ft) in height perpendicular to the railing on the San Sebastian Bridge. The poles were spaced approximately 3.7 m (12 ft) and kept birds hovering over the bridge from dropping down into traffic crossing the bridge, reducing bird kills.

State DOT Initiatives to Address Wildlife Habitat Connectivity Needs in Planning and Design

Caltrans Interchange Removal and Partnership to Identify and Address Habitat Connectivity Needs

Due to the rising importance of the wildlife connectivity issue and implications for future construction, Caltrans participated in a statewide symposium/workshop with scientists, activists, and planners from resource agencies and conservation organizations to identify "Missing Linkages" in fall 2000. The meeting report identifies 232 critical habitat linkages in the state, 59 percent of which are threatened. Connectivity areas identified in the report ranged from narrow choke points, like the Coal Canyon underpass, later removed by Caltrans, to long stretches of rivers and broad swaths of redwood forest. More than half of the linkages were deemed to be high priorities because of development threats and good opportunities for conservation.

The interchange Caltrans decided to remove was located where two intersecting state highways divided several protected natural areas, including greater diversity of vegetation types than any other area of comparable size in the United States. By closing the ramps, removing the pavement and lighting, rearranging fencing, and restricting access, Caltrans created a wildlife crossing with substantial height, width, ample natural lighting, and openness. In addition, Caltrans worked with State Parks to find funding to purchase approximately 685 additional acres of conservation lands adjacent to the freeway and interchange, ultimately linking the Tecate

Cypress Reserve, the Cleveland National Forest and the Irvine Company's Gypsum Canyon Preserve and lowering development pressure in the area.

Caltrans determined that the site has great mitigation value for transportation impacts, but no agreements exist with other resource agencies to obtain credits at this point. Instead, Caltrans still considers the site an excellent example of leadership and interagency cooperation, which "indirectly facilitates other transportation efforts." Wildlife passage features were incorporated into current and future state highway improvements nearby, benefiting both federally listed species and non-federally listed species with large habitat ranges.

Caltrans plans to utilize the products of the state's collaborative "Missing Linkages" project to assess viable communities, habitats, and wildlife movement corridors throughout the state. This resource will be used to help environmental impacts wherever possible, and as a guide for addressing habitat and wildlife connectivity needs when the state implements conservation measures. Generation of the statewide conservation and connectivity maps is providing the foundation for interagency buy-in, acknowledgement, and utilization of a common set of environmental priorities. The mapped priorities are expected to streamline interagency coordination and negotiation on a project-by-project basis, reduce conflict, and facilitate achievement of mutual stewardship objectives among Caltrans, FHWA, federal and state resource and regulatory agencies, non-profit conservation organizations, and environmental advocates. The Nature Conservancy (TNC) is now assisting Caltrans in comparing the 20-year transportation plan to priority conservation areas, to minimize potential impacts and to identify opportunities where Caltrans mitigation projects could achieve the greatest environmental benefit and make a tangible contribution to achievement of interagency, public and private conservation objectives.

Florida DOT Partnership to Determine and Prioritize Connectivity Needs and Contribute to "Green Infrastructure"

The State of Florida issued a report in 1994 that identified the state's highest priority wildlife habitat, which is the basis for a successful current state-funded effort to protect priority habitat conservation areas. The Florida Game and Fresh Water Fish Commission completed a land cover map of Florida's 34 million acres and performed modeling to identify the long-term habitat needs of many focal species on public and private lands. Florida DOT helped support the development of the extensive wildlife occurrence and habitat geographic information system database, which is used in roadway alignment analysis and impact assessment. The database includes: 1) a statewide vegetation map with 22 land cover classes; 2) habitat maps for over 150 individual wildlife species, constructed by modeling habitat requirements, radio-telemetry range data, museum records, and other surveys, and 3) statewide maps of strategic habitat conservation areas, defined as lands which have a high priority for protection and acquisition, but are not in public ownership.

Because significant efficiencies and ecological gains can be made by coordinating wildlife crossing installation with statewide efforts to map conservation areas and large scale linkage needs, FDOT and the Florida Game and Fresh Water Fish Department developed a decision-based geographic information system (GIS) computer model for FDOT road improvement projects associated with road mortality of wildlife and other environmental impacts. This system is integrated with other state environmental initiatives such as the greenways and CARL (Conservation and Recreation Lands) programs. An interactive CD-ROM allows the user to perform multiple scenarios and develop their own priorities, and contains all necessary data and information to perform analyses. The computer model program enables FDOT to appropriately schedule future projects according to critical environmental and transportation improvement needs.

In 2000, the Florida Department of Transportation DOT initiated a cooperative effort with the Florida Fish & Game Commission to prioritize and begin to address black bear roadkill problem areas on a statewide basis, to focus and direct investments in habitat conservation and connectivity improvements, and to streamline project approvals. Bear roadkill data were re-analyzed to rank road segments by the percent of total statewide roadkills and percentage of kills in the past ten years. This ranking was then combined with habitat information, including percent of road buffer encompassed by conservation lands and strategic habitat conservation areas. The ranking is providing guidance in siting wildlife underpasses on a statewide basis. Fifteen black bear roadkill problem areas were identified, comprising 40 percent of the total transportation-related bear mortality in the state. The core habitat systems surrounding these problem areas also provide important habitat for many species of mammals, amphibians and reptiles. At least as important as the priority crossing and connectivity needs, the analysis revealed that land management and conservation are critical in enhancing the black bear's potential for long-term survival in Florida. The results were shared with the state's Conservation and Recreational Lands program to help justify the purchase of a 22,260-acre tract associated with the Aucilla River Project in the Big Bend area of north Florida, a top three conservation priority as a result of the study.

As part of Florida's DOT's updated environmental policy, approved in February 2002, FDOT committed to cooperate in the state's Greenways Program of land acquisition and management through identification and prioritization of important habitat connections. The objective of the statewide greenways program is to establish an ecological network of green infrastructure to reduce wildlife mortality and restore connectivity to the landscape by restoring natural processes as they originally occurred across the landscape (e.g., wildlife movement and migration, flood, and fire). Where alternative mitigation strategies permit, FDOT will support land acquisition activities to help achieve this ecological infrastructure, and will utilize methods to preserve, enhance, and protect trees and other vegetation as valuable natural resources consistent with ecosystem management principles. So far, over one million acres have been preserved through this program, which has garnered the support of a diverse array of citizens, land managers, and state policy-makers.

New Hampshire DOT's Pilot Project for Identifying Habitat Connectivity and Wildlife Crossing Needs

The New Hampshire Department of Transportation (NHDOT) is engaged in a pilot project effort with the New Hampshire Audubon Society, the New Hampshire Fish & Game Department, and others to develop a methodology for predicting wildlife movement in the state. The effort is an outcome of a discussion on how NHDOT and these partners could cooperatively address wildlife and transportation issues. The partners hope to develop a geographic information system (GIS) layer of important wildlife habitat areas and locations of frequent wildlife crossings to be used as a planning and design tool for future projects.

The pilot effort focuses on Route 4, one of the state's major east-west routes. When sections of Route 101 were widened to four lanes, NHDOT extended bridges to improve habitat linkages.

NHDOT is now interested in further increasing the level of connectivity. To this end, NHDOT has contacted Fish & Game Conservation Officers, local road agents, conservation commission members, and NHDOT maintenance patrol foremen to collect anecdotal evidence of crossings and road kills and record that information in a database. In the future, roadkill data will be collected by maintenance staff. Concurrently, the New Hampshire Audubon Society is reviewing mapping of the corridor to identify prospective habitat units, for purposes of predicting where wildlife crossings are likely to occur. The partners will pool efforts to see how well the field data correlates with the mapping predictions. The goal is to develop a predictive model that can be used elsewhere in the State.

To further improve habitat linkages, NHDOT is also supporting efforts to develop an inventory of contiguous habitat areas, to be taken into consideration when siting new alignments, bridge extensions, and crossing locations. The New Hampshire Fish & Game Department has decided that investing in habitat preservation in key areas can be a higher priority than adding or enhancing crossing structures. The New Hampshire Ecological Reserve Project, a partnership between The Nature Conservancy and the University of New Hampshire, is working with the New Hampshire Department of Environmental Services and the Fish & Game Department to develop criteria for the identification of priority conservation parcels. This will generate information that NHDOT can use in planning and project development, and will also guide state investment through the New Hampshire Land and Community Heritage Investment Program.

Maryland SHA's Net Gain Wetland Mitigation Policy & Contribution to Regional Restoration/Connectivity Goals

The Maryland State Highway Administration (SHA) has made a commitment to mitigate for historical impacts to wetlands from transportation projects, with an overall "net gain" wetland mitigation policy. The SHA is working with local jurisdictions and watershed groups around the state to realize watershed goals and restore stream segments, and contribute to the state's green infrastructure at the same time.

Maryland has two million acres of ecologically significant land that has not been developed, of which almost three-quarters are unprotected. The state designated the GreenPrint program to preserve the state's remaining natural resources and to create an extensive, intertwined network of conservation lands. The purpose of the program is threefold:

- Identify, using the most up-to-date computer mapping techniques, the most important unprotected natural lands in the state;
- Link, or connect, these lands through a system of corridors or connectors; and
- Save those lands through targeted acquisitions and easements.

GreenPrint databases and watershed plans are available to Maryland State Highways' planning, environmental, and design staff to reference in avoiding, minimizing, and mitigating for unavoidable impacts from transportation. The State Highway Administration is currently undertaking internal discussions to maximize use of this resource.

MDSHA is contributing to watershed restoration and regional habitat connectivity through 23 separate stream restoration projects across the state, with funding matched by local project sponsors. MDSHA has plans to restore approximately nine miles of streams and install a number of stormwater retrofits to improve water quality and stream habitat over the next three years.

Maintenance and Management of Created, Modified, or Restored Habitat

Most state DOTs try to find a land management agency to provide maintenance for mitigation/conservation habitats. A few have sought to perform mitigation (modification or restoration) on public lands that are already being managed by a resource agency. While some federal resource agencies encourage this approach, others disallow it. Universities, conservation groups, resource agencies, and even private groups where consistent with the objectives of the mitigation have become involved in maintenance of habitat by taking possession or easement of land from the state DOTs. Few transportation departments are maintaining habitat except for wetland mitigation sites, though creative conservation partnerships have been developed in a number of states through in lieu fee arrangements. Texas, Tennessee, Kentucky, North Carolina, and Florida are among the DOTs allowed to provide funding instead of mitigation. Habitat management is frequently the responsibility of the agency or partnering organization holding title to the land or conservation easement.

In most cases, when a state uses a habitat strategy as a conservation or mitigation measure, the maintenance plans for these habitats contain a monitoring requirement. These requirements vary in length and design, but states are often required to maintain sites to varying performance levels (such as a percent survival of desired species and exotic/invasives free) for some period of time (commonly 3 to 5 years). Specific management plans including funding can also be a requirement. Such a monitoring program is designed to:

- Specify recommended mitigation and ensure that it is included in the final design process.
- Monitor the implementation of the mitigation through design, construction, and operation.
- Resolve issues that are contingent on the outcome of design as it progresses to more detailed stages.
- Report on progress toward implementation of mitigation measures to responsible parties.

Biologists from resource and conservation agencies associated with CDOT's Shortgrass Prairie Initiative crafted recommended Baseline/Annual Reporting Requirements that would provide an effective yet practicable framework for adaptive management and annual reporting: (*200*)

- Type of plant communities/habitats present:
- Size/extent of each present plant community or habitat group.
- Description of plant communities present and estimated percent cover.
- General condition of each plant community/habitat type (estimated percent weed cover, estimated weed sp. relative abundance, estimated percent bare ground, etc.).
- Juxtaposition of communities/habitats.
- Brief description of land use on-site and in surrounding areas documented in initial baseline. Report changes over the past year.
- Recommendations for management of parcel (i.e., grazing, controlled burns, plantings, etc.) to achieve conservation goals.
- Success of recommendations from previous year and suggested modifications.
- Observations on wildlife diversity, activity, and general trends. i.e. field notes. Surveys and quantitative data are not required.

- Photo points at established permanent locations according to protocols to be developed in the management plan. The on-site managers and regulatory oversight agreed that new aerial photos would be acquired as they become available.

3.5. CULVERTS AND FISH PASSAGE

As long linear ecosystems, rivers and streams are particularly vulnerable to fragmentation. A number of human activities can disrupt the continuity of river and stream ecosystems, the most familiar of which are dams. There is growing concern about the role of road crossings – and especially culverts – in altering habitats and disrupting river and stream continuity.(*201*) On U.S. Forest Service and Bureau of Land Management land in Washington and Oregon alone, there are over 10,000 culverts on fish-bearing streams.(*202*) Based on an estimate from GIS analysis over 28,500 road and railroad crossings affect Massachusetts streams.(*203*)(*204*) Over half of the culverts assessed on U.S. Forest Service and Bureau of Land Management (BLM) lands in Oregon and Washington are considered barriers to juvenile salmonid fish passage.(*205*) Fish habitat and fish passage improvement projects undertaken by DOTs include installation of baffles or weirs in culverts, construction of berms or detention facilities, and installation of deck curbs, new culverts or jump pools for fish passage.

Forms of Stream Crossings

Stream crossing methods include bridges, fords, open-bottom or arch culverts, box culverts, and pipe culverts. Depending on the type of crossing, its size, method of installation, and maintenance, a road crossing may have many or relatively few adverse impacts on a river or stream ecosystem. It is generally believed that culverts are more detrimental to streams than are bridges; consequently, wildlife regulatory agency biologists routinely recommend installation of a bridge instead of a culvert. Culverts, however, are more economical than bridges; they often cost less to install, require less maintenance, and have a longer effective life. Culvert crossings tend to provide very little or no habitat within the culvert. Some habitat can be provided if the culvert is sufficiently embedded such that the substrate in the culvert resembles the natural streambed. Open-bottom or arch culverts and bridge crossings often maintain natural streambeds, although some habitat may be lost to footings, piers, and abutments.(*206*)

Resource agencies often prefer that structure types should be considered for use in the following order of preference: (*207*)

- Bridge (with no approach embankment into the main channel).
- Streambed simulation strategies using a Bottomless Arch or embedded culvert designs.
- Streambed simulation strategies using embedded round metal or concrete box culvert designs.
- Non-embedded culvert; placed at less than 0.5 percent slope.
- Baffled culvert (various designs); placed at 0.5 percent to 12 percent slope or a structure with a fishway.

NCDOT hypothesized that the impact of culverts on the stream bed is not uniform, but varies due to its design, and size and site specific factors and that construction and renovation practices may be refined to minimize the impact of crossing structures on surface waters and achieve a delicate balance between construction and maintenance costs and ecosystem integrity.

Consequently, NCDOT is undertaking research, due in late 2005, that will compare the relative impact of culverts and bridges, and specific design attributes on freshwater mussel populations, in the interests of refining standard culvert designs to be more environmentally beneficial and acceptable to wildlife agency biologists.(*208*)

Providing for larger structures that mimic natural streambeds requires a greater capital investment, but the return on such an investment can be accrued over the long term with reduced maintenance and/or replacement costs.(*209*)

Potential Adverse Impacts of River and Stream Crossings

If not properly designed, crossing structures can block animal movements, delay migration (a process made worse where there are many crossings), and cause physiological stress as animals expend energy passing both natural and artificial obstacles. If crossing structures are not large enough, or lack banks or other dry passage, riparian wildlife may choose to cross over the road surface rather than pass through the structure. As barriers to animal movement, stream crossings for roads can reduce access to vital habitats. To the extent that road crossings act as barriers to animal passage, they can fragment and isolate populations, increasing vulnerability to genetic change and extinction due to chance events. Local extinctions can result from demographic chance events (e.g., change in sex ratio), natural disturbances, or human impacts. Barriers to movement can block the exchange of individuals among populations, eliminating gene flow and disrupting the ability of "source" populations to support declining populations nearby. Barriers to dispersing individuals also eliminate opportunities to re-colonize vacant habitat after local extinction events.

Culvert and embankment fill can cover up fish habitat on channel beds and banks. Flow concentration can raise velocities and increase erosion and sediment production and downstream deposition in the stream, increased slopes and flow velocities can block fish passage, and long culverts can discourage fish from entering if no light can be seen at the opposite end. Improper design or scour can result in a perched culvert which blocks fish passage.

Potential adverse effects of river and stream crossings that should be considered ineffective design for fish and wildlife include: (*210*)

- Habitat Loss and Degradation
- Alteration of Ecological Processes, including passage of large woody debris
- Inlet or outlet drop. Elevation drops at either the inlet or outlet of a crossing structure can represent physical barriers to many animal species. Piping (water flowing through the fill material rather than the culvert) and scouring can result in culverts that are perched above the stream channel making passage impossible for most aquatic species.
- Physical barriers. Animal movement can be blocked by clogged or collapsed culverts. Also, weirs or baffles associated with crossing structures can create barriers for some species.
- Excessive water velocities. Water velocities can be too high to pass fish or other organisms during some or all of the year.
- Absence of bank-edge areas. Passage by weak-swimming organisms can be inhibited or prevented by the absence of bank-edge areas within crossing structures.

- Excessive turbulence. Flow contraction at the inlet can create turbulence that inhibits or prevents animal passage.
- Insufficient water depth. Absence of a low-flow channel can result in water depths too shallow to allow passage for fish or other organisms.
- Discontinuity of channel substrate. Crossing structures that lack any natural substrate or contain substrates (including riprap or other armoring) that contrast with the natural stream channel create discontinuities in streambed habitats. Many benthic (streambed-dwelling) organisms are confined to the streambed and can only move through appropriate substrates. Streambed discontinuities caused by crossing structures disrupt and fragment populations of these benthic organisms.

Stream Crossing Design Considerations

Collecting Adequate Survey Information

Adequate survey information should be collected, to help ensure proper design and avoid costly mistakes:(*211*)

- *The original site survey* should have at least three durable reference points for location of all other site features and establishing additional references. Remote projects that are surveyed, then delayed for years, may lose reference points to vandalism, storm events or road maintenance activity. Site topography may also change, especially in stream channels due to flood events. Lost references have to be replaced. Existing culvert inverts and drill holes can be useful project references.
- *Preconstruction Survey.* An early review of project plans in the field with the contract administrators and designers can help prevent surprises later on by answering specific questions and verifying that the design still fits if some site changes have occurred.
    - Enough references and data points should be surveyed to be able to locate the structure and reestablish the road surface and embankment geometry.
    - Assure the road surface is adequately described by existing survey information; otherwise, survey additional points to assure that super elevation, vertical curves, curve widening, or any other critical geometric elements can be reestablished. A straight road segment is easy to recreate with a minimum of survey data, but others such as a super-elevated “S” curve are not.
    - Examine site plans and design elevations carefully. The project site may not seem to match the site plan or stream profile. If survey points near the existing or new structure are not marked and the channel is very rough, this may lead to confusion and uncertainty as to design elevations and assumptions. A stream classification system may be helpful in describing channel conditions. This could be due to the software used to generate the contour map. Rough channels can be confusing unless it is known exactly what points were surveyed in the channel. The “stream channel elevation” used to design the new structure invert can vary a foot or even more depending on where the survey rod was placed originally. Was it held on top of a boulder or between boulders? Are boulders dominant? Do they seem to define elevation more than the spaces between boulders? Some additional surveying may be needed. The designer and administrator should communicate

and verify design assumptions on the ground and during the contract as necessary to reduce potential questions such as these, and to prevent inappropriate "last minute" changes during construction. This is especially important when the decision affects the new structure elevation, orientation or gradient. Confusion may arise during construction surveys over contract drawings, survey points, elevations and design assumptions.

Designing for Target Species

When designing fish passage facilities, species of fish present, life stages to be impacted, and the migration timing of affected species/life stages should be considered. For example, in looking at non-anadromous trout in Virginia, researchers determined that culverts can be the best way to cross trout streams in Virginia, provided certain actions are taken. (*212*)

- The culvert should be on the same slope as the streambed.
- The slope of the stream should be less than 3 percent.
- The flow velocity should not exceed 1.2 meters (4 feet) per second under normal flow conditions.
- The culvert barrel should be properly countersunk at the outlet.
- In addition, newly installed culverts should not use baffles to control stream flow, and concrete aprons should not be used at culvert outlets.
- If these actions are not possible or feasible, then bridges should be constructed.

While in this case design is simplified by focus on one species, passage design for multiple species is normally based on the weakest species or life stage present that requires upstream access and should accommodate the weakest individual within that group. For fish, swimming ability is highly variable among species. While information exists on the swimming ability of stronger, migratory fish species, very little is known about the remaining. Even less is known about the swimming abilities of non-fish species that inhabit rivers and streams,(*213*) including aquatic salamanders, softshell and musk turtles, aquatic reptiles that rarely travel over land and are not strong swimmers (relative to migratory fish), though movement and population continuity is essential to the survival of their populations.(*214*) As a group the most vulnerable animal species in the U.S. are freshwater mussels. Over 70 percent of the 297 species native to the U.S. and Canada are endangered, threatened or of special concern.(*215*) Although adult mussels have a very limited capacity for movement, dispersal typically occurs when larvae (glochidia) attached themselves to host fish or salamanders. Therefore, survival and persistence of freshwater mussel populations is dependent on the capacity of host fish usually small, sedentary, and weak swimming, and therefore, highly vulnerable to movement barriers.(*216*) Many weak swimmers and crawling species take advantage of boundary zones along bank edges and the stream bottom where water velocities are much lower than in the water column. In addition to aquatic organisms, rivers and streams are used as travel corridors by riparian wildlife. To address these issues,

- Maintenance of unfragmented stream bottom and bank edge habitats is the best strategy for maintaining continuous and interconnected populations for these species. (*217*)

Avoiding Channel Constriction

Channel constriction is often evident from undersized culverts. Channel constriction results in increased water velocity within and exiting the structure, creating a barrier to upstream fish passage. Where the streambed is not composed of bedrock or properly aproned with riprap, streambed elevation can be reduced. Sometimes this reduction is in the form of a pool and does not alter the ability of fish to enter the culvert. More commonly the culvert outlet becomes "perched" above the lowered streambed, creating a barrier to the upstream migration of smaller, less aggressive swimming fish. The effects of increased water velocity due to channel constriction can also be compounded as a result of excessively high culvert gradient and/or flow augmentation via ditch lines with improper road drainage. To avoid channel constriction, the following stewardship practices are recommended: (*218*)

- Design and install road crossing structures that allow bankfull events to flow unimpeded. This requires larger culverts or alternative structures.
- Where channel gradients exceed 2 percent, design structures for the upstream passage of fish, imitating natural roughness inside culverts.

Energy Dissipation at Culvert Exits

Energy dissipation at box culvert outlets is important for reducing harmful impacts to the receiving channel and for minimizing soil loss through scour and erosion. Dissipaters include riprap, vegetated ditches, concrete or steel baffles, and tiger teeth. Debris racks should be installed only when regular maintenance is possible. Raised culvert inlets are raised by constructing a dike around the culvert, or by installing a culvert elbow. They keep water on the land longer and promote infiltration. These inlets increase vegetation vigor and diversity, reduce flash flooding, create sediment barriers, and raise water tables.

Currently the only options available to roadway designers are riprap basins or rigid concrete structures requiring significant additional costs for concrete and steel and right-of-way. The Nebraska Department of Roads is evaluating three different low-cost energy dissipating methods for concrete box culverts: a sill wall placed in the downstream apron of the box culvert, a vertical drop structure with stilling pool or sill, and the feasibility of using concrete forms to increase the hydraulic roughness of the interior walls and floor of a concrete box. Research results will be due in early 2005.(*219*)

Other Hydraulic Considerations

Primary hydraulic considerations include the upper and lower flow limit. In general:

- Acceptable hydraulic design of culverts includes selection of appropriate design flow from which the flow characteristics can be derived by hydraulic analysis. The low flow depth design should be based on the 2-year, 7-consecutive-day low flow discharge or the 95 percent exceedence flow for the migration period of the fish species of concern.
- The high flow design discharge should be the flow that is not exceeded more than 10 percent ($Q_{10\ percent}$) of the time during the months of adult migration.

Besides the upper and lower flow limit, other hydraulic effects need to be considered, particularly when installing a culvert:

- Water surface elevations in the stream reach must exhibit gradual flow transitions, both upstream and downstream. Abrupt changes in water surface and velocities must be avoided, with no hydraulic jumps, turbulence, or drawdown at the entrance. A continuous low flow channel must be maintained throughout the entire stream reach.

- In addition, especially in retrofits, hydraulic controls may be necessary to provide resting pools, concentrate low flows, prevent erosion of stream bed or banks, and allow passage of bedload material.
- Culverts and other structures should be aligned with the stream, with no abrupt changes in flow direction upstream or downstream of the crossing. This can often be accommodated by changes in road alignment or slight elongation of the culvert. Where elongation would be excessive, this must be weighed against better crossing alignment and/or modified transition sections upstream and downstream of the crossing. In crossings that are unusually long compared to streambed width, natural sinuosity of the stream will be lost and sediment transport problems may occur even if the slopes remain constant. Such problems should be anticipated and mitigated in the project design.

Fish passage should be designed to be adequate for high and low discharge. When that cannot be accommodated, mitigation may be required.

Mitigating Fish Passage Effects through Culvert Design Modifications

To mitigate the effects of culverts on fish passage, methods in order of preference, are: (*220*)

- Modify culvert design
- Depress invert culverts
- Replicate natural streams
- Use baffled culverts

There are several alternatives for modifying a standard culvert design to satisfy fish passage requirements. Design options may vary as long as fish passage criteria can be met. Any culvert design should be thoroughly reviewed by a professional engineer to ensure that both fish passage and flood conveyance criteria are satisfied.

The following is a representative list of possible modification options. (*221*)

- **Culvert size.** Culvert size may be increased to decrease water velocity.
- **Culvert shape.** A different culvert shape (e.g., ellipse, culvert arch, or box culvert) may be chosen to achieve fish passage requirements.
- **Invert level.** The invert level at an inlet or outlet is very important for managing flow effects at contractions (inlets), expansions (outlets), and flow regime in a culvert barrel. Invert levels affect habitat upstream and downstream of culverts. Lowering the invert may be necessary to allow the placement of natural substrate on the culvert bottom. Care should be taken to ensure a stable channel upstream and downstream of the culvert because erosion due to increased flow velocities can progress in both directions and create barriers to fish passage.
- **Roughness.** Changes in culvert roughness may effectively decrease water velocities to acceptable levels. For example, corrugated circular culverts can be chosen with large, helical corrugations to provide greater overall roughness and provide for a larger low flow water depth suitable for fish. Concrete box culverts can be modified by using

oversized aggregate or grouted riprap. The addition of energy dissipaters can control the hydraulic regime and thereby reduce velocities.

- **Grade Control.** Artificial resting areas upstream or downstream of a culvert can mitigate many adverse conditions in the culvert barrel and at the inlet or outlet. Weirs or sills downstream of a culvert can be used to maintain adequate water depth and prevent scouring of a plunge pool. An upstream resting pool can trap sediment while allowing recuperation time for 7-10 migrants. Combined with proper instream cover, culverts may provide migrants some protection against predators.

Measures for Non-Embedded Culverts

Fish passage through existing non-embedded culverts may be improved through the use of gradient control weirs upstream or downstream of the culvert, interior baffles or weirs, or in some cases, fish ladders. While these measures are not a substituted for good fish passage design for new or replacement culverts, the following guidelines can be adapted for target species and local conditions: (*222*)

- **Hydraulic Controls -** Hydraulic controls in the channel upstream and/or downstream of a culvert can be used to provide a continuous low flow path through culvert and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions: Control depth and water velocity within culvert, concentrate low flows, provide resting pools upstream and downstream of culvert and prevent erosion of bed and banks.
- **Baffles** - Baffles may provide incremental fish passage improvement in culverts with excess hydraulic capacity that can not be made passable by other means. Baffles may increase clogging and debris accumulation within the culvert and require special design considerations specific to the baffle type. Culverts that are too long or too high in gradient require resting pools, or other forms of velocity refuge spaced at increments along the culvert length.
- **Fishways** - Fishways are generally not recommended, but may be useful for some situations where excessive drops occur at the culvert outlet. Fishways require specialized site-specific design for each installation and resource agency specialists should be consulted.
- **Multiple Culverts** - Retrofitting multiple barrel culverts with baffles in one of the barrels may be sufficient as long as low flow channel continuity is maintained and the culvert is reachable by fish at low stream flow. Additional culverts may be used to improve conveyance conditions for fish passage. For example, box culverts can be separated into multiple sections where part of the flow enters a plain section, and part of the flow is carried through a baffled section. Multiple culverts can also be "stacked" by placing the inverts at different elevations to provide sufficient fish passage conditions at different stream stages. However, the effectiveness of these types of solutions is questionable, because fish need to choose which section or culvert to enter. Fish have been observed choosing the culvert with the most flow and highest velocity; consequently, one large culvert may be preferable to two or more smaller ones. In general, it is better for fish passage to use fewer culverts.(*223*)

Other General Recommendations

- Trash racks and livestock fences should not be used near the culvert inlet. Accumulated debris may lead to severely restricted fish passage, and potential injuries to fish. Where fencing cannot be avoided, it should be removed during upstream migration periods. Otherwise, a minimum of 9 inches clear spacing should be provided between pickets, up to the high flow water surface. Timely clearing of debris is also important, even if flow is getting around the fencing.(*224*)
- Cattle fences that rise with increasing flow are highly recommended.(*225*)
- Natural or artificial supplemental lighting should be provided in new and replacement culverts that are over 150 feet in length. Where supplemental lighting is required the spacing between light sources shall not exceed 75 feet.(*226*)
- Comply with in-stream work windows in each watershed. Work in the active stream channel should be avoided during the times of year target species are present. Temporary crossings, placed in streams for water diversion during construction activities, should meet environmental stewardship guidelines or BMPs.

Design Methods for New and Replacement Culverts

High water velocity, shallow water depth within the culvert, excessive vertical drop at the culvert outlet and debris blockages are the most frequent causes of fish passage problems at culverts. These design methods can help prevent some of these problems: (*227*)

Active Channel Design Method

The Active Channel Design method is a simplified design that is intended to size a culvert sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable bed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this method since the stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing. This design method is usually not suitable for stream channels that are greater than 3 percent in natural slope or for culvert lengths greater than 100 ft.

Structures for this design method are typical round, oval, or squashed pipes made of metal or reinforced concrete.

- *Culvert Width* - The minimum culvert width should be equal to, or greater than, 1.5 times the active channel width.
- *Culvert Slope* - The culvert should be placed level (0 percent slope).
- *Embedment* - The bottom of the culvert should be buried into the streambed not less than 20 percent of the culvert height at the outlet and not more than 40 percent of the culvert height at the inlet.

Stream Simulation Design Method

The Stream Simulation Design method is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the culvert are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing.

This approach to culvert design both avoids flow constriction during normal conditions and creates a stream channel within culverts that resists scouring during flood events.(*228*) Since the streambed longitudinal profile and cross section in the pipe are similar to the natural channel, water velocities and depths at flows up to bankfull are also similar, and the crossing should be essentially invisible to migrating aquatic organisms.

Culverts designed for stream simulation are sized wide enough to include either channel margins or banks. The most basic stream simulation culvert is a bottomless culvert placed over a natural streambed. Other culverts are filled with a sediment mix that emulates the natural channel and adjusts similarly during most flows. In steep channels, the bed may be designed to resist erosion during very large floods.(*229*)These culverts contain a streambed mixture that is similar to the adjacent stream channel.

Stream simulation culverts require a greater level of information on hydrology and geomorphology (topography of the stream channel) and a higher level of engineering expertise than the Active Channel Design method.

- *Culvert Width* - The minimum culvert width should be equal to, or greater than, the bankfull channel width. The minimum culvert width shall not be less than 6 feet.
- *Culvert Slope* - The culvert slope shall approximate the slope of the stream through the reach in which it is being placed. The maximum slope shall not exceed 6 percent.
- *Embedment* - The bottom of the culvert should be buried into the streambed not less than 30 percent and not more than 50 percent of the culvert height. For bottomless culverts the footings or foundation should be designed for the largest anticipated scour depth.

Certain channel features cannot be duplicated directly or can be simulated only partially in a culvert. Examples include channel-spanning wood, embedded wood, bank vegetation, cohesive bank stability, debris jams and rigid bed forms. Bank vegetation stabilizes most natural streambanks. Large wood that spans the channel provides roughness and complexity, as do bedrock exposures and other rigid bedforms. Debris embedded in the natural channel may anchor bed material and in some cases control all of the elevation change. Bank vegetation cannot grow inside a pipe; trees will not fall into them; and large, woody debris is difficult and risky to install. While vegetation and large wood are often critical to channel stability, it is usually possible to replace these functions with large rock to create a stable streambed inside a pipe. (*230*)

It is essential to understand what stream functions are critical at a site, as well as the consequences to the stream of placing a culvert and interrupting them to some degree. Riparian functions such as overbank flooding, side channel construction, and nutrient and debris exchange between stream and floodplain are not simulated within the culvert. The impact of floodplain contraction on up- and downstream floodplains may be reduced with a larger culvert, additional culverts in the floodplain, and/or overflow dips in the road. At any given flow, slope is an important factor affecting water velocity in culverts. Culvert size also affects velocities, especially when a structure is considerably undersized and a head (pooling above culvert) is developed. (*231*)

- If any of these functions cannot be adequately simulated by the design, other road alignments and/or crossing structures should be considered.

- Gradients (slope) for non-embedded, non-baffled culverts should not exceed 0.5 percent unless a tailwater situation exists to backwater the culvert to a suitable depth for its length. Properly baffled or weired culverts are appropriate for steeper gradients depending on design. Structures with fishways (i.e., fish ladders or culverts with weir-type baffles) generally will be required where culvert gradients exceed 5 percent and streambed simulation is not employed.
- Corrugated metal culverts should generally be used over smooth-surfaced culverts. Deep corrugations are preferred over shallow corrugations.
- Bottomless arches and all styles of embedded culverts should be placed at or near the same gradient as the natural streambed and should be at least as wide as the active stream channel (i.e., no lateral encroachment on the active stream channel). All embedded culverts (round or arch) must be embedded one foot deep or at least 20 percent of its height, whichever is more.
- When deciding between bottomless arch and embedded culvert designs, the primary consideration is foundation substrate. If considerable bedrock is present, an open bottom arch is generally the appropriate choice; embedding a culvert would require extensive excavation. Where deep unconsolidated gravel and cobble is present, failure (undermining) of a bottomless arch foundation is a major concern.
- Hydraulic controls may be required to 1) improve culvert entrance and exit conditions (e.g. using a beveled inlet configuration; providing resting pools at culvert entrance and exit), 2) concentrate low flows, 3) prevent erosion of stream bed and banks, or 4) allow passage of bedload material. The need for, and design of, these project features should be developed in consultation with the resource agency.
- If water-crossing structures are placed in spawning areas, they should incorporate mitigation measures, as necessary, to achieve no-net-loss of spawning area.
- Trash racks are discouraged at culvert inlets, but if necessary, these should be installed only above the high passage flow water level.

Hydraulic Design Method

The Hydraulic Design method is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. This method targets distinct species of fish and therefore does not account for ecosystem requirements of non-target species. There are significant errors associated with estimation of hydrology and fish swimming speeds that are resolved by making conservative assumptions in the design process. Determination of high and low fish passage design flows, water velocity, and water depth are required for this option.

The Hydraulic Design method requires hydrologic data analysis, open channel flow hydraulic calculations, and information on the swimming ability and behavior of the target group of fish. This design method can be applied to the design of new and replacement culverts and can be used to evaluate the effectiveness of retrofits of existing culverts.

- *Culvert Width* **-** The minimum culvert width should be 3 feet.

- *Culvert Slope* **-** The culvert slope shall not exceed the slope of the stream through the reach in which it is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5 percent.
- *Embedment* - Where physically possible, the bottom of the culvert should be buried into the streambed a minimum of 20 percent of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified above.
- *High Fish Passage Design Flow* - The high design flow for adult fish passage is used to determine the maximum water velocity within the culvert.
- *Low Fish Passage Design Flow* - The low design flow for fish passage is used to determine the minimum depth of water within a culvert.
- *Maximum Hydraulic Drop* - Hydraulic drops between the water surface in the culvert and the water surface in the adjacent channel should be avoided for all cases. This includes the culvert inlet and outlet. Where a hydraulic drop is unavoidable, its magnitude should be evaluated for both high design flow and low design flow and shall not exceed 1 foot for adults or 6 inches for juveniles. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth should be provided.

Structural Design and Flood Capacity

All culvert stream crossings, regardless of the design option used, should be designed to withstand the 100-year peak flood flow without structural damage to the crossing. The analysis of the structural integrity of the crossing should take into consideration the debris loading likely to be encountered during flooding. Stream crossings or culverts located in areas where there is significant risk of inlet plugging by flood borne debris should be designed to pass the 100-year peak flood without exceeding the top of the culvert inlet (Headwater-to-Diameter Ratio less than one). This is to ensure a low risk of channel degradation, stream diversion, and failure over the life span of the crossing. Hydraulic capacity must be compensated for expected deposition in the culvert bottom.

Culvert Evaluation for Fish Passage and Ranking for Remediation Efforts

Various methods for fish habitat and passage evaluation have been developed. The following sample ranking method assigns scores or values for the following five parameters: (*232*)

1. *Species Diversity* - Number of target species currently present (or historically present which could be restored) within the stream reach at each crossing location. Score - For each federally or state listed salmonid species; Endangered = 4 points; Threatened or Candidate = 2 points; not listed = 1 point. Consult state resource agency or NOAA for historic species distribution and listing status information.
2. *Extent of Barrier* - Over the range of estimated migration flows, assign one of the following values from the "percent passable" results generated with *FishXing*. GREEN crossings are considered 100 percent passable for all fish, while RED crossings are considered 0 percent passable for all fish. Do this for adult anadromous, resident, and target species for each culvert. Score - 0 = 80 percent or greater passable; 1 = 79-60 percent passable; 2 = 59-40 percent passable; 3 = 39-20 percent passable; 4 = 19 percent

or less passable; 5 = 0 percent passable (RED). For a total score, sum the values for all three.

3. *Habitat Value* - Multiply habitat quantity score by habitat quality score. Habitat Quantity - Above each crossing, length in feet to a sustained 8 percent gradient or field identified limit of anadromy. Score: 0.5 points for each 500 feet of stream (example: 0.5 points for <500N; 1 point for 1,000N; 2 points for 2,000N; and 5.5 points for 5,500N). The maximum possible score for Habitat Quantity is 10.
4. *Habitat Quality* - For each stream, assign a score of quality after reviewing available habitat information. Consultation with local state resource agency biologists to assist in assigning habitat quality score is recommended. Score: 1.0 = Excellent - Relatively undeveloped, with pristine watershed conditions. Habitat features include dense riparian zones with mix of mature native species, frequent pools, high-quality spawning areas, cool summer water temperatures, complex instream habitat, floodplain relatively intact. 0.75 = Good - Habitat is mostly intact but erosional processes or other factors have altered the watershed with a likelihood of continued occurrence. Habitat includes dense riparian zones of native species, frequent pools, spawning gravels, cool summer water temperatures, complex instream habitat, floodplain relatively intact. 0.5 = Fair - Erosional processes or other factors have altered the watershed with negative affects on watershed processes and features, with the likelihood of continued occurrence. Indicators include: a) riparian zone lacking mature conifers, b) infrequent pools, c) sedimentation evident in spawning areas (embeddedness ratings of 3), d) summer water temperatures periodically exceed stressful levels for target species, e) sparse instream complex habitat, and floodplain intact or slightly modified. 0.25 = Poor - Erosional processes or other factors have significantly altered the watershed. There is a high likelihood of increased erosion and apparent effects to watershed processes. Habitat impacts include riparian zones absent or severely degraded, little or no pool habitat, excessive sedimentation evident in spawning areas (embeddedness ratings of 4), stressful to lethal summer water temperatures common, lack of instream habitat, floodplain severely modified with levees, riprap, and/or residential or commercial development.
5. *Sizing* (*risk of failure*) - For each crossing, assign one of the following values as related to flow capacity. Score: 0 = sized for at least a 100-year flow, low risk; 1 = sized for at least a 50-year flow, low/moderate risk; 2 = sized for at least a 25-year flow, moderate risk of failure; 3 = sized for at least a 10-year flow, moderate/high risk of failure; 4 = sized for less than a 10-year flow, high risk of failure; 5 = sized for less than a 5-year flow, extreme risk of failure.
6. *Current Condition* - For each crossing, assign one of the following values. Score: 0 = good condition; 1 = fair, showing signs of wear; 3 = poor, floor rusting through, crushed by roadbase, etc.; 4 = extremely poor, floor rotted-out, severely crushed, damaged inlets, collapsing wingwalls, slumping roadbase, etc.

For each stream crossing, enter criteria values into a spreadsheet, sum the ranking criteria values, and compute the total scores. Then sort the list of crossings by total scores to determine a first-cut ranking for the project area. The results of the ranking matrix provide a rough, first-cut evaluation. There are other important factors that should be considered when deciding the exact scheduling of remediation efforts. The following list provides guidance that should assist in rearranging the first-cut ranking. On a site-specific basis, some or all of these factors should be considered:

- *Presence or absence of other stream crossings* - In many cases, a single stream may be crossed by multiple roads. If migration barriers exist at multiple stream crossings, a coordinated effort is required to identify and treat them in a logical manner, generally in an upstream direction starting with the lowest crossing in the stream.
- *Fish observations at crossings* - Sites where fish are observed holding during migration periods should receive high consideration for remediation. Identify the species present, count the number of fish, and record failed versus successful passage attempts. Consider the potential for predation and/or poaching. Sites with holding fish are areas where immediate recolonization of upstream habitat is likely to occur.
- *Amount of road fill* - At stream crossings that are undersized and/or in poor condition, consider the volume of fill material within the road prism. This is material which is directly deliverable to the stream channel if the crossing were to fail. Also determine if there is a potential for water to divert down the road if the crossings capacity is overwhelmed.
- *Remediation project cost* - The range of treatment options and associated costs must be examined when determining the order in which to proceed. In cases where federal or state listed fish species are present, costs must be weighed against the consequences of not providing unimpeded passage.
- *Opportunity* - Road managers should consider upgrading all migration barriers during road maintenance activities. The ongoing costs of maintaining an undersized or improperly installed culvert may exceed the cost of replacing it with a properly sized and installed crossing. When undersized or older crossings fail during storms, road managers should be prepared to install properly-sized crossings that provide unimpeded passage for all species and life stages of fish.

DOT Practice and Design Guidance for Culvert Installation, Design, and Prioritization for Fish Passage

The following state agency links contain installation guidance and stewardship practices for the listed culvert and stream crossing measures. Practices cover the designs, construction and maintenance of both temporary and permanent stream crossings, including culverts:

- Culvert Pipe with Access Road, MD
- Culvert Installation, MD
- Multi-Cell Culverts, MD
- Depressed Culverts, MD
- Pipe/Culvert Extensions, NCDOT, p. 22
- Pipe/Culvert Installation, NCDOT, p. 26
- Streambed Gravel, WA, p. 146
- Culvert Baffles, MD

Several DOTs have developed programmatic approaches to Fish Passage improvements, as detailed below.

Alaska Programmatic Agreement for Fish Passage Improvements

The Alaska Department of Transportation and Public Facilities (ADOT and PF)and the Alaska Department of Fish & Game(ADF&G) developed a Memorandum of Agreement (MOA), signed in August 2001, to improve fish passage through culverts and to streamline the review process for the increasing number of fish habitat permits processed annually for culvert work. The MOA is the result of more than 15 years of fish passage research by state agencies and the University of Alaska Fairbanks, in addition to extensive discussions with fish and wildlife and transportation counterparts in Washington and Oregon State, the Federal Forest Service, and the National Marine Fisheries Service (now NOAA Fisheries). Prior to development of the MOA, permitting decisions were often ad hoc, resulting in inconsistencies, unpredictability, and unnecessary tension and conflict in the permitting process. Now, the MOA provides a consistent, state-wide basis for evaluating and approving culvert structures.

Alaska's Memorandum of Agreement (MOA) applies to both new culvert installation and reinstallation of culverts during maintenance activities, where the ADF&G and/or the ADOT&PF have determined that culverts are the appropriate structure. Key to the agreement is a tiered approach to the culvert design. The level of information necessary for the permit depends on the "Tier." Opting for Tier 1 requires simulation of a natural stream, but requires minimal interagency design review and permitting paperwork and leads to faster approvals. Under the MOA, ADOT&PF's senior Regional Hydraulic Engineer reviews all proposed fish passage structures, including those proposed by Maintenance and Operations, for compliance with the design criteria contained in the MOA. ADF&G provides relevant information early in the design process, and if additional information from ADOT&PF is needed, requests such in a timely manner and in a consolidated form. The MOA also provides ADF&G reasonable opportunity to inspect culverts in the field and to review "as-built" plans prior to project shutdown, demobilization, or release of the contractor(s), in order to ensure that all culverts are installed in accordance with permit terms and conditions.

ADF&G and Alaska Department of Transportation and Public Facilities ADOT&PF believe the agreement is leading to more timely approval of permit applications for culvert installations, as well as improved passage for anadromous and resident fish populations through drainage structures, when migrating to spawning, rearing and over-wintering grounds. As their agreement represents current knowledge and state of the practice, ADF&G and ADOT&PF will meet annually to review the MOA and to amend it appropriately to accommodate new information and proven fish passage techniques.

Maine DOT's Fish Passage Policy and Design Guide

In early 2002, the Maine Department of Transportation (MDOT) issued guidance establishing a policy, process, and design guide for fish passage at MDOT projects with water-crossing structures such as bridges, struts, culverts, pipes, or pipe arches. In the past, case-by-case evaluation of crossings and the associated regulatory approvals added unpredictability to project timelines and budgets. The new guidance establishes consistent expectations and procedures, facilitating planning and budget estimation.

To reach agreement on how best to achieve interagency goals, representatives from MDOT and resource agencies met over several months to discuss the issues involved with fish passage and establish a protocol considering the need for passage and the feasibility of improvement, given site conditions and other potentially limiting factors. The team developed guidance that provide a framework and tools to evaluate crossing projects by balancing a variety of needs at a site (including regulatory requirements and resource needs) while delivering safe, cost effective, and timely projects.

When examining whether fish passage and associated habitat issues are compatible with new stream crossing structures or improvements to existing structures, Maine MDOT considers the following goals:

- Maintain or replicate natural stream channel or flow conditions, as appropriate.
- Pass peak flows in accordance with MDOT drainage policy.
- Comply with existing regulations on passing fish.
- Consider potential impacts to rights-of-way, utilities and traffic.
- Meet appropriate standards and safety requirements.
- Provide reasonable life cycle costs.
- Consider the least environmentally damaging solutions.

In addition to including a clear protocol for the nature and timing of agency coordination, the new guidance facilitates MDOT use of new and developing technologies. Currently MDOT addresses deficient culverts by rehabilitating a culvert through insertion of a smaller diameter pipe inside the existing culvert, placing a concrete lining at the inverts or throughout the entire length, or by replacing the culvert. This rehabilitation allows a culvert to be repaired in place, usually with less streambed disturbance and lower project cost than replacement would entail.

Oregon DOT Culvert Retrofit and Replacement Program Agreement

In 2001, the Oregon Department of Transportation (ODOT) and the state Department of Fish and Wildlife (ODFW) signed a Memorandum of Understanding (MOU) acknowledging that repairing or modifying ODOT-maintained culverts is a priority for the agencies that will take decades to resolve. The Oregon Department of Fish and Wildlife completed culvert inventories for the entire state of Oregon in 1999 and found that 96 percent of the barriers identified were culverts associated with road crossings. The project also identified high priority culverts for fish passage remediation.

ODOT has an ongoing program of culvert installation and maintenance, with the goal of making all ODOT culverts passable to fish. After research monitoring results demonstrated the effectiveness of baffle and weir designs in culverts, ODOT modified their culvert replacement programs to use these designs, significantly reducing the cost of improving fish passage at ODOT culverts. The designs improve fish passage by slowing water velocity and raising stream elevations to reduce entry jump heights or backwater culvert outlets. Use of retrofit designs are allowing culverts that are otherwise in good physical condition to be retrofitted until their service integrity is compromised, at which time they will be replaced with designs that more fully meet fish passage criteria and standards. Use of retrofits will thus allow many more culverts to be remediated each year, increasing the scope and pace of ODOT's contribution to salmon recovery in Oregon. The baffle and weir retrofits also provide ODOT an alternative to fish ladders, which have become increasingly problematic for ODOT from a maintenance standpoint.

According to the MOU, ODOT will continue internal education regarding the needs and requirement of fish passage, and prioritize its resources and culvert modification needs on an annual basis, demonstrating good faith in addressing culvert passage problems. On replacement culvert projects, ODOT will strive to simulate a natural stream and will determine if changes in culverts result in flows detrimental to fish passage. ODFW is supporting ODOT's efforts by providing the master inventory of culverts that do not provide adequate passage, along with technical assistance on educational activities, design, and construction techniques.

WSDOT Fish Passage Improvements on a System and Project-by-Project Basis

WSDOT is trying to tailor transportation investments in restoration and mitigation to mesh with state and community watershed restoration and enhancement goals. To that end, WSDOT has been pursuing watershed characterization research to better understand how watersheds store water naturally (e.g., wetlands, riparian areas, floodplains) and then identify where land use has resulted in the loss of natural storage capacity. So far, the agency has found that investments in watersheds with lower areas of impervious surface may yield greater marginal benefits than mitigation sited close to impact areas. Hence, WSDOT has directed mitigation investments to restoring natural, self-maintaining systems that provide many other valuable watershed functions such as groundwater recharge, water quality treatment and fish and wildlife habitat, along with aesthetic, recreational, and educational values to residents.

WSDOT's watershed approach aims to direct transportation mitigation and conservation dollars toward high priority watershed needs, including recovery of native fish species. Access to good quality habitat is a key factor in the recovery of listed salmon stocks and culverts can create fish passage barriers that fragment habitat. Common problems with older culverts include high water velocity, inadequate water depth, and large culvert outfall drops. Once these problems are corrected, the benefits to fish habitat are real and immediate; in many cases, fish have been observed upstream of improved culverts within weeks of restoring access.

WSDOT's environmental procedures manual describes their environmental retrofit program for construction and maintenance as retrofitting state highway facilities as appropriate to reduce existing environmental impacts.(*233*) This commitment extends beyond the agency's work in performing appropriate avoidance, minimization, and environmental mitigation as a part of all other highway system projects. The Washington State Highway System Plan update sets a 20-year goal for correction of all state highway culvert barriers. Expenditures for barrier removal in the current biennium are approximately $7 million, and estimates show that this spending level would have to double to complete correction of all culvert barriers on the highway system in 20 years. Consequently WSDOT has developed and funded a research strategy to improve understanding of how road crossings can become barriers to fish and the best approaches to correcting barriers, enabling retrofit projects to be prioritized so that those culvert barriers that promise to yield the greatest habitat benefits are corrected first.

The WSDOT fish passage barrier retrofit program is inventorying highways to locate impassable culverts, rating the potential habitat to be gained from fixing them, and prioritizing the fixes. WSDOT and the Washington Department of Fish and Wildlife jointly manage a statewide database for this inventory with over 900 identified culvert barriers, many of which have been added under more stringent criteria adopted in the past few years. Culverts associated with 2,000 of the 7,000 miles in the state highway system have been inventoried. Since 1991, 27 barriers have been corrected in the course of highway projects, and another 42 barriers have been corrected through the special retrofit program. WSDOT maintenance personnel also correct or at least improve some fish barriers during routine culvert maintenance.

WSDOT's Environmental Retrofit Program also includes:

- Noise Barriers — Adding noise mitigation along state highways where neighborhoods are exposed to unacceptable noise levels as defined by federal statute.
- Stormwater Discharge — Constructing new stormwater treatment facilities to treat runoff from existing untreated pavements.

MDSHA Incorporates Stream Morphology Concepts in Culvert Design

In 1992, the Maryland State Highway Administration (SHA) initiated new design procedures to limit the impact of constructing culverts and bridges in streams. Elements of the new procedures included studies to define the characteristics of Maryland streams regarding bankfull widths, depths, and discharges; training of engineers in basic and advanced courses in stream morphology; and updating the SHA culvert design manual to address consideration of stream morphology, fish passage, and other environmental features. The revised design procedure emphasized the need to identify all appropriate objectives at the start of the design process so the best overall solution can be determined. The design concept is to construct a stream system that is stable and that neither scours nor aggrades. Elements of this approach include maintaining the consistency of dimension, pattern, and profile of the stream with particular attention given to maintaining bankfull width and width/depth ratio. Initial efforts to construct culverts using stream restoration methodologies and to relieve the hydraulic load on the main channel culvert in some cases to limit downstream scour and erosion were quite successful; MDSHA concluded that it was practical to consider stream morphology concepts in culvert design.(*234*)

Alberta Transportation Practices and Measures for Protection of Fish & Aquatic Ecosystems

Practices and measures for fisheries and aquatic ecosystems have been established in Canada, and include the following:

- Crossings of a waterbody that provide fish habitat at any time of the year should be designed, constructed, operated and maintained such that no new barriers to fish passage, including physical, chemical or flow impediments (including maintaining minimum flows and depths), are created so that fish can pass and the ability for fish to pass is not reduced over time, unless authorized by the appropriate resource agency.
- If highway construction must proceed during a period when fish are moving between different areas of their habitat, their safe passage shall not be restricted for an unreasonable amount of time. The relevant period should be determined by a qualified fisheries biologist, for the target species/community, in consultation with the appropriate resource agency.
- Fish screens, guards, netting or other barriers should be installed and maintained across any water intake withdrawing water from any waterbody that contains fish (e.g. for the purposes of water-taking, dewatering, bypass pumping, etc.) or across the entrance to any channel constructed for the purposes of conducting water temporarily from any

waterbody that contains fish so as to prevent fish access until the water intake or diversion has been decommissioned.

- Any area of a waterbody containing fish that is temporarily isolated by guards, screens or other barriers should be inspected for the presence of fish, and all fish should be captured using appropriate means and released unharmed in adjacent fish habitat beyond the barriers. This fish transfer should be conducted under the direction of a qualified fisheries biologist, with the appropriate permit.
- Fish shall not be harmed in any manner unless authorized by the appropriate resource agency. Fish species, or parts or derivatives of fish species listed as extirpated, endangered or threatened shall not be killed, harmed, harassed, captured, taken, possessed, collected, bought, sold or traded except under a valid Permit.
- No harmful alteration, disruption or destruction of fish habitat is permitted unless authorized the appropriate resource agency. Destruction of any part of the critical habitat of any listed endangered or threatened aquatic species, or an extirpated species where a recovery strategy recommends reintroduction of that species to the wild, is not permitted.
- Where a harmful alteration, disruption or destruction of fish habitat is authorized by the appropriate resource agency. Appropriate compensation should be developed by a qualified fisheries biologist, to ensure no net loss of the productive capacity of the habitat occurs.
- Where the use of explosives is required during construction in the vicinity of a waterbody that contains fish, they should be used in such a manner as to ensure no harmful effects to fish occur.
- No substance of any type that is deleterious should be deposited in water frequented by fish, or be released or placed such that the deleterious substance could enter the water.
- Plans and specifications for highway construction that may affect fish habitat should be provided to Ministry of Natural Resources and Fisheries and Oceans Canada, and modified as required.
- Where a substance is released and/or deposited into water such that fish and/or their habitat could be harmed, it should be reported to the appropriate agencies (Ministry of Natural Resources, Fisheries and Oceans Canada, Ministry of the Environment).
- Where a substance is released and/or deposited into water such that fish and/or their habitat are harmed or likely to be harmed, all reasonable measures to remedy the situation should be undertaken as soon as possible.

Resource Agency and Other Design Guidance for Fish Passage

A number of agencies have guidance for design of culverts for fish passage, including:

- Improving Stream Crossings for Fish Passage: Final Report (2004 NOAA Fisheries)
  Final report of a multiyear research project investigating passage conditions for anadromous salmonids at numerous steam crossings within Northwestern California. The project evaluated the effectiveness of current fish passage guidelines. A main focus of the study was relating observed migration of adult and juvenile salmonids fish passage to existing and proposed design flows. The study also evaluated the leaping success of

different size classes of fish at various culvert outlets and examined hydraulic conditions within various culvert types.

- California Salmonid Stream Habitat Restoration Manual, (2003) Commonly called "The Green Book" this California Division of Fish and Game manual details many aspects of stream restoration and watershed monitoring and is the de facto standard (in California) for in-channel and in-stream structures for fisheries habitat improvement. The 3rd Edition contains a new section: "Part IX Fish Passage Evaluation at Stream Crossings," added to the manual in April 2003. The primary authors of this section were Ross N. Taylor and Michael Love. This section addresses fish passage evaluations at stream crossings (roads, bridges, etc.) and Data Collection for evaluations using the FishXing software.
- Design of Road Crossings for Fish Passage (2003) Comprehensive engineering manual by the Washington State Department of Fish and Wildlife detailing the design of manual permanent, new, retrofit, or replacement road crossing culverts without harmful impact to salmonid migration.
- Washington State DOT Fish Passage Barrier Removal Program
- Oregon DOT Water Quality and Habitat Guide, Best Management Practices (July 1999)
- Fish-stream Crossing Guidebook, British Columbia Ministry of Forests (2002) Culvert design manual for culverts, fords and low water bridges. Generally directed toward range and wild land roads.
- Geomorphologic Impacts of Culvert Replacement and Removal (2003) by the Oregon Department of Fish and Wildlife.
- DRAFT National Inventory and Assessment Procedure For Identifying Barriers to Aquatic Organisms at Road-Stream Crossings USDA Forest Service, San Dimas Technology and Development Center.
- Juvenile and Resident Salmonid Movement and Passage Through Culverts (1998) Washington State Transportation Center (TRAC), Univ. of Wash..
- Stream Characteristics and Hydrology – Design for Fish Passage and Aquatic Organisms (BLM)
- FishBase is a Searchable relational database with information to cater to different professionals such as research scientists, fisheries managers, zoologists and many more. Available on CD and on the web, it contains over 28,000 fish species, data on habitat range, swim speeds, references, research photos and much more.
- FishXing software and learning systems for the analysis of fish migration through culverts has added features for hydraulic analysis of culverts and expanded biological references, as of Spring 2004. FishXing gives detailed profiles of hydraulic conditions and fish performance inside a variety of culvert shapes.
- HydroCulv is an Excel-based macro that performs culvert hydraulic calculations to determine water surface profiles through culverts based on culvert geometry data and boundary conditions. Output includes key results such as freeboard, head loss, inlet and outlet velocities, as well as depth and velocity profile information throughout each culvert. Profile plots are available for each pipe and boundary condition.

- Flow Pro is a Windows-based program that computes steady-state water surface profiles for many prismatic open channel shapes, including circular, rectangular, trapezoidal, triangular, U-shaped, and tubular. It handles both subcritical and supercritical flow types, and flow through weirs, orifices, and underflow gates. Flow Pro also computes many useful flow and channel properties including critical depth and slope, hydraulic radius and wetted perimeter, normal depth, and channel roughness. It uses Manning's equation and numerical integration, and accepts both English and SI units of measure.
- CulvertMaster is a Windows-based program intended for use in design and analysis of culverts at road-stream crossings. The program uses US Federal Highway Administration Design of Highway Culverts (HDS-5) methodology to perform inlet control and outlet control computations, including pressurized flow conditions and hydraulic jumps. The software can model hydraulics for most commonly used culvert shapes. It allows the user to input the tailwater elevation or it can generate a tailwater rating curve based on a downstream cross-section. Additionally, the user is able to input road surface elevations to check overtopping conditions. CulvertMaster also contains a hydrology module that allows the user the ability to calculate peak design flows using the Rational Method or SCS Graphical Peak Method. It provides tabular and graphical output and can generate reports. The program accepts both English and SI units of measure.
- HEC-RAS is produced by the US Army Corps of Engineers, Hydrologic Engineering Center. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. HEC-RAS allows the user to perform one-dimensional steady and unsteady flow calculations within a graphical user interface. The steady flow component of the modeling system is intended for calculating water surface profiles for steady gradually varied flow. The system can handle a full network of channels, a dendritic system, or a single river reach. The steady flow component is capable of modeling subcritical, supercritical, and mixed flow regimes water surface profiles. The unsteady flow component was developed primarily for subcritical flow regime calculations.
- WinXSPro uses a resistance-equation approach (e.g., Manning's equation) to single cross-section hydraulic analysis, and is capable of analyzing both the geometry and hydraulics of a given channel cross-section. WinXSPRO was specifically developed for use in high-gradient streams and supports three alternative resistance equations for computing boundary roughness and resistance to flow. The program allows the user to subdivide the channel cross-section so that overbank areas, mid-channel islands, and high-water overflow channels may be analyzed separately. The program also allows input of variable water-surface slope so that is may be varied with discharge to reflect natural conditions.
- PEAKFQ from the US Geological Service is a DOS based program that performs flood-frequency analysis based on the guidelines delineated in Bulletin 17B, published by the Interagency Advisory Committee on Water Data in 1982. The program is interactive and contains the code from the WATSTORE program J407. PEAKFQ uses the method of moments to fit the Pearson Type III distribution to the logarithms of annual flood peaks. The skew that is used may be a user-developed generalized skew for a region, from the Bulletin 17B skew map, computed from the data, or weighted between the generalized

skew and station skew computed from the data. Adjustments can be made for high and low outliers and historic information. Qualification codes may be used to censor data from the analysis.

- CTE Literature Survey on Impacts of Culverts on Anadromous and Non-Anadromous Fish Passage (December 2002)
- FISHPASS program for culvert installations – Alaska Department of Fish and Game
- Fish Protection Screens:
    - Hydraulic testing of static self-cleaning inclined screens – U.S. Bureau of Reclamation, Water Resources Research Laboratory
    - Juvenile fish screen criteria for pump intakes –National Marine Fisheries Service, Portland, Oregon

Post-Construction Evaluation and Long Term Maintenance and Assessment

Post-construction evaluation is important to assure the intended results are accomplished, and that mistakes are not repeated elsewhere. There are three parts to this evaluation: 1) Verify the culvert is installed in accordance with proper design and construction procedures. 2) Measure hydraulic conditions to assure that the stream meets these guidelines. 3) Perform biological assessment to confirm the hydraulic conditions are resulting in successful passage. Staff and resource agency biologists may assist in developing an evaluation plan to fit site-specific conditions and species. The goal is to generate feedback about which techniques are working well, and which require modification in the future. These evaluations are not intended to cause extensive retrofits of any given project unless the as-built installation does not reasonably conform to the design guidelines, or an obvious fish passage problem continues to exist.(*235*)

Any physical structure will continue to serve its intended use only if it is properly maintained. Hence the following practices should be employed.

- Ensure timely inspection and removal of debris for culverts to continue to effectively move water, fish, sediment, and debris.
- Inspect all culverts should be inspected at least annually to assure proper functioning. Summary reports should be completed annually for each crossing evaluated. An annual report should be compiled for all stream crossings and submitted to the resource agencies. A less frequent reporting schedule may be agreed upon for proven stream crossings. Any stream crossing failures or deficiencies discovered should be reported in the annual cycle and corrected promptly addressed.

3.6. STREAM RESTORATION AND BIOENGINEERING

The traditional approach to designing highway structures over water crossings has been based on channel hydraulics, with little consideration of stream stability, causing reduced meanders, costly upstream and downstream erosion problems, water quality impacts, barriers to fish passage, and altering associated wetland and floodplain function. Increasingly, engineers and environmental professionals are turning toward design procedures that minimize disruption of stable stream channels and design in accordance with the natural fluvial geomorphology of rivers. These principles can also be used to restore the physical, biological, and aesthetic characteristics of degraded rivers or help to maintain the natural stream properties for newly constructed projects.

Stream restoration and mitigation is a complex process that addresses the active channel as well as the floodplain and the vegetation along its edges. Geomorphically mature natural channels are dynamically stable and are characterized by an equilibrium of sediment supply and transport. The active channel, floodplain, slope and discharge of natural channels provide the velocity necessary to transport sediment generated in the basin. The aquatic community that resides in the natural channel and along its floodplain has evolved to exploit the features of the channel and to respond to the dynamic equilibrium that has been established. Healthy fish communities tend to exist in productive, dynamically stable channel systems. Such systems provide a suitable mix of habitat features: pools, riffles, bed materials, bank features, aquatic and stream bank vegetation, woody debris, etc. that provide for the basic life requisites of food, reproduction and cover. Therefore, dynamically stable natural channels provide good fish habitat that is sustainable over a wide range of hydrologic conditions. It is generally recognized that natural channels provide optimal sustainable fish habitat for the given natural climate, geology and terrain. Improving fish habitat in natural conditions may not be sustainable over the long term, although short-term improvements are feasible. Natural stream channels are the result of the gradual evolution of the natural landscape and exist in a state of dynamic equilibrium. Natural channels typically lie in valleys with floodplains that attenuate peak flood flows. Their geometry (e.g., channel depth, slope, width, sinuosity, meander wavelength and width-to-depth ratio) can be described by regime equations which depend on the geology and geography of the watershed. This provides a tool that can be used to design channel diversions or realignments in accordance with natural regime conditions and to design watercourse crossings to accommodate natural channel processes.(*236*)

When changes to the channel, floodplain, vegetation, flow or sediment supply significantly affect this equilibrium, the stream may become unstable and start adjusting toward a new equilibrium state. This transition may take a long time and may substantially change water quality, habitat and adjacent property. Stream restoration re-establishes the general structure, function and self-sustaining behavior of the stream system that existed prior to disturbance, so the stream does not aggrade or degrade and so that it provides the highest level of aquatic habitat and biological diversity possible. To accomplish this, restoration may involve:

- Removal of the watershed disturbances that are causing stream instability.
- Installation of structures and planting of vegetation to protect streambanks and provide habitat.
- Reshaping or replacement of unstable stream reaches into appropriately designed functional streams and associated floodplains.

Bioengineering is the use of plant material, living or dead, to alleviate environmental problems such as shallow rapid landslides, and eroding slopes and streambanks. Plants are an important structural component of bioengineered systems, not just an aesthetic element. This approach to slope stabilization requires a true partnership between engineering geologists, maintenance personnel, civil engineers, and landscape architects. Bioengineering mimics nature by using locally available materials and a minimum of heavy equipment. Hence it can offer designers and roadside managers an inexpensive way to resolve local environmental problems. These techniques can also be used in combination with “hard” engineering techniques such as rock or concrete structures.

The following benefits of bioengineering, or soil bioengineering as it is commonly called, are outlined by: (*237*)

- Soil bioengineering work is often the only practical alternative on sensitive or steep sites where heavy machinery is not feasible.
- Installation of soil bioengineered systems while problems are small will provide economic savings and minimize potential impacts to the road and adjoining areas. Erosion areas often begin small and eventually expand to a size requiring costly traditional engineering solutions.
- Many designs can be implemented by hand crews.
- Native plant species are usually readily available and adapted to local climate and soil conditions. Costs might be limited to labor for harvesting, handling, and transport to the project site.
- Soil bioengineering projects may be installed during the dormant season of late fall, winter, and early spring. This is the best time to install plants and it often coincides with a time when other construction work is slow.
- Years of monitoring have demonstrated that soil bioengineering systems provide limited initial benefits, but grow stronger with time as vegetation becomes established. Even if plants die, roots and surface organic litter continue to play an important role during reestablishment of other plants.
- Once plants are established, root systems remove excess moisture from the soil profile. This often is the key to long-term soil stability.
- Soil bioengineering provides improved environmental functions, such as slope stabilization, stormwater retention, and habitat values.

Nationwide, there is strong support for this natural stability approach from federal and state regulatory agencies involved in the review of highway projects.

Planning Considerations for Stream Restoration and Bioengineering

A literature review for Transportation and the Environment (CTE) and NCDOT by the NCSU Stream Restoration Institute for the Center found that despite research gaps in understanding the goals of restoration, spatial and temporal aspects of structure use and placement, and the reach level hydraulic effects of structures, most authors agree that the process and design of stream restoration should cover the following principle areas: (*238*)

- Analysis of channel history and evolution
- Analysis of cause and effect of change
- Analysis of current condition
- Development of specific restoration goals and objectives prior to design
- Holistic approach to account for channel process, riparian and aquatic function
- Consideration of passive practices (such as fencing against livestock)
- Natural channel design to restore function

WSDOT outlines the following stewardship practices when planning and designing bioengineering projects.(*239*)

- Evaluate soil bioengineering methods as a possible tool for remediation and restoration of degraded slopes. Soil bioengineering has unique attributes, but is not appropriate for all sites. In some cases a conventional vegetative treatment works with less cost, or it may be best to use a geotechnically-engineered system alone or in combination with soil bioengineering.
- Evaluate projects that leave exposed slopes, and slopes requiring high maintenance for stabilization, for possible application of soil bioengineering technologies.
- Include bioengineering technologies as an alternative when evaluating costs.
- Include a slope stability analysis in plans for large erosional slopes.

Consider the natural history, cultural, and social issues of the surrounding landscape as well. A proposed soil bioengineering project within a forested landscape, for example, requires knowledge and understanding of:

- Road construction methods and current maintenance practices.
- Objective of the bioengineering project - repair, remediation, prevention, habitat, etc.
- The area's geologic and glacial history.
- Its propensity for wild fires, wind storms, and floods.
- Occurrence and trends of natural and management related erosion.
- Sequence of vegetation removal and revegetation efforts.
- Fire management history.
- Soil types and properties
- Hydraulic and hydrological erosion and scour characteristics.

The following basic planning considerations are good environmental stewardship practice when planning and designing stream restoration and bioengineering projects:

Channel Features

The channel must possess key habitat characteristics including food supply for production, appropriate areas for reproduction, areas for refuge and rest, and linkages between these areas. When designing a channel reach these habitat characteristics need to be considered in relation to the role of the reach in the stream habitat system. Features of the channel that should comply with channel regime relationships and replicate local natural analogues include: (*240*)

- **Channel morphology:** width, depth, pool area, riffle area, sinuosity, meander wave length, bed material, bank material and slope.
- **Habitat substrate:** percentage area in boulders (substrate larger than 256 mm), percentage area in cobbles (64 to 256 mm), percentage area in gravels (2 to 64 mm), percentage area in fines (< 2 mm), percentage bed area vegetated; and
- **Habitat structure:** type of instream cover, percentage of instream area covered, length of undercut bank, percentage of channel eroding, percentage bank area in debris cover, shading.

- **Riparian Zone:** type of riparian vegetation, extent of riparian vegetation. The channel design should produce an overall channel form consistent with that which would evolve naturally under the same conditions. This can be accomplished by comparing stream classification attributes with representative stream reaches that are nearby. The use of natural analogues to determine channel characteristics is recommended wherever possible.

Conveyance Capacity

Flows that entrain sediment, cause bed and bank erosion, and flood the areas adjacent to the channel are important to aquatic habitat. Bankfull discharge is considered to be the flow that determines channel characteristics of width, depth, sediment size and sorting, and channel plan form.

Flows exceeding 1:10 and 1:25 year recurrence intervals are normally the flows that connect the channel to the riparian zone and affect the floodplain features of wetlands, vegetation cover, and sediment deposition. Depending on the type of stream system, the floods greater than the 1:25 year and up to the 1:100 year flow fill the valley bottom, defining the limit of fluvial influence on the landscape. The active channel area should, wherever possible, provide conveyance up to the 2-year return period event. Additional conveyance should be supplied by the riparian zone or floodplain. When site conditions limit the use of a floodplain to convey flows, structural measures such as additional armoring, may be required.(*241*)

Low Flows

Low flow discharge characteristics in a stream system govern the ability of a stream to maintain aquatic life and suitable water quality. Periods of low flow represent various levels of stress on the system for the maintenance of fish populations. If a channel is not capable of providing sufficient flow to maintain habitats or prevent periodic extinctions, then the habitat is not sustainable. Key low flow characteristics include the following: (*242*)

- **Habitat maintenance**. Streams should maintain sufficient flow depths exceeding 0.2 m along the entire stream up to the 7-day low flow that recurs once every 2 years on average ($7Q_2$). This represents a period of stress on the system that causes some reduction of populations, and thus some loss of productive capacity.
- **Local extinction flow**. Fish habitat streams should maintain sufficient flow depths exceeding 0.2 m along critical life cycle reaches up to the 7-day low flow that recurs once every 10 years on average ($7Q_{10}$). The $7Q_{10}$ represents a major period of stress on the system and in many cases will cause local extinctions, especially in smaller systems.
- **Systems extinction flow**. Fish habitat streams should maintain sufficient flow depths (e.g., depth should exceed 0.2 m) in overwintering pools up to the 7-day low flow that recurs once every 20 years on average ($7Q_{20}$). The $7Q_{20}$ is a significant stress on the system and in many cases will result in extinctions of fish throughout many sections of smaller stream systems.

Low flows are defined by the flow duration curve for the watershed. If the data for the derivation of the low flows are not available they can be developed from regional relationships for estimating low flows. Provided a natural channel can support sustainable fish habitat, design guidelines should be incorporated into the channel design based on target fish species. For example, intermittent streams would provide habitat for forage fish or spawning habitat for spring spawners such as arctic grayling or northern pike. Streams with permanent flow could be designed to support target sport fish or other target species.

Information Requirements

Channel measurements include a site description, cross-sectional characteristics across the channel and valley, an assessment of bed and bank material, documentation of bank vegetative cover, channel profile and channel planform.

Site Description

The recommended procedure for characterizing the reach, the riparian zone, and the valley bottom is as follows: (*243*)

- Locate the reach to be designed on a map with a scale of 1:2000 for urban areas with contour intervals of 0.3 m. A 1:10,000 scale map should be used for rural areas. Also locate the reach on air photos with a scale of 1:2000, if possible. As air photos of this scale are unlikely to be available unless they are taken specifically for the project, it may be necessary to use smaller scale air photos.
- Determine the upstream drainage area.
- Locate the upstream drainage basin and document its condition in terms of land use and level of disturbance. Identify any potential changes to it, including development, impervious surface development, channelization, drainage of wetlands, installation of stormwater ponds, or infiltration fields.
- Locate the valley and document its width, terraces and breaks in the slope, and any evidence of floodlines.
- Locate and identify any structures and other modifications to the channel, banks, and floodplain.
- Locate and map out existing tree cover, shrubs, and understory cover. Locate any debris, stumps, or large boulders in the channel, banks, or floodplain.

Cross-Sectional Measurements

Measurements of channel and valley cross-sections should extend across the valley slope and include the following: (*244*)

- Stream width at the time of measurement of the flow.
- Average depth and maximum depth at the time of flow measurement.
- Bankfull width.
- Average and maximum depth at bankfull discharge.
- Stream entrenchment ratio.

Bed and Bank Material

Assessment of bed and bank material should be carried out by taking the following measurements: (*245*)

- Sieve particle size analysis for various samples taken from all representative material types in the section. If bed materials are too large for sieve analysis, characterize the grain size distribution by counting stones.
- A sketch of the location and a description of the condition of each representative material type.
- Visual estimates of the percentage of the bed's area covered by boulders, cobbles, gravel and sands, and fines.
- The area and nature of the vegetative cover on the bed.
- The particle size data should be plotted as cumulative percent to calculate d_{15}, d_{50} and d_{84} of the particle size distribution.

Bank Vegetative Cover

Bank vegetative cover should be documented to include the following: (*246*)

- Density and height, using a gridded sampling frame to assess cover and to sample numbers of plants, for the smaller plants.
- Plant species, associates, and each type's percentage of cover should be noted.
- In the case of trees, sampling should be carried out at regular intervals along the transect.
- Location of snags and overhanging vegetation should be noted.
- The height of vegetation and width of the vegetative buffers along the bank should be assessed.

Profile and Plan Measurements

For the design of a channel, the important variables required include the following: (*247*)

- For each station at which the cross-sectional data were gathered, the following should be measured according to a standard datum: water level, bed level, top of bank level, and levels of any terraces. Any historical high water marks should also be recorded.
- The plan form of the channel should be mapped. The map should include the thalweg's path, cut banks and point bars, mid-channel bars, riffles and pools, snags, and other obstructions.
- Meander characteristics including wavelength, radius of curvature, and meander belt width and amplitude.
- All elevations should be placed on the map so that the geometry of all features can be referenced.
- Depressions, wetlands, and other water storage areas in the floodplain should be mapped.
- Vegetative cover in the channel and snags should be mapped.
- Bank vegetative cover, overhanging vegetation, and riparian and floodplain vegetation should be mapped.

Design Steps

Many criteria need to be taken into account for the complex process of designing a channel realignment or channelized section. These include: (*248*)

- Discharge capacity (e.g., major flood)
- Channel stability and sediment equilibrium (channel regime)
- Riparian zone vegetation
- Fisheries habitat (possibly species specific)
- Recreational opportunities (active or passive)
- Aesthetics (viewscapes)
- Erosion protection

Since these objectives are not necessarily compatible, design conflicts can arise. For example, the objectives for fisheries habitat will affect requirements for vegetation and physical features, recreational and aesthetic objectives could affect topography and vegetation requirements, and the geomorphological features required to provide a stable stream may reduce its capacity during flood events. Physical constraints, such as urban encroachment, may exist and must be considered in the design process. Choosing the right design parameters involves careful consideration of all the objectives for the stream system and the constraints that exist within the valley. Tradeoffs may be necessary to reconcile differences to establish workable design parameters. The recommended design steps are outlined as follows: (*249*)

- **Step 1: Define Objectives for Design.** Identify the objectives to be met in the design. Multiple objectives may include conveyance, fisheries, habitat, recreation, aesthetics, and maintenance.
- **Step 2: Define Existing Conditions.** The existing characteristics should be identified and detailed.
- **Step 3: Define Expected Natural Regime.** Once the existing conditions are identified, the change in natural regime should be established.
- **Step 4: Identify Inconsistencies.** The predicted regime and the existing regime should be compared to identify any inconsistencies and to determine if the stream is in equilibrium.
- **Step 5: Design Parameters for Unconstrained Design.** Design parameters for the channel should be developed that will meet the objectives and provide stable, natural conditions.
- **Step 6: Identify Constraints.** Identify the constraints to the channel such as property encroachments, roadways, etc.
- **Step 7: Identify Tradeoffs.** The constraints and optimum conditions should be compared and the tradeoffs should be identified.
- **Step 8: Develop Final Design Parameters.** The tradeoffs should be evaluated and decisions made about selecting design parameters. The design should be compared to the objectives and any shortcomings should be identified.

- **Step 9: Evaluate Design.** The design parameters should be compared to the unconstrained condition (see Step 5) and the differences should be evaluated for acceptability.

Climatic Conditions

Climates near the ground can vary considerably within short distances. South facing valley walls, for example, receive more direct sun rays, which cause higher soil temperatures, increased evaporation, more rapid snowmelt in the spring, and generally drier conditions than on the more shaded north facing walls. This difference will influence erosion rates and the composition and vigor of revegetation efforts.

- Consider precipitation types, amounts, seasonal variation, and duration.
- Consider temperatures, including seasonal averages and extremes.

Topography and Aspect

- Slope gradient.
- Terrain shape (for example, gentle slope to valley or sharp peaks).
- Elevation of project area.
- Direction of sun exposure.

Soils

Identify conditions above, below, or within the project site that might have an effect on the project and incorporate these considerations into the design. Consult with the HQ Engineering Geologist to determine need for slope stability analysis. Some categories below will require soil testing to determine.

- Substrate - take soil probe sample from potential site.
- Soil types
- Soil permeability
- Moisture holding capacity
- Nutrient availability

Water

Detailed analysis or work in streams or rivers will require consultation with a hydraulics engineer. Work affecting streams or rivers will require consultation with the DOT environmental office.

- Water velocity: Lateral stream stability
- Hydrologic regime: general and site specific.
- If applicable, stream and fish types affected by the erosion site.
- Location of natural drainage channels and areas of overland flow from road surfaces.
- Areas for safe water diversion.
- Condition of ditch line and culvert inlets and outlets.

Erosion Process

- Evidence of past sliding: deep or shallow failure surface in vicinity.
- Regional geomorphic trends or slope features (review aerial photos).
- Type of mass wasting or surface erosion feature.
- Source of eroding material: road fill slope, cut slope, landing, etc.
- Trend of site: improving naturally, remaining uniform, or worsening.

Vegetation

Living vegetation is the most critical component of a bioengineered system. Existing vegetation and knowledge of predisturbance plant communities can inform the designer of project limitations, opportunities, and long-term ecological goals. Plants that can resist mechanical stresses of erosion, floods, and landslides, while developing a strong, stabilizing root system are best suited for soil bioengineering applications. The best indicator of which plant materials to consider for the soil bioengineering project is the plants growing on or adjacent to the project site. Deciding which plants to use is affected by the following factors:

- Site characteristics (topography, elevation, aspect, soil moisture, nutrient levels).
- Existing vegetation.
- Intended role of vegetation in the project.
- Growth characteristics and ecological relationships of the plants.
- Availability.
- Locations for plant and seed collection.
- Plant species and amount growing within and adjacent to project site. It is especially important to identify colonizing species.
- Logistical and economic constraints.

Plant materials are chosen from among those species available on the site or nearby. Alternatively, it might be possible to salvage like species from a similar area where vegetation is scheduled to be removed. Logistical concerns are important in the selection of plant material.

Coordination and Communication on Bioengineering Projects

The complexity of the project dictates the level at which the following environmental stewardship practices in bioengineering or stream restoration are performed. An interdisciplinary team is typically necessary for all steps.(*250*)

- Involve all associated disciplines early in the process.
- Establish clear project objectives.
- Conduct predesign field review.
- Conduct plan-in-hand field review.
- Have a prework meeting with contractor to highlight key areas.
- Scheduling and timing of project is important when considering erosion outputs.

- When laying out the project, be consistent with the flagging.
- Ensure that terraces are level (on the contours) so that they do not act as stream channels. Level terraces will act to slow erosion.
- Diligent inspections of work-in-progress and timely feedback are critical. Develop a good working relationship with heavy equipment operators and hand crews. Poor inspection and poor communications can ruin a well designed project. Remember "You get what you inspect, not what you expect"!
- Monitor and document project effectiveness.
- Disseminate this information to colleagues and adjust future prescriptions based on monitoring results.
- Annual peer review by land managers provides good feedback and keeps them informed.

Available Guidebooks and Research in Progress

In October 1998, FHWA, AASHTO, and TRB sponsored a scanning review of European practice for bridge scour and stream instability countermeasures.(*251*) Since that time, state DOTs have undertaken a number of research efforts to establish regionally appropriate guidelines. NYSDOT and NCDOT are among other DOTs that include recommendations for appropriate practices when working near streams in maintenance or construction manuals.

- NCDOT has developed Guidelines for Relocations of Mountain Streams in North Carolina and jointly funded the Stream Restoration and Natural Channel Design Guidebook.
- Mn/DOT has developed Guidance for Stream or Water Body Modification,
- KYTC has put together a manual of BMPs for streamside areas.
- WSDOT Roadside Manual Chapter 740 - Soil Bioengineering addresses definitions, planning, design, implementation, site evaluation, and eleven upland soil bioengineering techniques.
- The Nebraska Cooperative Extension Service has published Bioengineering Techniques for Hillslope, Streambank, and Erosion Control.

The Stream Restoration: A Natural Channel Design Handbook prepared for the North Carolina Department of Transportation by the NCSU Stream Restoration Institute, is available on-line and contains River Cross Section Survey, Fact Sheets on River Courses, and Structure Details for Vanes and Rootwads in addition to:

1. Introduction to Fluvial Processes
2. Existing Condition Survey
3. Gage Station Analyses and Bankfull Verification
4. Restoration Priority Options for Incised Streams
5. Reference Reach Survey
6. Design Procedures
7. Structures
8. Vegetation Stabilization and Riparian Buffer Re-establishment

9. Erosion and Sediment Control Plan
10. Flood Studies
11. Evaluation
12. References

Materials for an accompanying four-day workshop held for 35 NCDOT staff are available from the NCSU Stream Restoration Institute, NCDOT, or CTE.

- Maryland's Waterway Construction Guidelines recommends that the planning and design of any stabilization, restoration, or in-stream construction project should include a set of clearly defined restoration objectives, a comprehensive monitoring strategy, and an adaptive management plan. Objectives vary from aesthetic improvements to habitat enhancement to safety and installation of hydraulic structures and roadways. Identifying the objective of the project must be accomplished before the design process can begin. Regardless of the nature of the objective, it should include measurable performance criteria. Performance criteria are quantitative measurements that are made in the stream corridor and compared to the project's objectives and can include parameters such as suspended sediment load and rate of lateral channel migration. A comprehensive monitoring strategy including appropriate baseline studies and timing, frequency, and location of field measurements, is necessary to assess the degree of project success or failure and to determine an adaptive management plan. Options for an adaptive management plan include adjustment or maintenance of individual measures, modification of project goals and objectives, and project redesign.
- The Washington Department of Fish and Wildlife resources for stream restoration includes a Glossary, Overviews of Hydrology, Hydraulics, and Fluvial Geomorphology and overviews of various restoration techniques.

Federal efforts have included the following:

- EPA's Principles for the Ecological Restoration of Aquatic Resources (*252*)
- Stream Corridor Restoration: Principles, Processes, and Practices.

The latter incorporates and reflects the experiences of the fifteen collaborating agencies and has received the endorsement of and awards from the American Society of Landscape Architects. It is more general than some of the other guidebooks available and is easily applicable nationwide in both urban and rural settings, to a range of stream types. The guide is divided into three principal parts. Part I provides back-ground on the fundamental concepts of stream corridor structure, processes, functions, and the effects of disturbance. Part II focuses on a general restoration plan development process comprised of several fundamental steps. For example, in analyzing stream restoration alternatives, a management summary of proposed activities should be prepared, including an overview of the following elements:

- Detailed site description containing relevant discussion of all variables having a bearing on that alternative.
- Identification and quantification of existing stream corridor conditions.
- Analysis of the various causes of impairment and the effect of management activities on these impaired conditions and causes in the past.

- Statement of specific restoration objectives, expressed in terms of measurable stream corridor conditions and ranked in priority order.
- Preliminary design alternatives and feasibility analysis.
- Cost-effectiveness analysis for each treatment or alternative.
- Assessment of project risks.
- Appropriate cultural and environmental clearances.
- Monitoring plan linked to stream corridor conditions.
- Anticipated maintenance needs and schedule.
- Alternative schedule and budget.
- Provision to make adjustments per adaptive management.

Part III briefly covers Restoration, Installation, Monitoring, and Management. The information lacks detailed design guidance for various stream restoration techniques, but state environmental agencies and DOTs have begun to fill that gap, as will NCHRP 24-19, results of which are due in late 2004.

- NCHRP 24-19 seeks to fill part of the gap in DOTs abilities to use and rely on environmentally sensitive bank and erosion control measures. Traditional channel- and bank-protection techniques have relied on countermeasures such as riprap, gabions, cable-tied blocks, or grout-filled bags, which may not offer sufficient in-stream functions, such as habitat diversity, fish passage, water quality, and energy dissipation. Environmentally sensitive channel- and bank-protection measures (ESCBMs), such as bioengineering, root wads, large woody debris, riparian vegetation, bendway weirs, and energy dissipaters, are being called for more frequently to protect transportation facilities from erosion, scour, and lateral migration. The CD will include for each ESCBM covered:
- A review of the technical literature from foreign and domestic sources pertaining to environmentally sensitive channel- and bank-protection measures.
- Performance data.
- Examples, charts, tables, figures, drawings, and specifications.
- Guidance pertaining to selection and application.
- Critical evaluation of the extent and adequacy of existing information pertaining to the current state of practice for the selection and design of the measure.
- Upcoming NCHRP projects will cover Riprap Design Criteria, Specifications and Quality Control and Hydraulic Loss Coefficients for Culverts.
- EPA's Decision-Making Guide for Restoration and a Stream Restoration Glossary
- Stream Corridor Inventory and Assessment Techniques
- Assessing Conditions of Stream Corridors at the Areawide Level -- Using Proper Functioning Condition (PFC) Methodology Technical Report
- TR 1737-12, Using Aerial Photographs to Assess Proper Functioning Condition of Riparian-Wetland Areas

- TR 1737-15, Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas

The following new state DOT research is in progress:

- **Mn/DOT** is undertaking a "Scoping Study for the Development of Design Guidelines for Bioengineering in the Upper Midwest," with research results due in early 2005.(*253*) The project will assess current design methods, clarify current practices, propose areas where better design guidance is needed and outline further research requirements.
- **Georgia DOT** is investigating the feasibility of using recently developed stream restoration techniques, specifically in-stream structures, to restore the previous channel geometry and habitat continuity in the vicinity of bridges.(*254*) The project will develop a database of the effectiveness of three different materials (rock, wood, and salvaged concrete slabs) for the restoration structures and restoration failures in the region. Results are due in 2006.
- **Florida DOT**, in conjunction with USFWS, is also collecting regional data; in particular the agencies are developing regional curves to characterize and stream channel hydraulic geometry (i.e., width, depth, and cross-sectional area) in relationship to bankfull discharge and watershed area and assist in natural channel design for FDOT projects. This study is expected to provide a model for future efforts to analyze streams statewide and result in improved guidelines for designing culverts and bridges to preserve natural bankfull channel dimensions and their associated floodplains and wetlands. Study results are expected in 2005.(*255*)
- **Nebraska DOR** is establishing guidelines about when and where to use vegetation to control erosion on streambanks, how to establish the vegetation, and what types of vegetation are most practical in any given situation. The research team also investigated combined erosion control methods to see if bioengineering can improve the stability and appearance of non-biological erosion control techniques in locations where vegetation by itself provides insufficient protection against erosion. MDT and FHWA are also undertaking research in alternative strategies in stream restoration.(*256*)

Bioengineering Technique Selection

Selection of the appropriate technique, or techniques, is critical to successful restoration. NCHRP 24-19 Environmentally-Sensitive Channel and Bank Protection Measures will provide guidelines for 44 bioengineering techniques, accompanied by 19 Special Topic guidance documents, and a total of 55 typical drawings in both AutoCAD and MicroStation formats. For each of the 44 different bioengineering techniques, the following information will be provided:

- Description
- Purpose
- Planning
    - Useful For Erosion Processes
    - Spatial Application
    - Hydrologic / Geomorphic Setting
    - Conditions Where Practice Applies

  - Complexity
  - Design Guidelines / Typical Drawings
- Environmental Considerations / Benefits
- Hydraulic Loading
- Combination Opportunities
- Advantages
- Limitations
- Materials And Equipment
- Construction / Installation
- Cost
- Maintenance / Monitoring
- Common Reasons / Circumstances For Failure
- Case Studies And Examples
- Research Opportunities
- References

Bioegineering techniques are grouped into four major categories, viz., 1) River Training Techniques, 2) Bank Armor and Protection, 3) Riparian Buffer and River Corridor Treatments, and 4) Slope Stabilization. The CD will include a rule-based selection system that relates the hydraulic, geotechnical, and environmental constraints of each technique to site conditions and project constraints to aide the user in selecting an applicable measure. Also included will be reference material "hot-linked" within the various design criteria provided. The material will be considered state-of-the-art when it is due out in late 2004 and will cover the following practices: (*257*)

Example 6: Environmentally Sensitive Channel- and Bank-Protection Measures to be Included in NCHRP 24-19

River Training

1. Spur dikes
2. Vanes
3. Bendway weirs
4. Large woody debris structures
5. Stone weirs
6. Longitudinal stone toe with spurs
7. Longitudinal stone toe
8. Coconut Fiber Rolls
9. Vegetated gabion basket
10. Live cribwalls
11. Vegetated Mechanically Stabilized Earth
12. Live siltation
13. Live brushlayering
14. Willow posts and poles
15. Trench fill revetment
16. Vegetated floodways
17. Meander restoration

Bank Armor and Protection

18. Vegetation alone
19. Live staking
20. Live fascines
21. Turf reinforcement mats
22. Erosion control blankets
23. Geocellular Containment Systems
24. Rootwad revetments

Bank Armor and Protection, cont.

25. Live brush mattresses
26. Vegetated articulated concrete blocks
27. Vegetated riprap
28. Soil & grass covered riprap
29. Vegetated gabion mattress
30. Cobble or gravel armor

Riparian Buffer and Stream Corridor Opportunities

31. Live gully repair

Vanes with J hooks

32. Cross Vanes
33. Boulder clusters

Slope Stabilization

34. Diversion dike
35. Slope drain
36. Live pole drain
37. Chimney drain
38. Trench drain
39. Drop inlet
40. Fascines with Subsurface Drain
41. Flattening
42. Stone - Fill Trenches

Special Topics

1. Bankfull Discharge
2. Bio-Adaptive Plant Response
3. Checklist/Guidelines for Effective Design
4. Combining Techniques
5. Designing Stone Structures
6. Ecological Aspects of Bridge Design
7. Geotextiles and Root Penetration
8. Harvesting/Handling of Woody Cuttings
9. Management of Conveyance
10. Optimal Compaction and Other Strategies
11. Physical Aquatic Habitat
12. Proper Functioning Condition
13. Resistive (Continuous) vs. Redirective (Discontinuous)
14. Revetments to Resist Wave Wash
15. Self-Launching Stone / Well Graded Stone
16. Sources, Species, and Durability of Large Wood
17. The Key to Stability is the Key
18. The Role of Geotextiles and Natural Fabrics

Bank Protection and Stabilization Techniques

Streambank stabilization affects many of the structural characteristics and functions of a stream. These impacts can be viewed as either adverse or beneficial, depending upon the perspective of the individual assigning values to the system. The prevailing philosophy in ecosystem management is that physical alterations of the structure and character of an ecosystem are most significant if they also impact process-based functions. Erosion control measures are most likely to impact morphological evolution, sediment processes, and habitat, and are least likely to impact the stream's hydrologic character and the chemical processes and pathways.

River functions most likely to be impacted by stabilization measures include stream evolution processes, riparian succession, sedimentation processes, habitat, and biological community interactions. Those least likely to be impacted include the functions related to hydrologic balance and chemical and biological processes.

Bank protection practices are designed to protect the stream bank from erosion or potential failure. Bank protection practices include practices that are structural in nature, as opposed to practices often grouped as bank stabilization, which tends toward less structural and more vegetation-reliant techniques such as bioengineering, to stabilize streambanks. Bank protection practices are used along stream reaches where eroding streambanks threaten private property or public infrastructure or where available space or highly erosive flows are a constraint.

The most common examples of bank protection practices are rootwad and boulder or riprap revetments. Fact sheets on Bank Protection Techniques, provided by the Washington Department of Fish and Wildlife, cover the following Structural Techniques:

- Anchor Points
- Roughness Trees
- Log Toes
- Roughened Rock Toes

Bank stabilization practices generally involve regrading the stream banks to a stable angle and geometry, followed by the use of vegetative plantings and biodegradable materials to stabilize the streambank and prevent future bank erosion. Widely used practices within this latter group include coir fiber logs, live fascines and willow plantings. A Caltrans Stormwater Fact Sheet on Stream Stabilization is available online. This source describes Best Management Practices that can reduce the discharge of sediment and other pollutants and minimize the impact of construction activities on watercourses

A number of the following techniques are also used in river training or channel restoration, are reviewed here rather than in those later sections.

Riprap

Riprap usually refers to natural stone (i.e., cobbles, boulders, or broken stone), used for shoreline, streambank, or streambed armoring for erosion control. Riprap has many advantages over other bank protection techniques including: low cost, relatively simple construction techniques as necessary, easily repaired, ability of vegetation to grow between rocks, increasing stability of the bank and improving habitat value of the structure, and performance is not impaired.(*258*)

Riprap structures can have ecological benefits and can even be used specifically to improve the quality of riverine habitat. Stabilizing stream channels with riprap can reduce sediment loads, improve water quality, and allow re-establishment of riparian vegetation. Stone used in riprap structures provides hard substrate habitat that can be important in some sand bed streams where it might be limited, and spaces between riprap stones provide velocity refuge and cover for aquatic invertebrates and small fishes.

Generally, streams with healthy riparian vegetation communities and the habitat features associated with such communities (shade, relatively stable undercut banks, large woody debris, etc.) will be harmed ecologically from the addition of riprap structures. On the other hand, habitat may be improved on streams where natural hard substrate is rare or lacking. Systems with excessive erosion due to anthropogenic causes are most likely to benefit ecologically from riprap. According to the literature, the impacts for coldwater fisheries are predominantly adverse, whereas impacts for warmwater organisms are overwhelmingly beneficial.(*259*) Although a number of variables are involved, this general trend appears to be related to the character of the habitat afforded by the riprap relative to the habitat it replaces and the other habitat in nearby reaches. In most of the warmwater systems studied, coarse hard substrate was very limited, so the addition of riprap provided a habitat niche that was rapidly exploited by a number of species.(*260*) The Washington State Department of Fish and Wildlife produced a Literature Review of Revetments and found predominantly adverse effects in these cold water environments.(*261*)

Design Considerations and Practices for Minimizing Environmental Impacts from Riprap

Careful planning can minimize impacts due to construction, and design features can often be incorporated into riprap structures to improve their habitat value. According to the U.S. Army Corps of Engineers, most of the impacts associated with rmoring a streambank are the same regardless of whether the armor material is riprap, concrete, vegetation, or a synthetic product; material-related impacts are generally associated with the habitat characteristics of the structure, and the influence of the structure on riparian vegetation.(*262*)

Impacts associated with the use of riprap as an erosion control measure can be minimized by modification of structures and incorporation of the following environmental stewardship practices. Similar modifications can be employed to minimize the impacts associated with riprap used as toe protection in a slope stabilization project.

- When used as an armor material, minimize riprap impacts by reducing the height of the protection, by increasing the slope of the embankment, and by sizing the riprap to afford adequate habitat within the aquatic environment.
- Plant the interstices of a riprap revetment with woody vegetation.

Measures to reduce the impacts associated with flow deflection structures incorporating riprap include the following:

- Carefully locate the deflection structures to minimize impacts to the riparian corridor
- Modify the structure design in order to generate desired habitat characteristics within the aquatic environment.

Structure designs that result in diverse conditions or that restore or generate necessary habitat can produce generally positive impacts. The size and gradation of stone for both flow deflection and armor structures can be adjusted to reduce impacts in some cases. Most impacts caused by energy reduction structures are related to the height of the structure. High structures significantly decrease the energy and water surface slope, induce sediment deposition upstream and scour downstream, and can present a barrier to the migration of aquatic organisms. These impacts can be minimized by the following measures:

- Replace single structures with a series of low-head structures.
- Incorporate structural modifications to improve sediment continuity and fish passage.

Construction Practices to Minimize Adverse Environmental Impacts from Use of Riprap

Construction methods used to place revetments should be carefully reviewed to ensure that they do not contribute to environmental degradation. Construction of a typical riprap structure requires extensive use of heavy equipment, and steps should be taken to minimize damage to riparian vegetation and instream habitats.

- Plan movement of construction materials to minimize impacts to riparian vegetation outside the area of interest.
- Conduct riprap placement so as to preserve existing trees along the bank that are not in danger of windthrow or toppling.
- Regulate equipment operation on the upper banks to minimize soil compaction in the riparian zone, which leads to plant mortality.

Common methods of riprap placement include hand placing; machine placing, such as from a skip, dragline, or some form of bucket; and dumping from trucks and spreading by bulldozer. Hand placement produces the best riprap revetment, but it is the most expensive method except when labor is unusually cheap. Steeper side slopes can be developed with hand-placed riprap than with other placing methods.

- Where steep slopes are unavoidable (when channel widths are constricted by existing bridge openings or other structures, and when rights-of way are costly)consider hand placemen.

- With machine placement release sufficiently small increments of stone as close to their final positions as practical.
- Minimize rehandling or dragging operations to smooth the revetment surface, as this tends to result in segregation and breakage of stone, and can result in a rough revetment surface.
- Avoid dropping stone from an excessive height as this may result in the same undesirable conditions.
- Minimize riprap placement by dumping and spreading as a large amount of segregation and breakage can occur. In some cases, it may be economical to increase the layer thickness and stone size somewhat to offset the shortcomings of this placement method.

Timing of construction is important when managing for certain impacts.

- Construction activities should generally be avoided when they will disrupt spawning or nesting activities of nearby sensitive species.
- Designs that incorporate vegetation may require that the installation occur during the dormant season.
- Construction activities should generally be abandoned when flows are sufficient to heighten the risk of catastrophic failure.

NCHRP 24-19 will outline environmental stewardship practices for implementing Cobble or Gravel Armor, Vegetated Riprap, and Soil and Grass Covered Riprap. Currently available on-line guidance includes:

- Riprap, MD
- Imbricated Riprap MD
- Riprap, WSDOT, p. 103
- Riprap, WA Fish & Wildlife, p. 6.67
- Riprap Slope Protection, NCDOT, p. 105
- Riprap Outlet Protection, NCDOT, p. 107
- Spruce Tree Revetments, AK

Gabions

Gabions are stone-filled wire baskets that are used to protect the stream bank from erosive water currents. NCHRP 24-19 will provide guidance for the use of Vegetated Gabion Baskets and Vegetated Gabion Mattress. Meanwhile, guidance is available on-line on implementation of gabions from the Maryland Department of the Environment.

Toe Protection

Toe Protection consists of reinforcing bank toes with vegetation, bioengineering methods, or rigid engineering techniques to ensure the dynamic or rigid stability of the stream corridor. NCHRP 24-19 will have forthcoming information on Longitudinal Stone Toe with and without Spurs. Maryland and Alaska have online resources for toe protection as follows.

- Toe Protection, MD

- Live Siltation, AK

Vegetated Concrete Blocks

Vegetated Articulated Concrete Blocks or Cellular Concrete Blocks are precast perforated concrete blocks which stabilize slopes or streambanks but also allow vegetation to establish itself through openings in the block.(*263*) NCHRP 24-19 will provide practice guidance for Vegetated Articulated Concrete Blocks. Meanwhile, practice guidance for implementation is available on-line from Florida:

- Cellular Concrete Blocks, FL, p. 79
- Grid Confinement Systems, FL, p. 75

Live Crib Walls

Live Crib Walls are hollow, box-like frameworks of untreated logs or timbers filled with riprap and alternating layers of suitable backfill and live branch layers and are used for slope, streambank, and shoreline protection.(264) They are sometimes used in channel restoration or river training as well. Environmental stewardship practices for live crib walls and vegetated cribbing are available online in the form of fact sheets and guidelines from the following states:

- Live Crib Walls, MD
- Log Cribwalls, WA, p. 6.99
- Vegetated Cribbing, AK

Root Wads

Root Wads are a streambank protection technique that provides immediate riverbank stabilization, protects the toe of slope and provides excellent fish habitat, especially for juveniles. Root wads are particularly well suited for higher velocity river systems and riverbanks which are severely eroded. They provide toe support for bank revegetation techniques and collect sediment and debris that will enhance bank structure over time. Because of their size, root wads usually require the use of heavy equipment for collection, transport and installation.(*265*)

NCHRP 24-19 will cover rootwad revetments. Environmental stewardship practices for live crib walls and vegetated cribbing are currently available online in the form of fact sheets and guidelines from the following states:

- Root Wads, MD
- Structure Details For Vanes And Rootwads, NCDOT
- Root Wads, AK

Live Staking

Live plants can be incorporated into a riprap structure to enhance its habitat and aesthetic value. Live staking (i.e., planting live woody vegetation) of the riprap interstices is common, and root wads can be incorporated into a riprap structure. The woody vegetation enhances the habitat value of the structure, and as an added benefit, it can also increase bank stability and reduce chances of structure failure. In areas where aesthetics are especially important, the stone above the normal high water level can be covered with soil and planted in grasses. Cuttings (live stakes) are the most beneficial means of adding vegetation to riprap structures.

- Cuttings should be prepared from woody plants that root adventitiously (e.g. Salix spp.), obtained from as near the site as possible, and should be free from obvious signs of disease.
- To root effectively, cuttings must have good soil/stem contact, (difficult to achieve in many riprap structures) and must be placed to a depth sufficient to access groundwater during drought.
- Woody cuttings or posts can be placed through many riprap sections using a stinger mounted on an excavator. The stinger creates a pilot hole into which the cutting is inserted. A recently patented procedure allows the installation through riprap of plants that are encapsulated with soil, greatly improving survival, as a lack of soil contact within the riprap section is a leading cause of mortality for plants installed with a conventional stinger. Alaska has added information online under the heading of Dormant Cuttings.

Live staking BMP fact sheets and resources online include:

- Live Stakes, MD
- Live Staking, AK
- Live Staking, WSDOT, p. 93

Live Staking, Willow Posts, and Poles, to be covered in NCHRP 24-19

Large Woody Debris

Research on the effect of wood structures includes both biological and hydraulic study. Large organic debris or large woody debris has an important influence on stream process and morphology by hydraulically controlling areal sorting and storage of sediment, spacing of pool-riffle sequences and channel geometry.(*266*)

Two studies in wood placement examine the effect on trout habitat.(*267*) Both papers report increases of trout fry and biomass associated with large woody debris. Hilderbrand et.al compared the effect of random design and human judgment-based placement of large wood structures. Their most significant finding was the 146 percent increase in pool area associated with systematic placement opposed to 32 percent pool area increase in random placement.(*268*)

The Washington Department of Fish and Wildlife has produced guidance on Anchoring and Placement of Large Woody Debris that is available on-line. Another Washington document also has guidance on Large Woody Material (p. 88).

Live Fascines

Live fascines are groups of dormant branches bound together to create a log-like structure that will root and grow, quickly providing plant cover. The bundle is used to revegetate and stabilize slopes, secure the toe of streambanks, or provide a transition from one revegetation technique to another (e.g., a brush mat to a live siltation). Bundles are planted in shallow trenches and provide immediate physical protection to a site before plant growth begins. Bundles create small shelves that collect native seeds and water.(*269*) Environmental stewardship practice guidance on implementing these techniques will be available from NCHRP 24-19 and is currently available from the following states:

- Bundles (Fascines), AK

- Live Fascines, MD

Brush Layering or Branch Packing

Brushing Layering is a revegetation technique which combines layers of dormant cuttings with soil to revegetate and stabilize both streambanks and slopes. It is one of the best techniques for these purposes. Living and non-living brush layers provide fish habitat. Branches are placed on horizontal benches that follow the contour of the slope and provide reinforcement to the soil. Steep slopes and streambanks are better stabilized when a biodegradable revegetation fabric is used to hold the soil in place between the plant layers. Additional stability is provided when the front of the soil layer is seeded with grass while the woody plants are becoming established.(*270*) This technique is sometimes used in channel restoration or river training as well.

Branchpacking is another similar revegetation technique which consists of alternating layers of live branch cuttings and compacted backfill to repair small, localized slumps and holes. One of its advantages is that as the plant tops grow, the branchpacking becomes increasingly effective in reducing erosion and runoff. The trapped sediments then refill slumps or holes while the roots stabilize the surrounding area.(*271*)

Environmental stewardship practices for brush layering are available online in the form of fact sheets and guidelines from the following states:

- Brush Layering, MD
- Brush Layering, AK
- Hedge-Brush Layering, AK

Brush Mattresses

Brush mattresses are a revegetation technique that provides a protective covering to a slope as soon as it is installed. A brush mat can be constructed with dormant branches of willows and poplar that will root and grow. Alternatively a brush mat can simply be constructed with any brushy, woody branches to provide effective slope protection from erosion. A brush mat is often combined with other revegetation and/or protection techniques which are used to secure the toe of the slope including root wads, live siltation, bundles, coir logs and spruce tree revetments.(*272*) Brush Matting/Live Brush Mattresses will be covered in NCHRP 24-19. Environmental stewardship practice guidance on implementing these techniques is currently available from the following states:

- Brush Matting, Alaska
- Brush Mattresses, Maryland

Coir Fiber Logs

Coir fiber logs are constructed of interwoven coconut fibers that are bound together with biodegradable netting. Commercially produced coir logs come in various lengths and diameters, and the product needs to be selected specifically for the site. Fiber logs composed of other sturdy biodegradable materials may function equally as well.

Applications for coir logs occur in many streambank, wetland and upland environments. The log provides temporary physical protection to a site while vegetation becomes established and biological protection takes over. The logs can provide a substrate for plant growth, protect plants growing adjacent to the log, can be used as a transition from one revegetation technique to another, and used to secure the toe of a slope. Both the upstream and downstream ends of the coir log(s) need to transition smoothly into a stable streambank to reduce the potential to wash out.(*273*) NCHRP 24-19 will offer environmental stewardship practice guidance on Coconut Fiber Rolls. Meanwhile, guidance is available on-line in the form of fact sheets and design specifications from the following states.

- Natural Fiber Rolls, MD
- Coir Logs, AK
- Coir Log, WSDOT, p. 31
- Coir Fabric, WSDOT, p. 29

Ditch Lining, Turf Reinforcement Mats, and Geocellular Containment Systems

Ditch lining provides a long/short-term erosion resistant lining of the ditch flow line and side slopes utilizing biodegradable or non-biodegradable geo-textile fabrics and/or angular rock to stabilize ditches and channels from erosion and soil particle movement.(*274*) NCHRP 24-19 will provide environmental stewardship practice for Turf Reinforcement Mats, Erosion Control Blankets (covered in this document under Erosion Control), and Geocellular Containment Systems.

Research on the use of compost blankets in stream rehabilitation projects has found that although flood events completely submerged the compost blankets and much of the staked vegetation, the compost blanket held in place while some of the woody vegetation was destabilized and/or washed won stream.(*275*) It may be advantageous to have the compost contained (e.g., in a sock), because rising stream levels submerge the compost.(*276*) The Washington Department of Fish and Wildlife has produced guidance on Planting Considerations and Erosion Control Fabric that is available on-line.

Other available resources from North Carolina and Washington include:

- NCDOT Slope Repairs Adjacent to Jurisdictional Waters, p. 33
- Concrete Containment (1&2), WA, pp. 34, 37

Other Vegetative Streambank Stabilization and Bank Protection Practices

Shields et al studied the effect of specific woody vegetation combined with rock bank protection finding native woody species, especially willow, to be best adapted to streambank environments; however, success of vegetation was successful only in reaches where the streambed was not degrading and banks were stabilized by grading or toe protection.(*277*) In a similar study, Shields et al combined stone placement with willow planting in a deeply incised sand channel. Stage-discharge, channel geometry and grain size were unaffected, though average depth of scour holes and pool habitat increased along with fish number and size, woody vegetation cover, mean depth and width. Additionally, they reported the occurrence of erosion beneath stones.(*278*) Shields et.al. also conducted a study on the addition of spurs to stone toe protection indicating a modest increase in overall pool width and habitat availability, and local effects on depth.(*279*)

Environmental stewardship practices in streambank stabilization and vegetation are included in on-line fact sheets and guidance from the following states:

- Stream Bank Stabilization (Bio-engineering), WSDOT, p. 141
- Grass Rolls, AK
- Transplanting, AK
- Vegetative Streambank Stabilization, FL, p. 51

Bioengineering Techniques provided by the Washington Department of Fish and Wildlife, cover the following:

- Woody Plantings
- Herbaceous Cover
- Soil Reforcement
- Bank Reshaping

NCHRP 24-19 also has forthcoming guidance on Large Woody Debris Structures as well as a discussion using "Vegetation Alone" in protecting stream banks.

Borrow

This item consists of supplying, loading, hauling and satisfactorily placing additional material necessary to complete embankments to subgrade and other features of the work. Materials should be obtained outside the limits of the ROW.

- Borrow, New Brunswick, p. 4-14

Drains and Trenches

NCHRP 24-19 project lists the following areas in slope stabilization to be discussed in the upcoming publication due in late 2004. Drainage practices discussed as part of this project, NCHRP 25-25(04) include:

- Diversion dike
- Slope drain
- Live pole drain
- Chimney drain
- Trench drain
- Drop inlet
- Fascines with Subsurface Drain
- Flattening
- Stone - Fill Trenches

River Training and Channel Rehabilitation Techniques

Grade Control Structures

Grade control structures are designed to maintain a desired streambed elevation. They can be either used to raise the stream invert to reverse past channel incision or to maintain the channel invert at a current elevation. Common examples of grade control structures are rock vortex weirs and rock cross vanes and step pools.

Low-head stone weirs (LHSW) are boulder structures that extend across the entire bed of a stream channel, and have an effective height of less than 3 ft. The structures are primarily used to prevent streambed degradation, reduce the energy slope to control erosion, create backwater for reliable water surface elevations, and increase aquatic habitat diversity.

Unlike traditional grade control structures, which can adversely impact fish passage, habitat, recreation, and other environmental functions, LHSW are designed to provide stabilization and riffle and pool habitat, reoxygenate water, establish desired substrate characteristics, improve local bank stability, and enhance habitat diversity and visual appeal. LHSW structures are flexible in that their design characteristics can be altered to achieve specific objectives and to address unique site characteristics. LHSW structures are designed to remain stable under the full range of anticipated flow conditions, and to permit fish passage.

All LHSW structures obstruct the flow, creating a backwater area upstream that, at least temporarily, serves as a pool and reduces upstream erosion. Most concentrate the energy losses in a scour hole or dissipation basin immediately downstream of the structure. They can be designed to arrest bed degradation, or can have virtually no effect upon this phenomenon. The extent to which these and other characteristics are manifested depends upon the structure dimensions, shape and orientation, material, and the character of the stream.

A common configuration for conventional LHSW structures is a V-shaped structure with the apex pointing upstream, a depressed central region to serve as a low-flow notch, and boulders or riprap as a foundation with the ends keyed well into the banks. The dimensions can be varied for effect, but the structure height is commonly set at about the bankfull elevation at the banks, and is generally 0-2 ft above the bed at the apex.

The V-shape is intended to concentrate flows in the central portion of the channel and minimize the velocity gradient near the banks. The friction generated by the water flowing over the weir crest causes the streamlines to “bend” approximately perpendicular to the crest alignment. This phenomenon only persists for a narrow range of flow depths (generally less than one fifth the structure height), so on an LHSW with a sloping crest, the effect varies with discharge.

Log and Check Dams

Log and check dams are used to pool water and for grade control. The pooled water is used either to create aquatic habitats or to trap sediment runoff from work sites or drainage ditches along the roadside. Following are examples of these dams available online.

- Log & Rock Check Dams, MD
- Temporary Rock Sediment Dam Type “B”, NCDOT, p. 60
- Rock Check Dam, WSDOT, p. 105
- Step Pools, MD

Flow Deflection/Concentration Practices

Flow Deflection/Concentration Practices are designed to change the direction of flow or concentrate flow within the stream channel. The practices within this group may be used to deflect flow away from eroding stream banks, concentrate the flow in the center of the channel, redirect water in and out of meanders, or enhance pool and riffle habitats. Common practices within this group include rock vanes and log vanes.

Stream Deflectors

- Stream Deflectors, MD
- Wing deflectors
- Single wing deflectors
- Double wing deflectors
- Linear deflector

Vanes

- Cross Vanes MD
- Rock Vanes MD
- J-Hook Vanes MD
- Log Vanes MD

Bendway Weirs

Bendway Weirs are an important tool in current multi-purpose erosion control, stream restoration, and habitat improvement projects. A series of upstream-angled low-elevation stone sills (Bendway Weirs) are designed to control and redirect currents and velocities throughout a bend (and the immediate downstream crossing) of a river or stream. The U.S. Army Corps of Engineers provides an Overview of bendway weirs, What Is A Bendway Weir?, How Do They Work?, Advantages, A Real-World Example, Design Considerations, History And Development, and Applications for Bendway Weirs (Case Studies) along with technical assistance contacts.

Following are some guidelines available online that cover Weirs and Sills:

- Weirs, MD
- Cross Vane Rock Weirs, NCDOT, p. 111
- Sills, NCDOT, p. 110

NCHRP 24-19 Environmentally-Sensitive Channel and Bank Protection Measures will be forthcoming in providing guidelines for the following techniques in the area of River Training (Stream Restoration, Channel Relocation):

- Vanes
- Weirs
- Spur Dikes
- Bendway Weirs
- Stone Weirs

Boulder Placement In-Stream for Habitat Creation

Maryland's Fact Sheet on Boulder Placement describes guidelines for placing boulders in stream channels to encourage riffles and pools and to provide habitat and spawning areas for aquatic life. When properly utilized, boulder placements create small scour pools and eddies which can be used as rearing areas for various species of fish. They can also help restore meanders and pools in channelized reaches and to protect eroding streambanks by deflecting flow. Boulder placements are most effective when used in moderately wide, shallow, high velocity streams with gravel or cobble beds and stream reaches with pool densities less than 20 percent. See guidelines for further details.(280) NCHRP 24-19 will also have information on Boulder Clusters available online in late 2004.

Other Flow Redirection Techniques

Flow Redirection Techniques provided by the Washington Department of Fish and Wildlife, cover the following:

- Groins
- Buried Groins
- Barbs
- Engineered Log Jams
- Drop Structures
- Porous Weirs

Stream Restoration Evaluation and Monitoring

DOTs evaluate and monitor stream restoration efforts to help determine whether the design objectives have been met and in order to identify needed adjustments to design parameters, installation procedures and/or stabilization methods. The following areas are typically monitored:

- Proper functioning of stabilization and grade-control structures.
- Check channel stability by measuring dimension, pattern and profile; particle-size distribution of channel materials; sediment transport; and streambank erosion rates. This is usually accompanied by a reassessment of stream morphology, using permanent cross-section measurement areas.
- Biological response (i.e., vegetation, macroinvertebrates and fish).
- Whether the specific objectives of the restoration have been met.
- On a site-specific basis, shading and temperature are occasionally monitored as well.

Resource agencies generally require photo-documentation to supplement the above. Monitoring often occurs at least once a year for five years after construction.

CTE and the NCDOT developed the evaluation and monitoring recommendations for stream restoration projects as noted in the Appendix:

3.7. Design Guidance for Stormwater and Erosion & Sedimentation Control

All projects should incorporate certain minimum design elements with respect to water quality concerns. Such design goals include the following: (*281*)

- **Minimize Impervious Surfaces:** The intent of this goal is to reduce the volume of runoff.
- **Prevent Downstream Erosion:** Stormwater drainage systems should be designed to avoid causing or contributing to downstream erosion.
- **Stabilize Disturbed Soil Areas:** Disturbed soil areas should be appropriately stabilized.
- **Maximize Vegetated Surfaces Consistent with Existing Policies:** Vegetated surfaces prevent erosion, promote infiltration (which reduces runoff), and remove pollutants from stormwater. See the following section on design for sustainable, low maintenance roadsides.

NYSDOT's Operations & Maintenance Manual for Stormwater Facilities contains the following general pre-construction stormwater facility design considerations: (*282*)

- Discuss proposed facilities with the Maintenance Environmental Coordinator and Residency personnel.
- Make facilities visible. Visible structures get more attention.
- Select low-growing suitable grasses to reduce mowing needs. Add nitrogen fixing plants such as clover to reduce fertilizing needs.
- Incorporate reference points into basins and other features that require clean-out in regard to an absolute elevation. How would someone know how much sediment has accumulated? Percentage of capacity reduction is difficult to estimate.
- Consider mosquito control such as introducing natural predators into a permanent pool (for example mosquito eating fish) or placing commercial mosquito traps. Non-native species should not have a means of escape.
- Features to be maintained must be accessible. Consider access roads, ramps to basin bottoms, sturdy slopes.
- Trash racks should be accessible at normal pool elevations.
- Do not plant trees and shrubs on embankments, side slopes or dam areas.
- Slopes that should be mowed should be 1 on 3 or flatter. If slope is higher than 5 feet, slope should be 1on 4 or flatter. If steeper, explore other treatment options.
- For non-vegetated covers, loose stone or rip rap, which encourages the growth of weeds, should be discouraged. Can consider using gabion lining.
- Consider effects of sediment removal from vegetated surfaces. Can vegetative cover recuperate on its own?

Aesthetic features of the stormwater management facilities requested by municipalities should be maintained by the requester. Commitments by municipalities must be made by signed resolutions.

Almost every state DOT has a guide to development of such plans and design of stormwater BMPs. Detailed selection guidance and information on BMP effectiveness will be available from NCHRP 25-20(01) later this year.

Federally Sponsored Stormwater BMP Manuals

- Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. FHWA-EP-00-002.
- Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements. ASCE/EPA (2002) 821-C-02-005.
- Stormwater BMP Design Supplement for Cold Climates. Prepared by the Center for Watershed Protection for the U.S. EPA.
- EPA's Stormwater Website also contains comprehensive reference and guidance materials for construction site stormwater runoff control and post-construction stormwater management in new development and redevelopment, including guidance on implementation of water quality control measures or BMPs and resources on contractor certification and inspector training, construction review, and BMP inspection and maintenance.

State Sponsored Stormwater BMP Manuals

The U.S. EPA Region 10: The Pacific Northwest provides web links to Stormwater BMP manuals from various State agencies: According to a 2003 survey by the author, 54 percent of all the states have developed a Highway Runoff Manual; Caltrans, FDOT, Illinois DOT, MoDOT, Ohio DOT, and TxDOT completed revisions in the last two years. Almost 30 percent of state DOTs have developed manuals for stormwater management at non-highway facilities (AR, CA, FL, GA, IH, MO, MT, NH, NV, WA) and stormwater manuals for construction(AR, CA, FL, GA, IH, IA, IN, LA, MI, MO, MT, NM, OH, WA.)(*283*) Following is list of manuals available on-line:

California

- California Stormwater Quality Association Stormwater BMP Handbooks
- Los Angeles Stormwater Program (click "Publications")
- California Department of Transportation (Caltrans) Stormwater Quality Handbooks
- Stormwater Quality Handbook - Project Planning and Design Guide
- Caltrans Construction Manual includes details for a wide array of construction drawings and standard water quality best management practices.

Georgia

- Georgia Stormwater Management Manual

Idaho

- Idaho Department of Transportation (IDT) Design Manual (July 2001)

Illinois

- Illinois Department of Transportation. Erosion and Sediment Control NPDES for Standard Specifications for Road & Bridge Construction.

Maine

- Erosion & Sedimentation BMP Manual

Maryland

- Maryland Stormwater Design Manual, Volumes I & II

Massachusetts

- Massachusetts Department of Environmental Protection Stormwater Handbooks

Michigan

- DEQ Index of BMPs/Individual BMPs
- Michigan DOT Drainage Manual

Minnesota

- Protecting Water Quality in Urban Areas: A Manual
- Urban Small Sites Best Management Practice Manual

Missouri

- Protecting Water Quality: A Construction Site Water Quality Field Guide

Montana

- Montana Department of Water Quality – Stormwater Program – BMPs and Erosion Control Plans

New Hampshire

- Innovative Stormwater Treatment Technologies Best Management Practices Manual

New Jersey

- Revised Manual for New Jersey: BMPs for Control of Nonpoint Source Pollution from Stormwater

New York

- New York State Stormwater Management Design Manual
- NYSDOT Highway Design Manual

North Carolina

- North Carolina Department of Environment and Natural Resources

Ohio

- Ohio EPA Stormwater Program Index

Oregon

- Department of Environmental Quality Guides
- Oregon Department of Transportation. Field Manual for Erosion and Sediment Control (2000). The reference for the field guide is the ODOT Hydraulic Manual Volume 2 entitled Erosion and Sediment Control, which provides a source of more in-depth information.

Pennsylvania

- Pennsylvania Handbook of Best Management Practices

South Carolina

- NPDES Stormwater Program Guide
- Sediment, Erosion and Stormwater Management Program Index to Guides

Tennessee

- Tennessee Department of Environment and Conservation Water Pollution Index to Guides
- City of Knoxville, Best Management Practices Manual

Texas

- Texas Nonpoint Sourcebook
- TxDOT "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002)

Utah

- Utah Department of Environmental Quality Stormwater Program Index to Guides
- West Valley City Stormwater Utility Best Management Practices
- Utah DOT Roadway Drainage Manual of Instruction

Virginia

- Northern Virginia Regional Commission Best Management Practices
- Virginia Department of Conservation & Recreation BMP Guides
- Virginia DOT Drainage Manual

Washington

- WSDOT 2004 Standard Specifications for Erosion Control (Section 8-01)
- WSDOT Standard Plans Section I - Erosion Control
- WSDOT Temporary Erosion Sedimentation Control (TESC) Plan Template
- WSDOT When is a TESC plan needed?
- WSDOT 2004 Highway Runoff Manual

- WSDOT Hydraulics Manual

Wisconsin

- Wisconsin Construction Site Erosion Control and Stormwater Management Procedures

Wyoming

- Urban Best Management Practices for Nonpoint Source Pollution

State Stormwater BMP Manual Builder

The Stormwater Manager's Resource Center has developed a "Manual Builder" on-line, a toolbox for developing a stormwater treatment practice (STP) design manual. It includes stormwater treatment plan design and construction criteria and provides schematics and graphics for each practice. It also provides information about maintenance requirements and the typical local review process for treatment plan design and construction. As manuals need to be customized to meet the needs of the state or community where they are being applied, the manual builder does not prescribe one specific set of criteria, but instead presents a series of options for stormwater managers to choose from. A good manual contains specific guidance on how to select, size, design, construct, and maintain practices at each development site.

A typical manual will contain the following elements:

- Basic Stormwater requirements.
- Procedures for Reviewing Stormwater Plans. In this section, the manual outlines the process a community should go through to review the stormwater plan.
- Basic Sizing Criteria. The manual needs to identify minimum sizing criteria for practices to meet groundwater recharge, water quality, channel protection, and flood control requirements.
- List of Acceptable Practices. The manual should include a list of practices that can meet water quality requirements. An engineer can choose from this menu of practices to treat stormwater runoff from a new development.
- Performance Criteria. The performance criteria provide required minimum elements and guidance to ensure that practices are designed and maintained to ensure practice longevity and performance.
- Guidance on STP Selection. This section presents criteria to guide the design engineer to select the best practice for the site, based on characteristics such as soil type, site slope, and the local watershed conditions.
- Stormwater Credits. Stormwater credits are reductions in stormwater volume requirements given in exchange for incorporating site design techniques that minimize the need for STPs on the site. Many manuals do not incorporate credits, because they can increase the burden of review on local governments substantially.
- Design Examples. Design examples step the engineer through designs for a representative group of STP design variations. They should illustrate how to select, size, and locate the practice on the site.

- Construction Specifications. Construction specifications detail specific materials and construction standards that ensure that the practice will function as designed.
- Checklists for Construction Inspection. These checklists outline what minimum elements are needed for each practice group during construction.

In addition to extensive design guidance available in both manual and on-line formats, a number of BMP selection and evaluation systems are emerging. NCHRP 25-25(01) is designing a BMP effectiveness and evaluation system that will be available in late 2004. MDSHA has developed an evaluation system for all stormwater facilities and criteria for improvements. In the late 1990s WSDOT and FDOT also developed systems for categorizing outfalls and, in the case of WSDOT, assessing which projects provide the best return on investment in terms of environmental effectiveness and pollution reduction.(*284*) WSDOT's system included a condition indexing methodology and support program that enables users to quickly evaluate and compare projects and generate benefit-cost ratios for projects. (*285*)

3.8. Drainage Ditches, Berms, Dikes, and Swales

Ditches, berms, dikes and swales are temporary or permanent measures used to intercept and direct surface runoff to an overside/slope drain or stabilized watercourse, away from the road. Several variations of ditch treatments include raised curbs, berms, vegetated, rock-lined, and lead out ditches. Raised curbs, or berms, are used to prevent water from entering or exiting the roadway. Numerous lead out ditches are typically installed to remove water impounded by the curbs and release it where water can be handled appropriately, with minimal resource damage.

Ditch treatments can be used on roadsides, trails, parking areas, urban and rural settings, and any other place where managing runoff is important. A scoured, entrenched roadside ditch and the presence of gullying on the downslope side are indicators that a ditch treatment may be necessary. Ditches, berms, dikes and swales are usually implemented for the following purposes:

- To convey flow around maintenance activities.
- To divert flow away from maintenance stockpiles.
- At the top of slopes to divert run-on from adjacent slopes and areas.
- At bottom and mid-slope locations to intercept sheet flow and convey concentrated flows.
- At other locations to convey runoff to overside/drains, stabilized watercourses, stormwater drainage system inlets (catch basins), pipes and channels.
- To intercept runoff from paved surfaces.
- Along roadways and facilities subject to flood drainage.

Vegetated ditches are ditches with vegetation to reduce water velocities, and erosion control grass mixtures are typically used to vegetate ditches. Vegetated ditches help improve the quality of stormwater that runs off a highway by slowing water velocities and trapping sediment, metals, nutrients, petroleum products, pesticides, bacteria and other contaminants.

Lead out ditches are built to carry water away from the roadway, onto grassed or forested areas, allowing infiltration and dispersion of water. *Rock or stone-lined ditches* reduce velocities and capture sediment in the interstices. Maintenance cleaning is required when trash or debris have accumulated.

Temporary diversion dikes are intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on sloping, disturbed areas. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility. This practice is considered an economical one because it uses material available on the site and can usually be constructed with equipment needed for site grading. The useful life of the practice can be extended by stabilizing the dike with vegetation.

Design and Construction Considerations and Practices for Ditches, Dikes, and Swales

Caltrans has an excellent Fact Sheet on Earth Dikes/Drainage Swales and Lined Ditches available on-line, which provides implementation guidance, drawings, specifications, and maintenance considerations. The EPA and Florida DOT have online information on permanent diversions and diversions. Diversions are preferable to other types of constructed stormwater conveyance systems because they more closely simulate natural flow patterns and characteristics. Flow velocities are generally kept to a minimum. Recommended environmental stewardship practices for implementation of ditches, berms, drains, swales, and diversions include: (*286*)

- Evaluate risks due to erosion, overtopping, flow backups or washout.
- Consider outlet protection where localized scour is anticipated.
- Examine the site for run-on from off-site sources.
- Conveyances should be lined if high flow velocity is anticipated. Consider use of riprap, engineering fabric, asphalt concrete, or concrete.
- Establish adequate vegetation as soon as possible after installation of a diversion.
- Stabilize the drainage area above the diversion so that sediment will not enter and accumulate in the diversion channel.
- Diversions should be constructed before clearing and grading operations begin. If used to protect a flat, exposed area, a diversion might be constructed as a dike or berm. Berms made of gravel or stone can be crossed by construction equipment.
- Diversions should have stabilized outlets which will convey concentrated runoff without erosion. Acceptable outlets include paved flumes, stormwater conveyance channels, outlet protection, and level spreaders. Outlets should be constructed and stabilized prior to the operation of the diversion.
- Disturbed areas draining into the diversion should be seeded and mulched prior to or at the time the diversion is constructed.
- Permanent diversions should include a filter strip of close growing grass maintained above the channel. The width of the filter strip, measured from the center of the channel, should be one-half the channel width plus 15 feet (4.5 m).
- Unless otherwise stabilized, the ridge and channel should be seeded and mulched within 15 days of installation in accordance with permanent seeding.
- If the diversion dike is going to remain in place for longer than 30 days, it is very important that it be established with temporary or permanent vegetation.

- The slope behind the dike is also an important consideration. If the channel slope is less than or equal to 2 percent, stabilization may not be required. If the slope is greater than 2 percent, the channel should be stabilized in accordance with BMPs for stormwater conveyance channels.
- Whenever feasible, the dike should be built before construction begins on the project.
- The dike should be adequately compacted to prevent failure.
- The dike should be located to minimize damages by construction operations and traffic.

Slope Diversions for Intercepting Stormwater

Diversions are channels constructed across a slope with a supporting ridge on the lower side, to reduce slope length and to intercept and divert stormwater runoff to stabilized outlets at non-erosive velocities. On moderately sloping areas, they may be placed at intervals to trap and divert sheet flow before it has a chance to concentrate and cause rill and gully erosion. Diversionsmay be placed at the top of cut or fill slopes to keep runoff from upland drainage areas off the slope. They can also be used to protect structures, parking lots, adjacent properties, and other special areas from flooding.

Diversions are often constructed:

- Where runoff from higher areas may damage property, cause erosion, or interfere with the establishment of vegetation on lower areas.
- Where surface and/or shallow subsurface flow is damaging upland slopes.
- Where the slope length needs to be reduced to minimize soil loss.
- Below stabilized or protected areas. They should not be used below high sediment producing areas unless land treatment practices or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions.
- Diversions should not be placed on slopes greater than fifteen percent.

Level Spreaders

Level Spreaders are outlets for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope whereby concentrated runoff may be discharged at non-erosive velocities onto an undisturbed area stabilized by existing vegetation. Their purpose is to convert concentrated runoff to sheet flow and release it onto an area stabilized by existing vegetation. This practice applies only in those situations where the spreader can be constructed on undisturbed soil and the area below the level lip is stabilized by natural vegetation. The water should not be allowed to reconcentrate after release.

- Level spreaders should be constructed on undisturbed soil (not fill material).
- The entrance to the spreader should be shaped in such a manner as to insure that runoff enters directly onto the 0 percent channel.
- The level lip should be constructed on zero percent grade to insure uniform spreading of storm runoff.

- The released runoff should outlet onto undisturbed stabilized areas in sheet flow and not be allowed to reconcentrate below the structure.

3.9. Design for Sustainable, Low Maintenance Roadsides

An ecologically based program of roadside vegetation design and management seeks to produce low-maintenance, self-sustaining plant communities. WSDOT defines sustainable roadsides as those roadsides that are designed and maintained with the intent of integrating successful operational, environmental, and visual functions with low life cycle costs.(*287*)

The use of native plants planted in the right location is integral to achieving such a sustainable system. This requires good stewardship practice in design:

- **Include a Landscape Architect in the design development process** to improve the design, environmental and visual quality of the roadsides, and chances of planting success.
- **Consider construction requirements such as site accessibility and constraints such as contract timing in design documents.**
- **Ensure noxious weeds are addressed and not incorporated in plantings.** Check with the state's noxious weed control board for a list of noxious weeds in the state if not available through the DOT.
- **Review and comments on plans during the development of the plans, specifications and engineering (PS&E).** Maintenance review (such as by the maintenance supervisor in charge of the contract area) is essential because DOT maintenance crews often maintain landscape projects after installation.
- **Have project partners review design documents and plant material selection prior to installation.** Some projects have special partnership arrangements, for example, the DOT might require the project sponsor or partner to maintain plant communities. Project sponsors have included cities, counties, tribes, transit agencies, and other agencies, who can often contribute labor, funding, and materials.

Integrated vegetation management plans, though oriented to Maintenance needs and covered in detail in that section, also provide guidance in design for sustainable, low maintenance roads. According to the interim report for NCHRP 20-5, 33-04, to be published in late 2004, Alaska, Arkansas, Connecticut, Florida, Illinois, Indiana, Maryland, Pennsylvania, South Carolina, Texas, and Washington indicated that they have policies that include vegetation management considerations in project planning and design phases, and Florida, Indiana, Maryland, Ohio, and Pennsylvania have performance measures for roadside design.(*288*)

Pre-Construction Soil Considerations

Sustainable, vigorous plant growth is difficult to achieve on degraded soils from which topsoil has been removed by construction or erosion. Studies have indicated that plant available levels of phosphorous (P), potassium (K). calcium (Ca), magnesium (Mg), sulphur (S), micronutrients, soil acidity or salt are unlikely to limit plant growth on barren materials.(*289*) Low plant available nitrogen (N) and poor soil physical characteristics that result in poor root development and low water holding capacity remain the most likely and common reasons for poor plant growth, aside from insufficient water.(*290*)

The observation that nutrient deficiency may be a cause of the decline of plant cover is thought to result from the absence of topsoil as a growth medium; during construction the topsoil is often buried beyond the reach of plant roots by fill material (crushed, unweathered, siltstones and metamorphic sediments).(*291*) The loss of topsoil and humus removes the major source of available plant nutrients and reduces soil structure, nutrient retention capacity and microbial activity.(*292*) Microbial activity is reduced because the loss of organic matter eliminates the food supply of plant decomposing microorganisms; with death, the microbial nitrogen is available for leaching from the plant-soil cycle.(*293*) A continuing supply of plant-supplied carbon prevents this loss.(*294*)

In nutrient deficient soils, mycorrhizal fungi typically function to increase nutrient acquisition by plants. This occurs when certain fungi colonize the plant root and form a mutual relationship called a mycorrhizal infection. In this beneficial infection the plant provides energy for the fungi while the fungi provide nutrients for the plant. The loss of the topsoil removes the fungal spores or hyphae which are required to begin the infection.(*295*) The plant is then left without either the original nutrient rich topsoil or the mycorrhizae necessary to improve uptake.(*296*)

Claassen et al. have performed a large percentage of the studies on topsoil usage and compost, with funding from FHWA and Caltrans. Their work and recommendations augment that of DOT handbooks, and are summarized in the remaining bullets in this section.

- **Stockpile topsoil.** Topsoil harvest, stockpiling and reapplication is strongly recommended wherever possible as the best method for restablishment of plant communities on disturbed soils. Equivalent levels of chemical fertilizer cannot substitute for the benefits provided by topsoil reapplication. Topsoil provides, in addition to available nutrients, slow release nutrient reserves, improved soil structure and water holding capacity, increased microbiological activity for nutrient cycling and retention, increased mycorrhizal infection, and a potential source of native seed.(*297*)

  Because of its high soil organic matter content, topsoil is an excellent method of providing the slow release, high N content needed to regenerate barren slopes, as it contains the well stabilized, slow release N needed to reestablish plant communities, as well as plant seeds and microbial inoculum.(*298*)

  - **Stockpiling of topsoils apparently has little or no negative impact on topsoil quality.** Caltrans studies of stockpiled and reapplied topsoils found that storage of topsoil material in a stockpile for periods of up to five months is an acceptable method of handling these materials during construction; topsoil nutrient content and biological quality was not degraded. Infection potential of mycorrhizal fungi did not decrease during stockpiling. Topsoil reapplication improved plant growth by 250 percent after three years compared to fill slopes which had no topsoil, with equivalent application of all other nutrients, erosion control and seed materials.(*299*)
  - **Topsoil fraction had to exceed 20 percent of soil volume before significant improvements in plant growth and soil characteristics occurred. Higher rates are recommended in more severe environments.** Plant and mycorrhizal production peaked in the 60 percent treatments. The researchers extrapolated these greenhouse results to field situations by recommending **10-20 cm (4-8 in) topsoil application over fill material**, if available. If a volume of topsoil equivalent to less than 2 cm (1 in) topsoil is available, it should be concentrated in

smaller volumes such as in furrows or roughened surface, rather than being spread thinly over the slope surface.(*300*)

  - **The soil material which should be harvested includes the** "**duff,**" including decomposed, broken or chipped plant material and the mineral soil material down to the color change from the darker topsoil to the redder or grayer subsoil.(*301*)
  - **Use of moderate amounts of fertilizer can be used to increase the total amount of mychorrhizal infected plants roots.** Moderate fertilization improved plant growth without decreasing mycorrhizal root production. Mineralizable nitrogen was shown to be predominantly derived from soil microbes. Chemical fertilizers cannot by themselves regenerate soils, but their moderate use in conjunction with topsoil application was shown to be beneficial in promoting both plant growth and increased total mycorrhizal infection. Rates of P amendment should be limited to the range of the 39 kg P/ha (35 lb P/ac) treatment because the mycorrhizal infection dropped off significantly when the P rates were doubled.(*302*)

- **Develop a plan for stockpiling and redistribution within the contract's order of work.** Washington State DOT makes the following recommendations with regard to developing a plan for soil preservation; e.g. a plan to stockpile and redistribute existing topsoil within the contract's order of work.(*303*)

  Perform a site analysis

  - Examine proposed planting areas for any apparent drainage problems. Note any underlying characteristics that might affect drainage (hardpan, compacted subsoil, clay layers, and so forth.). Plan to correct deficiencies or plant appropriate species.
  - Analyze soil for susceptibility to erosion from stormwater runoff.
  - Determine solar exposure of slopes (slope aspect) and its effect on soil and vegetation.
  - Conduct a plant inventory or a germination test to determine seed bank to decide if topsoil stockpiling is practical. An examination of the site with an inventory of existing vegetation is necessary prior to determining when to use existing topsoil. Stockpiling of topsoil might not be advisable when noxious weeds and their seeds are present. Consult with a Landscape Architect for assistance. Imported topsoil can be used to provide a medium for plant growth when native soil has been removed or is highly disturbed.
  - Determine where to stockpile soil on-site and the extent of clearing and grading.
  - Set clearing and grubbing limits to minimize soil disturbance. In some areas grubbing is unnecessary. Stumps and root systems may be left in the soil to provide stability. Decomposition of trees varies in time depending upon species and climate, but all decomposition provides nutrients, organic matter, and habitat for microorganisms.

  Perform a soil analysis (type, compaction, and fertility) , including a soil test to determine *nutrient content and pH of soil.*

  - Obtain a soil sample bag or a plastic bag capable of holding approximately one quart of soil
  - Select a representative area for the sample. If the soil seems to vary in color and composition within the project area, sample those soils also.
  - Dig a hole 300 to 460 mm (12 to 18 inches) deep and set the material to the side. Scrape off a small amount of material from the top to the bottom of the side of the hole and place into plastic bag. Do not include any material taken from the hole initially. Refill the hole with the set aside material.
  - Locate the test pit on the site map. If more than one sample is taken from the site, number the test pits to correspond with the samples taken.
  - Seal the bag tightly and place in a manila envelope and write all the information on the paper surface: name, date of sampling, site location, and sample identification (such as test pit #1). Fill out Soil Test Form and include it with the sample; box or wrap sample for mailing; and send the soil sample to a soil chemistry lab.
  - Consult with the Landscape Architect for specific amendment recommendations when test results arrive, if necessary.

  Analyze the soil for compaction. Appropriate soil treatment is crucial for the success of roadside restoration (including erosion prevention seeding). Soil compaction can be tested using the bulk density test. Test the soil to a depth of 0.6 m (2 feet). If the density is greater than 80 percent, take steps to break up the compacted soil. Contact the regional Materials Engineer for assistance.

  - Pay close attention to areas that have been, or will be, staging areas. These areas will have to be ripped to restore pore spaces between the soil particles. Rip compacted soils, ideally in two directions, to a minimum depth of 460 mm (18 inches) before planting. The roots of most plants are above this depth.
  - Specify in all contracts that the contractor has the responsibility to restore the soil to a less than 80 percent density in all staging areas. Higher compaction rates are allowed in areas that are critical for road or structure stability. Include the costs of these procedures as part of the contract. The contract should not be closed until this step is completed.

- **Revegetation success should not be based on short term growth increases in the first season or year**, but performance and biomass production in the 3-5 year range.(*304*)
- **Maximum slope design for topsoil application should be 1½:1 for fill slopes and 2:l for cut slopes.** Placement to topsoil on steep slopes can lead to sloughing.(*305*)
- **Where topsoil is not available other amendments can be used, but the quantity and quality of the N materials applied is critical**. The N release should be **slow enough to keep plant-available N at modest levels**, but the total amount of N amended should be high enough so that the site does not run out of N before the plant community is well established. The N amendment should be **able to support three to five years' plant growth**, for example. Controlled release of N is important because excessive N availability promotes weedy annual grass growth, drying out the site and crowding slow growing perennials. While the maintenance of moderate, sustained nitrogen levels may

be achieved from commercial, slow release fertilizer sources, the inclusion of organic matter in the amendment is also important to improve the hard setting and poor water holding capacity of low organic content materials.(*306*)

- **Biomass associated with compost has been more effective than N amendments** that were evenly disturbed throughout the profile (0-30 cm) or applied deeply within the profile (20-30 cm).(*307*) Studies of plant communities established on "problem soils" amended with commercial fertilizers have shown vigorous initial growth, but that vegetative cover often becomes sparse or nonexistent within several years.(*308*) In addition to transportation related studies, those of fertilized mine reclamation spoil observed that revegetated areas tended to be highly productive for two to five years followed by a sharp decline in plant growth and nutrient availability.(*309*) Reapplication of topsoil to subsurface materials enhanced reestablishment of vegetation by increasing nutrient availability, water holding capacity, and microbial activity.(*310*) Compost can be used to replace the organic matter and nutrients and can act as a surface mulch to protect against erosion, extreme temperatures, and droughtiness.(*311*)

  Long-term nitrogen release rates from most yard waste compost materials approached the N release rates of moderately fertile soils. Composts were shown to be able to regenerate the N availability characteristics of low-nutrient substrates that have been stripped of topsoil organic matter. Well-cured composts and co-composts (biosolids blends) approached the N release rates of highly fertile soils. Compost application provides longer N release duration compared to chemical fertilizer and also provides organic materials for improved infiltration and microbial activity.

- **Potential compost sources and soils at the site should be analyzed before amendment, as compost products and the soils that are to be revegetated vary in fertility and water availability.** Even after adequate N fertility amendment, some sites may still support insufficient plant cover if water or other nutrient deficiencies restrict plant growth. Improved soil and compost tests can guide selection of appropriate amendments to harsh and variable site conditions.
- As compost materials are variable from producer to producer and variability in source material, processing method and curing time have significant effects on field performance, **an interim recommendation is to apply in the range of 72 Mg/ha (dry weight) compost to extremely low-nutrient sites and in the range of 36 Mg/ha compost to low- or moderate- nutrient sites, or sites with shallow soils. Incorporate into the top 15 cm if possible**. Plant-available N on drastically disturbed sites (on which the majority of the topsoil and organic matter has been removed) can typically be regenerated with a 500 to 1000 kg N/ha application of typical, common yard waste compost. This N application rate is roughly equivalent to 36 to 72 Mg/ha dry weight of compost (32, 143 to 64,286 lb/ac), or a volume of 85 to 170 m^3 (45 to 90 cu yd/ac), or a thickness of 0.84 to 1.7 cm (3/8" to ¾"). This rate can be reduced for sites that are not as nutrient poor as drastically disturbed sites.
- **The compost material should be moderately to well cured, meaning 3 to 6 months curing after the thermophillic compost process is to support plant growth.** Recognizing the variability of compost N release behavior, the site should be monitored to detect if plant growth is too slow so that supplemental N can be applied if needed.

- **Yard waste composts need to be aged in order to achieve desirable rates of nitrogen release.** Caltrans research showed that nitrogen (N) release rates change with time with a long-term incubation experience, and that extended curing after thermophilic composting increases N release rate. Long-term N release rates were in the range of the reference topsoils. Finely screened (<9 mm) compost can be applied with hydroseeder equipment, but this application method benefits from the addition of other structural material (straw, coarse wood fibers) to improve erosion control on barren slopes. The findings support the use of compost as a primary erosion control and soil amendment.(*312*) In addition, there is an environmental and social benefit derived from using these waste-stream materials for erosion control.
- **Avoid poorly composted or poorly cured materials**, which, will not be biologically stabilized and can have atypical effects. Information on checking compost processing is available at the Composting Council Research and Education Foundation and at website for the UC Workshop on Compost Use for Pest Management. Cautions regarding use of uncomposted materials, especially in coastal regions are also found online.

  Give special consideration to certain categories of materials, for best utilization in field situations to avoid negative impacts on field sites.

  - **Fibrous or poorly cured yard waste composts can have an initial period of N immobilization** when high carbon materials are being decomposed. This period may last from several months to several years. Additional available N may need to be added to support plant growth N during this period.
  - **Fibrous or poorly cured yard waste composts may benefit soils in other ways than just N availability.** Composts are rich sources of other nutrients as well as organic materials that improve water infiltration into the soil and water retention within the soil. The continued decomposition of compost by soil microbes further helps build soil aggregates, which improves drainage and water retention. If weed seeds and pathogen propagules have been killed, uncured materials can be used as surface mulches, or incorporated if N immobilization is not a problem. Do not transport infested, uncomposted materials to uninfested areas.
  - **Co-composted materials (biosolids blends) have much larger N release rates than yard waste composts.** Co-composts should be used at about one half to one quarter of the amount of yard waste compost or at sites with rapid plant growth to absorb the higher N release rates. Because of the slow rate of N release, most hard waste composts are expected to have small or non-existent potential to leach N to watercourses, even when using large amendment loadings.
  - Sites with residual fertility (topsoils not completely removed, or some soil material has been re-applied to the site) may not need compost amendment. Additional N may accelerate weed growth. Surface applied wood chip mulches may provide erosion control, microbial activity and mulch effects (temperature and evaporation protection) without the additional fertility of a composts material.
  - **Non-composted materials may produce phytotoxic compounds during decomposition.** Any unprocessed plant material amendments other than wood chips should be stabilized using EPA regulation (40 CFR, part 503c)

thermophillic composting, which sterilizes against weed seed and pathogen propagules.

- **While composts are shown to be able to replace the N release function of native soil organic matter *the best method for revegetation is still to harvest, stockpile and reapply the native topsoil that was on the site before disturbance.*** The quality of the organic matter is better, the harvested soil has better aggregate structure, the soil contains microbial inocula and site adapted plant seeds, and the costs are often less than regeneration of soil fertility from component parts. Extra steps may be needed to eliminate weeds, such as spraying, tillage or incorporation of topsoil beneath the surface.

Plans, Specifications, and Estimate (PS&E) for Soil Preparation

The challenge to the roadside designer is to specify the appropriate soil preparation for planting, to prevent soil erosion, and to achieve desired soil structure. Appropriate soil preparation, including possible amendments, is crucial for the success of desirable roadside revegetation.

- Specify **soil amendments** to achieve revegetation and restoration requirements.
- Specify **structural soils** if needed in urban environments. The Urban Horticulture Institute at Cornell University has developed a cost effective structural soil mix that can improve the survivability of street trees in urban environments. The mix is:
    - 80 percent angular stones ¾ to 1¼ inch in diameter.
    - 20 percent topsoil with organic matter content of 10 percent.
    - Soil stabilizer per the manufacturer's specifications.
    - Potable water – enough to cause soil to coat the stones without having water run off.

  Angular stones form a skeleton that provides the weight-holding capability for the mix. Specialized compaction tests are not needed with this mix. The water-storing polymers bind the stones together and stabilize the soil mix. In addition, this structural soil mix leaves a large volume of rooting space that allows the plants to get oxygen and water. More information can be found at the website for the Society of Municipal Arborists.
- Specify wide-track construction equipment in contract documents when it is necessary to work in wet soils.
- Specify stripping topsoil and stockpile for redistribution after completion of rough grading. This is the best source of native seeds but it is also a source of exotic invasive vegetation and noxious weeds. (The plant inventory and germination test performed during the site analysis determine what plants are growing in the soil.)
- Assess the entire project for other places to use removed topsoil. Restoration sites are practical locations to place excess topsoil.

Planning for Native Vegetation and Consistent Roadside Design

A Federal Executive Memorandum on beneficial landscaping became effective in April of 1994, encouraging the use of native plants as much as practicable on all federal lands and in all federally-funded projects. In 2000, this EM was incorporated into Executive Order 13148, on the Greening of Government. That EO also required agencies to purchase "environmentally preferable and recycled content products, including compost and mulch, that contribute to environmentally and economically beneficial practices."(*313*)

The following considerations and specifications are recommended environmental stewardship practices in designing with native vegetation.(*314*)

- Use natural region maps commonly available from the State's Natural Heritage Program instead of cold hardiness zones when designing with native plants. Visit native plant preserves that can serve as references for plantings. The State Natural Heritage Program can recommend sites.
- Use seed mixes specific to the different conditions on the site. Dry conditions may be present on sandy slopes or forest edges and wet conditions in ditches, requiring different or adjusted mixes in these areas.
- Eradicate weeds from planting site before planting.
- Consider a line item for the contractor to control weeds and clean equipment.
- Plant as much diversity as possible, unless an adjacent native seed source exists.
- Match site microclimates with distinct seed mixes as much as practical.
- Specify a locally-grown or collected source if possible. Most native species will establish more easily if locally grown or collected.
- Order native seed when the contract is let to prevent unwanted substitutions.
- Limit bids to experienced contractors and approved vendors for these projects.
- Separate the planting contract from the general contract for best timing.
- Extend the establishment period to three years.
- Learn appropriate seed test criteria and seeding rates to avoid waste.
- Plan for seed collection and plant salvage if native remnants will be disturbed by the project

The following resources may assist designers. The Natural Areas Association, an international nonprofit with a mission to preserve natural diversity, provides information on appropriate management of natural areas. Nature Serve Explorer is an online encyclopedia for 50,000 plants and ecological communities of the United States and Canada. With the common or scientific name of a plant, it is easy to locate the life history, distribution map, and more. The Center for Plant Conservation site offers a State by State Directory of conservation contacts, and the Northern American Plant Society provides an easy way to contact state and provincial native plants plant societies. The Native Plant Initiative, an interagency coalition, has worked together to share information and resources to improve public awareness, educate their own forces, increase planting success, and more. Their Plant Conservation Alliance is online. USDA Natural Resources Conservation Service provides a national plants database. USFWS provides a national list of plant species that occur in wetlands.

WisDOT Uses STURRA to Fund the Ongoing Use and Preservation of Native Plants

WisDOT utilized the 1987 Surface Transportation and Uniform Relocation Assistance Act (STURAA) to fund the ongoing use and preservation of native plants. STURRA contains a mandatory requirement that native wildflower seeds or seedlings or both be planted as part of landscaping projects undertaken on the Federal-aid highway system. At least one-quarter of one percent of the funds expended for a landscaping project must be used for native wild-flowers. WisDOT established a waiver which allows the agency avoid planting native wildflowers where doing so would be inappropriate, but bank the unused dollars for larger projects in the future. WisDOT also banks native plant communities where possible.

WSDOT's Roadside Classification Plan

Roadside management at WSDOT encompasses roadside planning, design, construction and maintenance. The agency identified their primary challenge in roadside management as preservation and restoration of roadside character and to fulfill roadside functions, regardless of fluctuations in funding and personnel. To this end, WSDOT developed a Roadside Classification Plan that provides WSDOT employees a consistent policy to follow on roadside character classifications and appropriate treatment levels for revegetation. The RCP is extensive roadside vegetation management guidance that coordinates and guides all aspects of the management of Washington State highway roadsides. It includes treatment level guidelines for Forest, Open, Rural, Semiurban, and Urban roadside character classifications and treatment tools to restore roadside character in those environments, using native plants, Integrated Vegetation Management, and a long-term management approach to achieve sustainable roadsides.

Designing for Salt Resistant Vegetation

To ensure long-term survival of vegetation in high salt exposure environments, the Transportation Association of Canada makes the following suggestions.(*315*)

- Avoid planting sites in heavy runoff collection areas such as depressions.
- Landscaping should be planted on the back side of ditches to permit maintenance access and ensure that salt laden roadway runoff is not directed towards plants.
- In urban areas protect newly planted conifers by erecting burlap screens during the winter months.
- In urban areas consider applying anti-desiccants and anti-transpirants to the tender shoots of sensitive plants.
- Use species tolerant of salt laden runoff. The following categories of species may be considered:

Example 7: List of Salt Tolerant Trees and Shrubs

Salt Tolerant Trees	
Common Horsechestnut *(Aesculus hippcastanum)*	Austrian Pine *(Pinus nigra)*
Serviceberry *(Amelanchier canadensis)*	Jack Pine *(Pinus banksiana)*
Maidenhair Tree *(Ginko biloba)*	Hop Tree *(Ptelea trifoliata)*
Honey Locust *(Gleditsia triacanthos)*	White Oak *(Quercus alba)*
Tulip Tree *(Liriodendron tulipifera)*	Red Oak *(Quercus rubra)*
Colorado Blue Spruce *(Picea pungens glauca)*	English Oak *(Quercus robur)*
Mugho Pine *(Pinus mugho)*	Black Locust *(Robinia pseudoacacia)*

Moderately Salt Tolerant Trees

Amur Maple (*Acer ginnnala*)	Trembling Aspen (*Populus tremuloides*)
Manitoba Maple (*Acer negundo*)	Cottonwood (*Populus deltoides*)
Yellow Birch (*Betula alleghaniensis*)	Black Cherry (*Prunus serotina*)
Paper Birch (*Betula papyrifera*)	Japanese Pagoda Tree (*Sophora japonica*)
White Ash (*Fraxinus americana*)	Eastern White Cedar (*Thuja occidentalis*)
Large-toothed Aspen (*Populus grandidentata*)	

Salt Intolerant Trees

Balsam Fir (*Abies balsamea*)	Red Pine (*Pinus resinosa*)
Red Maple (*Acer rubrum*)	White Pine (*Pinus strobus*)
Sugar Maple (*Acer saccharum*)	Scot's Pine (*Pinus sylvestris*)
Silver Maple (*Acer saccharinum*)	London Plane Tree (*Platanus acerifolia*)
Eastern Redbud (*Cercis canadensis*)	Douglas Fir (*Pseudotsuga menziesii*)
Shagbark Hickory (*Carya ovata*)	Basswood (*Tilia americana*)
Black Walnut (*Juglans nigra*)	Littleleaf Linden (*Tilia cordata*)
Ironwood (*Ostrya virginiana*)	Hemlock (*Tsuga canadensis*)
Norway Spruce (*Picea abies*)	

Salt Tolerant Roadside Shrubs

Silverberry (*Elaeagnus commutata*)	Staghorn Sumac (*Rhus typhina*)
Sea Buckthorn (*Hyppophae rhamnoides*)	Buffaloberry (*Shepherdia canadenis*)
Common Ninebark (*Physocarpus opulifolius*)	Snowberry (*Symphoricarpus albus*)
Choke Cherry (*Prunus virginiana*)	Japanese Tree Lilac (*Syringa reticulata*)

Moderately Salt Tolerant Shrubs

Forsynthia (*Forsynthia ovata*)	Smooth Sumac (*Rhus glabra*)
Red Cedar (*Juniperus virginiana*)	Elderberry (*Sambucus canadensis*)
Mock Orange (*Philadelphus coronarius*)	

Salt Intolerant Shrubs

Grey Dogwood (*Cornus racemosa*)	Winged Euonymous (*Euonymous alatus*)
Red-osier Dogwood (*Cornus stolonifera*)	High-bush Cranberry (*Viburnum trilobum*)

3.10. Designing to Reduce Snow, Ice, and Chemical Accumulation

The environmental stewardship practices profiled in this section are intended to increase the roadway and bridge designer's awareness and consideration of techniques, configurations, and design parameters to reduce the amount of snow and ice accumulation, and thus sand, salt, and other chemical applications.

Designing Roads to Minimize Snow Drift

Understanding the cause of snow drift accumulations and designing to minimize the causes can reduce the severity of an icing problem, thus lowering salt usage. A significant amount of the snow that needs to be removed from roadways is deposited through drifting. Throughout all phases of roadway development (route location, planning, preliminary design and detailed design) the designer has the opportunity to make decisions regarding the location, configuration, and design details of the facility, which will affect the potential for snow and ice accumulation and the actual application of salt throughout the life of the facility.

Benefit to cost ratios for permanent snow fences, based only on reduced costs for snow removal range from 10 to 35:1, depending on the quantity of blowing snow, according to the National Research Council.(*316*) It costs 3 cents to intercept and divert a ton of snow with a snow fence over the life of the fence, and $3 to plow the same amount of snow.(*317*) Wyoming DOT reports that with the installation of snow fences along Interstate 80, snow removal costs dropped as up to 50 percent and the accident rate during snowy, windy conditions fell by up to 70 percent.(*318*)

Level of service and safety are often improved as well. The Alaska Department of Transportation and public works videotaped snow accumulation on test sections of roadway where it had installed snow fences in order to extend the season in which the roadway was opened. Snow accumulation on the roadway in areas protected by the fences ranged from zero to one meter, but the accumulation on the sections of road without fence protection reached nearly three meters. In the spring, crews took two to four days to clear unprotected sections, whereas only two hours were needed to clear protected sections. Other benefits included reduced labor costs, reduced wear and tear on maintenance equipment, and a safer work environment for road crews.Drifting problems can be increased by poor roadway and bridge design and decreased by good design. By promoting the infiltration of water under pavement, snowdrifts can contribute directly to pavement damage. In addition to serving as a water source, drifts can adversely drainage by blocking ditches, drains, culverts and wildlife crossings. Reduced wind speed areas caused by changes in grade, vegetation, plowed snow banks, safety barriers, and bridge abutments can cause snow accumulation affecting the roadway and/or bridge if the obstructions are close enough to the travel lanes. Drifting can also be controlled through the erection of drift control devices such as snow fence and snow ridges at the proper distance from the road.

- **As a guiding principle, designers should consider maintenance requirements when determining the location, concept designs, preliminary designs and final designs for roadway infrastructure.** Research and case studies have confirmed that there is a direct relationship between certain roadway design parameters, and snow and ice accumulation. It is possible that the incorporation of features to minimize snow and ice build up into a roadway or bridge design will add to the capital cost. However, it is also clear, however, that from a broader life-cycle view, such initiatives are likely to increase safety and reduce maintenance costs throughout the life of a roadway. These trade-offs and value engineering on a life-cycle basis should be considered as an integral part of route location, preliminary design and detailed design. .

The Transportation Association of Canada has outlined the following factors to consider in Roadway and Bridge Planning Design to minimize snow accumulation and salt usage: (*319*)

Example 8: Factors to Consider in Roadway and Bridge Planning Design to Minimize Snow Accumulation & Salt Usage

Meteorological Data

Roadway maintenance staff are often familiar with local conditions and are a source of useful "hands on" information. The following meteorological data should be obtained as background information:

- Average daily and annual snowfall.
- Prevailing wind directions and speeds.
- Storm directions and the amount of snowfall typical to a winter storm.
- Mean monthly temperatures and expected winter extremes.
- Number of freeze/thaw cycles.

Surrounding Terrain

- The terrain surrounding a site will affect the amount of snow that can drift towards the roadway or bridge.
- In establishing the location of a new roadway alignment bear in mind that the upwind terrain is key. The distance from the alignment to any major upwind features (e.g., a ridge, a heavy tree line, a building line, etc.) is referred to as the "fetch". The bigger the fetch, the larger the snowdrift potential and the larger the problem on the roadway or bridge.
- The surface of the upwind fetch area is also a major concern. A "smooth" area such as frozen water or short grass will not trap snow and hence will not assist in reducing drifting conditions. Rougher terrain, such as ploughed fields, crop stubble, long grass, shrubs or particularly mature trees with dense winter branch structure, will trap snowfall and may reduce the potential drifting conditions at the roadway or bridge.

Interchanges

Complex wind flows are associated with interchanges and usually it is necessary to conduct a model study to fully assess conditions.

- From the point of view of snow accumulation, a roadway with a higher level of service (LOS) should cross over roadway with lower LOS as prevailing winds would blow snow off major roadway.
- Open style abutments should be considered over closed abutments to reduce snow accumulation, although the higher cost of open style abutments, and their typically rural nature may dictate the use of closed abutments in many instances.

Roadway Shading / Exposure to Sun

In areas of high tree cover, consider:

- Winter altitude and azimuth (bearing, measured clockwise from true north) of the sun.
- Potential shadow effects of the tree cover which will affect the potential for ice melting on the road surface. Trees should be cleared back far enough to maximize the heating effect of the sun.
- Similar considerations should be given to site conditions where vertical walls are part of the roadway design. In this case, the vertical wall should be replaced with a sloped embankment if possible.

Elevated Road on Fill Section

With divided roadways and a median width which will allow the establishment of independent grades for the two directions of travel, it is desirable to set the elevation of the upwind lanes lower than those of the downwind lanes, or at least, at the same elevation as the downwind lanes.

- Preferably the top of pavement should be approximately 1 m above typical snow depths in the area.
- If possible eliminate the need for safety barriers, and therefore, the obstruction that causes snow drifting with slope flattening of fill side slopes. Ideally, side slope should be flattened to 7:1 for effective snow accumulation.
- Generally, a road cross-section totally on fill without significant terrain features upwind is more likely to blow clear of snow than any other design configuration.

Wide Ditches
Wide ditches provide storage for plowed snow which otherwise would be piled along the edge of the roadway and would promote more snow accumulations.

Use of Guide Rails

- Box beam / cable guide rails have the least obstruction and in theory, accumulate the least amount of drifted snow but in practice, plows push snow against box beam / flex beam to create a solid barrier therefore, for the purposes of snowdrifting / accumulation, assume all barriers are solid.
- Solid Jersey barrier is easiest to plow against.
- Tall solid barrier has increased drifting area and increased shaded area.
- Flex-beam guide rail, in theory, collects the largest amount of drifted snow.
- Reduce the need for barrier at side of roadway through slope flattening.

Berms for Snow Accumulation

- Locate berms unpwind of the roadway, setback 7 times the berm height.
- To obtain the maximum snow collection capacity, maximize the berm height and ensure berm slopes are as steep as practical.
- One tall berm is more efficient at accumulating snow than a number of rows of shorter berms.
- To maximize the effectiveness of tree plantings, locate trees on a berm. However, the setback should be 15 times the combined height of the berm and coniferous tree planting.

Backslope
Flatten upwind backslope (ideally 7:1 or flatter) to minimize drifted accumulations on roadway.

- With roadways in cut sections, consider a wider cut on the upwind side than on the downwind side, ideally meeting the 7:1 minimum gradient discussed above. If the roadway cut is a source of material for other sections of the roadway, consider taking the majority of the material from the upwind side of the cut.

Obstruction Close to Roadway

- Obstructions that can cause snow accumulation problems are as follows trees too close to road; mail boxes; utility poles; guide rails; plowed snow banks; and fence rows.
- Consideration should be given to eliminating / minimizing these obstructions if they are causing snow accumulation problems.
- Where possible locate obstruction on downwind side of roadway.
- As a general rule of thumb a 50 percent solid obstruction (snow fencing, vegetation) should be placed a distance of 15 times its height from the edge of roadway, on level ground. A solid obstruction (buildings, double vegetation) should be placed 10 times its height on level ground.
- Noise walls do not typically present a problem with snow accumulation as they usually are located in residential areas that limit snow movement towards the wall and the roadway, however snow drifting at end details should be considered.

Vegetation Management
With appropriate landscape design, many snow drifting problems could be solved or lessened. Similarly, improper design or placement of vegetation can aggravate a snow accumulation problem (particularly at interchanges).

- Before vegetation is removed for the construction of new roadways (or for existing roadway improvements) designers should evaluate existing site conditions in order to determine whether or not existing vegetation could prevent a snow related problem or could cause a future snow related problem. Preserving existing vegetation is more economical and time efficient than planting new vegetation. This approach also allows existing vegetation to be incorporated into new landscape plans.

- The objective of upwind snow fences (non-living or living) is to encourage a snow drift immediately downwind of the fence or vegetation with the result that little snow is left to drift onto the roadway.
- Upwind vegetation planting can have a similar effect to snow fences providing the configuration and location is appropriate and the planting is not close to the roadway.
- Plants with dense branch structure will hold snow to approximately one half its height. Trees and woody plants are better as they do not tend to bend as much under the weight of the snow.
- Corn stalks left in agricultural fields on the upwind side can slow wind speed and reduce drifting and blowing snow. Five or six rows of corn with a similar setback to that shown in Figure 13 will be effective in reducing snowdrifts.
- Uncut grass in the ROW is better than cut grass as it keeps snow from blowing with the exception of grass directly adjacent to the roadway, which ideally should be cut short to avoid drifts that would extend onto the roadway.
- If there is sufficient land area available, at least 60 metres, a snowbreak forest is a viable option. However, a much more economical solution for new roadways is to retain existing forest. This saves the time required for newly planted vegetation to reach their required height. Snowbreak forests also provide substantial benefits to wildlife and may be managed for timber production.
- As the transportation right-of-way is usually too small to accommodate the setback required for living snow fences, cornrow fences, snowbreak forests or even structural snow fences; it may be necessary to enter into land use agreements with private landowners.

Urban Considerations

In an existing urban environment, little can be practically done to reduce snow accumulation, as roadway rights-of-way are constrained and adjacent lands typically built-up; accumulated snow is removed as per the municipalities' snow removal program.

- Snow storage in an urban environment is often a challenge and consideration should be given to providing larger cul-de-sacs, bicycle paths and wider curb lanes (especially across bridges) for temporary snow storage, where appropriate.

Drainage

Good roadway drainage will lead to reduced ice accumulation, and as such reduced salt usage (this includes intersecting roadways and accesses as well as the main roadway).

- Set maximum and minimum grade to help maintain an even distribution of salt, and to allow melted ice/snow to drain to catch basin.
- Optimize salt usage by using lower superelevation rates (to help maintain even distribution of salt).
- Use crowned roadways, and good crossfalls (2 percent-3 percent).
- Mark all culvert ends to make them easier to locate for cleaning and thawing activities.

Pavement Choice in Salt Vulnerable Areas

- Though open friction course asphalt or grooved concrete pavements will shed surface brine more quickly, they can reduce salt spray and therefore may be beneficial in proximity to areas that are vulnerable to the effects of salt spray.

SHRP Report H-381, Design Guidelines for the Control of Blowing and Drifting Snow, also describes how to design effective and economical measures for controlling blowing and drifting snow, including various snow fence designs to accommodate land use and right-of-way considerations; considerations for pavement design and appurtenances; proper siting of snow fence to compensate for terrain; and ways to use trees and plants as natural snow fences. The field research and sources of information are included too.(320)(321)

Designing Snow Fences

Highway segments with wide, open stretches are vulnerable to blowing snow accumulation on the surface and reduced visibility for roadway users. Traditional snow fences are designed to permit 40–60 percent airflow, slowing the wind and piling the snow safely downwind. The Strategic Highway Cooperative Research Program's Snow Fence Guide provides construction plans and guidelines for placement of snow fence for maximum effectiveness and cost-efficiency, as well as ways to work with landowners to obtain cooperation with a snow fence program.(*322*)

Consideration should be given to the use of roadside plantings or solicited cooperation from local municipalities to require land owners/developers to include plantings in their buffer zone plans to curtail drifting. Another means is to request farmers to leave corn stalks high where the land adjoins a state highway.

If properly designed, tree plantings can be as effective as structural snow fences. The requirements for effective living snow fences are the same as those for structural snow fences

- Adequate snow storage capacity
- Absence of openings or gaps
- Adequate setback

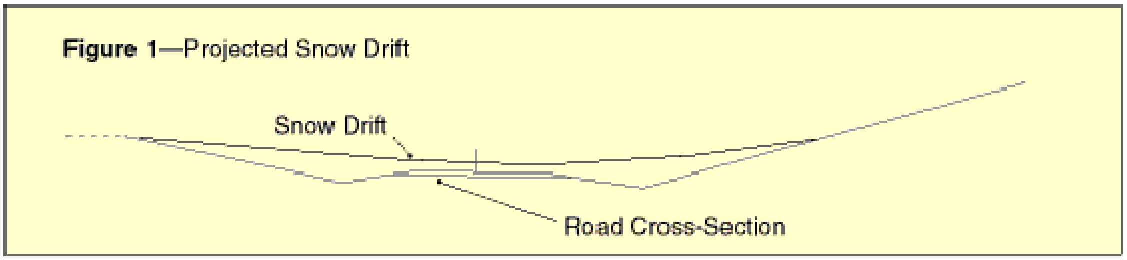
Snow Fence Site Design and Placement Tools

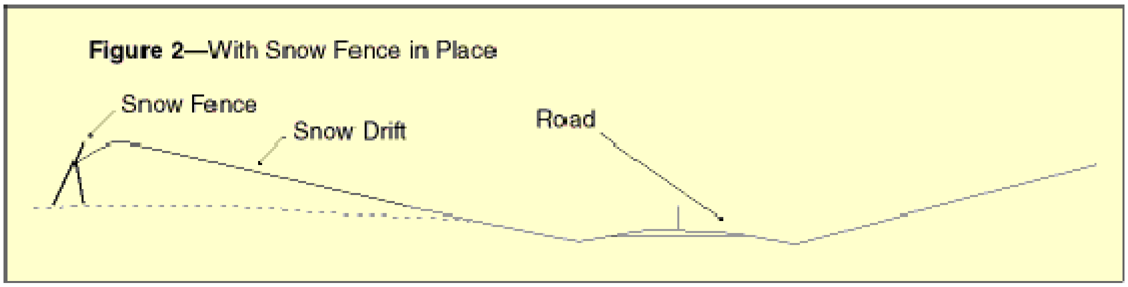
WYDOT and NYSDOT Software

For nearly 30 years the Wyoming DOT (WYDOT) has been using snow fences to prevent blowing and drifting snow from covering roads and impairing motorists' ability to see other vehicles, reducing maintenance costs and salt application and runoff to the environment at the same time. To ease the process of determining exactly which sections of road will be affected by blowing and drifting snow and where snow fences should be placed or the topography should be changed to keep roads clear, WYDOT developed software tools based on research conducted under the Strategic Highway Research Program (SHRP).(*323*) The research resulted in precise guidelines for placing snow fences for maximum benefit, using average snowfall, winter temperatures, wind speed and direction, and the project site's topography. The WYDOT software handles virtually all the steps in the SHRP guidelines, from assembling the needed weather information to determining the location of a snow fence. The system has two components. The first is a set of computerized maps containing information on prevailing winds and average snow accumulations. The second component is a customized snow drift module that works with commercial roadway design software. The snow drift module, which uses the formulas in the SHRP guidelines, determines where snow drifts will form based on prevailing weather conditions and the project site's topography. The module determines if the site's weather conditions and topography will cause a snow drift to form on the road and plots the shape and location of the drift (Figure 6-1 below). If the user adds a snow fence upwind of the road, the module plots where the drift will form, showing at a glance that the fence will protect the roadway (Figure 6-2 below). Designers can also change the topography of the road to prevent a drift from forming.(*324*)

NYSDOT has contracted with the State University of New York–Buffalo and Brookhaven National Laboratory to develop a similar software program that will allow roadway design engineers and maintenance engineers to enter readily available or easily obtained information on weather and topography and then determine the best approach to snow drift control at the site—redesigning the highway cross-section, installing snow fences, or planting trees or other vegetation. The ability to look at different solutions makes the software particularly useful for states where the lack of public land and the relatively high population density can make it hard to find suitable locations for snow fences.

Figure 6: Projected Snow Drift with and without Snow Fence in Place





From June 1998, FOCUS, http://www.tfhrc.gov/focus/archives/Fcs698/068snow.htm

Mn/DOT Snow Fence Design Module

Mn/DOT funded a team of researchers and practitioners to develop a model to determine proper mitigation strategies, including appropriate living snow fence design. Entitled Implementation of Climatological Summaries for Blowing Snow Control: Design, Training, and Website Development, the project investigated several climatological factors such as snowfall season (onset and end date), snowfall amount and density, and wind frequency distributions.

To check for potential problems when designing a roadway or solve a drifting problem on an existing roadway, two parameters must first be quantified. These are the total seasonal snow transport, and the direction of greatest snow transport. Research results from a previous project provided the necessary climatological data to quantify these parameters on a site-specific basis. The three attributes that are required are: 1) length of snow season, 2) snowfall during the season, and 3) the potential snow relocation coefficient based on topography, wind speed, and vegetative cover. Data were analyzed using a database containing the climatic history of 370 locations, some dating back to the 1850s. With this information, a web-based snow-control design module was developed that allows users to obtain necessary climatological attributes for various road and snow fence designs. The web site is an interactive snow control design tool utilized by design/pre-design Mn/DOT personnel and natural resource managers. With it designers can utilize this site to:

- Obtain necessary climatological information for GEOPAK,

- Test for problems on an existing roadway and investigate possible solutions, and
- Design a living or structural snow fence for a given problem area. The web environment allows the user to select any location in Minnesota and in so doing; necessary climate information will be given.

Plastic Snow Fence Research Results

Research on the configuration of the openings in plastic snow fence by the North Dakota Department of Transportation indicated that the configuration did not have a bearing on the amount of snow that accumulates in front of the fence; however, the Morton County road crew who installed and maintained the fence made the following observations: (*325*)

- Plastic fence is easy to handle, not near as bulky as wood fence. A two-person crew can handle the installation.
- It is critical to have a good installation, solid end posts, and midway supports such as lath. If end posts loosen, the fence will sag and become ineffective.
- There is considerable variation in the quality of the fence, with some types tearing more easily and some that are more difficult to handle.
- More maintenance is required with plastic fences than with wood fences.
- The effectiveness of plastic fence in holding back snow appears to be as good as wood fence.
- Costs of plastic fence vary considerably. Usually plastic fence is considerably less costly than wood fence; however, a high-quality plastic fence may cost almost as much as wood fence and should have a useful life considerably longer than a wood fence, since wood slats and wire tend to break.

Living Snow Fence

All of the principles pertaining to snow fences apply to vegetative barriers as well, but guidelines for plantings must consider the variability or irregularity of height and porosity, and how these factors change with time. In addition, biological requirements must be considered in the planting and maintenance of living snow fences, as well as ecological factors that affect survival and growth. For these reasons, designing living snow fences requires the knowledge of agronomists, foresters, landscape architects, and engineers. Living snow fences include rows of trees and shrubs that, if planted in the right location, can cause snow to accumulate in a more convenient area and can also improve visibility during and after snowstorms. Considering direct and indirect costs, living snow fences cost about the same as structural fences.(*326*)

Living Snow Fence Placement and Design

The following guidelines for living snow fence placement and design were developed by Mn/DOT.(*327*)

- To improve visibility and/or prevent drift accumulation on highway sections in areas where there is 10,000 feet of “fetch distance” (open distance perpendicular to the centerline), a living snow fence should be planted 250 feet from the centerline. Note that normal rights-of-way are typically 75–100 feet from the centerline, but that planting on existing rights-of-way may extend drift formation onto the road surface. In these situations, additional right-of-way should be purchased, or easements obtained, to plant the snow fence. In areas where the “fetch distance” is only a few thousand feet, a living snow fence planted 100 feet from centerline will still be effective.

- A strip of tall grasses 12 feet wide will actually trap the snow and hold it. Native grasses are an attractive addition to farmsteads and field borders because they remain upright during the winter and provide wildlife with excellent cover for the winter and nesting habitat in the spring.
- Proper design of a living snow fence involves three key elements: height, density, and length.
- **Height:** This affects the snowdrift length and depth. Snow storage capacity increases by more than four times when the height is doubled. Typically, vegetative barriers should be set back from the area to be protected 10–15 times the mature height of the vegetation.
- **Density:** This affects both windward and leeward snowdrift lengths and heights. The species, number of rows, and plant spacing determine density. Winter density of deciduous trees must also be considered. Density should be uniform with no openings and gaps.
- **Length:** This determines the maximum length of the area that can be protected. Less snow is stored at the ends of barriers, so the snow fence must extend 100 feet beyond the area to be protected.

Strategies in the Use of Plant Materials

There are two basic approaches to the use of plant materials to control blowing snow:

- **Snow collection** – Trapping incoming blowing snow with rows of trees or shrubs
- **Snow retention** – Holding the snow in place with grass, shrubs, or trees. These control measures will be referred to as *retention plantings.*

The latter strategy is applicable where the source of the blowing snow is confined to the immediate vicinity of the road, such as embankment slopes, medians, and interchange areas.

Selecting Plants for a Living Snow Fence

Trees and shrubs suitable for drift control should have relatively dense foliage that extends to ground level. General recommendations include:

- Use dense foliage species that are fast growing; resistant to drought, frost, and disease; unpalatable to livestock and wildlife; tolerant of crowding without shedding lower branches; and should have a service life of 30 to 50 years. Secondary considerations include ornamental value and value for cover and food for wildlife. Coniferous species have the advantages of year-round dense foliage and relatively low palatability for wildlife. Deciduous trees and shrubs can also be used, but more rows are generally required and many species are browsed preferentially by livestock and wildlife.
- Use plants that are adapted to site conditions such as soil pH, soil moisture extremes, and soil texture. County extension services can provide information regarding general conditions, but the advice of a forester or agronomist should be sought for recommended species for climate and soil conditions at specific sites.

- Avoid self-pruning species.
- Avoid plants for which a major insect or disease is known to cause problems with establishment and long-term survival. Most plants have characteristics that make them susceptible to one or more problems, such as insects, disease, and storms. Although in most cases pest- and weather-related problems are minor concerns, selecting a variety of plants with similar growth and site requirements can minimize the risk of a single problem destroying the snow fence planting.
- Shrub rows between the road and tree plantings provide a temporary control until the trees become fully effective.
- The best in-row spacing for coniferous trees is approximately 2.4 m (8 ft), with rows spaced 2.4 to 3 m apart (8 to 10 ft). Three rows are recommended to reduce the possibility of gaps forming when trees die.

The Minnesota Interagency Living Snow Fence Task Force developed "winning combinations" for snow fences, based on observations made during the winter of 1996–1997, site visits, past experience, and recent work understanding snow transport. The required fence height and setback for any of these combinations is based on the principal of snow transport. Design criteria can be obtained from the 1999 publication titled "Catch the Snow with Living Snow Fences," published by Mn/DOT Office of Environmental Services. The five winning combinations for use as a living snow fence are:

- Twin row tall grass native prairie snow catch
- Twin shrub row
- Deciduous tree windbreak
- Vertical side community shelterbelt
- Structural snow fence

Partnerships with Farmers to Leave Standing Corn

Iowa DOT is using standing-corn snow fences to save about 75 percent of the cost of erecting snow fences. In several Iowa counties, farmers are paid 50 cents more than market price to leave four to six rows of corn standing in areas where there are major problems with drifting snow on the roadway. This natural snow fence also helps improve visibility during snowstorms. Farmers benefit by a fair price for their corn, which is often picked by nonprofit groups in the spring. If the corn is given away at that time, the farmers may deduct the value of the corn as a charitable donation.(*328*)(*329*)

Minnesota DOT will pay $1.50 more than the current bushel price for cornstalks that farmers leave standing in their fields to act as living snow fences. Mn/DOT determined that one 40-foot-wide, quarter-mile-long snow fence is capable of capturing 11,800 tons of snow, minimizing snow and ice on roads and decreasing removal costs.(*330*)

Designing Drainage to Minimize Anti-Icing and Deicing Impacts to Natural Resources

The main purpose of any road drainage system is to safely convey runoff downstream to either a natural or man-made drainage system. Management measures should be implemented to ensure that this is done with minimal impact to the infiltration characteristics, water quality, erosion potential, and flood risk of the receiving drainage system. Training for drainage designers should include design options for managing the adverse effects of snow and ice control chemicals. Drainage designers need to consider the environmental setting into which their drainage system will be placed. The Transportation Association of Canada's synthesis of best practice for doing so recommends the following: (*331*)

- **At the onset of any drainage design, sufficient information should be collected to characterize the existing drainage system surrounding and downstream** of the roadway.
- **A surface water assessment should be completed to identify all potential impacts to natural features as a result of the roadway.** The assessment should include a review of the impacts of salt-laden surface water on potable water taken from **groundwater sources, sensitive aquatic habitat, agricultural lands, wetlands, and wildlife.** The requirements of the assessment are defined by the policy framework in the area where the drainage design is being completed. Specific site characteristics may require that other features be considered as well. The impact potential identified for all significant features assists in the selection of suitable mitigative measures.

  Oregon DOT recommends review of the following environmentally sensitive areas and natural resources:(*332*)

  - Spawning streams and those inhabited by protected aquatic species, especially salmon and trout.
  - Those receiving direct runoff from treated roads & highways where there would be less than 100:1 dilution.
  - Those where a large volume of highway runoff can directly reach small, poorly flushed ponds, lakes and wetlands.
  - Those where receiving water temperatures have warmed by the time highway runoff arrives.
  - Those areas where shallow ground water is overlain by very coarse and permeable soils.
  - Drywells, French drains, or similar facilities that allow surface water access to underground aquifers.
- **The relative importance of each feature as defined by low, medium or high potential for impact should be established.** Further guidance on considering impacts to various classes of resources is included below. The potential for salt impacted drainage to affect each of these vulnerable areas should be assessed.

Groundwater

The suitability of groundwater for potable use and irrigation can be significantly impaired by the infiltration of salt captured by roadway runoff. For example, the Maine DOT noted that road salt is gradually accumulating in bedrock aquifers, causing some drilled wells to become unusable. The rate at which salt enters aquifers and how much salt is eventually discharged naturally from aquifers is unknown, making prediction of long-term impacts problematic. In 2004, MDOT decided to establish two sites where new highway construction is proposed for monitoring well installations over the next five years.(*333*)

To determine the potential for impact from salt-laden runoff on groundwater, the following questions must be addressed:

- Are there domestic wells near the roadway?
- If there are wells, do they draw from a surficial aquifer?
- Are the surficial soils permeable (sands and loams)?

Aquatic Habitat Impacts

Salt-laden runoff can potentially impact aquatic habitat in two ways: sudden pulses of chlorides during spring runoff, and continuous levels of chloride present in the groundwater discharging to the receiving stream. Although both types of impacts are a concern, the literature generally points to sudden pulses as the greater concern. With either type of impact, the existing literature is not clear on "how much is too much." The following provides a guideline for assessing the potential impact:

- High: The receiving watercourse has a permanent baseflow, and the catchment area of the road represents more than 10 percent of the catchment area of the stream.
- Medium: The receiving watercourse has a permanent baseflow, and the catchment area of the road represents less than 10 percent of the catchment area of the stream.
- Low: All other cases (i.e. receiving watercourses with no permanent baseflow).

Agricultural Land

Salt-laden runoff can impact crops in cases where there is the potential for water to pond on agricultural lands. This situation can arise where there is poor positive drainage or an outlet has been blocked by ice or debris. Guidelines for assessing potential impacts are as follows:

- High: Agricultural land is adjacent to the road, and off road drainage has a high likelihood of ponding or blockage.
- Medium: Agricultural land is adjacent to the road, and off road drainage has a low to moderate potential for ponding or blockage.
- Low: Agricultural land is either outside the road runoff influence zone, or there is no agricultural land adjacent to the road.

Wetlands

Swamps, peat bogs, marshes, and other types of wetlands can be impacted where runoff is directed to natural roadside vegetation features. In these cases the runoff may enter the wetland as sheet flow or via a roadside ditch. With very high and prolonged chloride loading, changes in local plant composition may occur, with the possibility of a reduction in the overall value and diversity of the wetland. Small, perched wetlands that intercept the shallow water table or that are primarily surface water dependant may be most susceptible to chloride loading effects due to their small size and a reduced dilution potential. Large wetlands with extensive catchment areas and high dilution potential are likely more tolerant of chloride loading. Potential impacts may be classified as follows for wetlands located adjacent to the roadway:

- High: No clear flow path evident through the wetland and/or small perched roadside wetlands present (<5 ha in size).

- Medium: Poorly defined channel evident through the wetland and/or moderate sized wetland with better dilution potential (5 -20 ha in size).
- Low: Clearly defined channel evident through the wetland and/or large wetland with good dilution potential (>20 ha in size).

Wildlife

Ponded runoff can serve as a salt source for wildlife. The attraction of the wildlife to the saltwater can be a safety hazard. Potential impacts may be classified as follows:

- High: Roadway located in an area where large mammals (such as elk, big horned sheep, white-tailed deer and moose) are present and where roadside ponding is a current problem or has a high potential based on design limitations and topography.
- Medium: Roadway located as above but roadside ponding is not a current problem or has only a moderate potential based on design limitations and topography.
- Low: Roadway located as above but there is no existing or future roadside ponding problem, or large mammals are limited or absent in the area.

Structural Roadside BMPs to Control Deicing and Anti-Icing Chemical and Abrasive Laden Runoff

The range of potential impacts from salt-laden runoff offers considerable challenges to the designer. There are a number of practices that can aid in the management of runoff, however each practice may mitigate some types of impacts while accentuating others. For example, promoting rapid conveyance of runoff to a receiving watercourse will reduce the potential for impairment of potable groundwater while increasing potential impacts on aquatic environment. Special design modifications to traditional stormwater management measures may be warranted to protect vulnerable areas. Measures to protect salt vulnerable areas may include clay or geosynthetic liners in conveyance ditches and ponds, infiltration ponds, or use of storm sewers to transport drainage past vulnerable areas.

The Transportation Association of Canada (TAC) recommends consideration of eight alternative management practices, which are often used to achieve other drainage objectives and may be used in combination to effectively minimize impacts related to salt rich surface drainage.

- **Records should be kept on the chloride or conductivity levels and snow and ice control events to determine how the levels fluctuate around an event and whether BMPs are having the desired effect.** The analyst will want to be able to draw conclusions on whether or not the applications of best salt management practices are having an effect on the chloride levels in the aquatic environment. It will be important to determine whether or not drops in chloride levels can be attributed to improved practices and not just different weather conditions. This will require coordination with Maintenance.

TAC's table below illustrates the merits of each management practice in addressing the potential impacts that can result from salt-laden runoff. Practices which benefit groundwater impacts are typically consistent with those that benefit agriculture, wetlands, and wildlife. However, most of these practices have the potential to negatively impact aquatic resources. Thus, measures should be selected as part of the overall management strategy formulated to achieve overall drainage and stormwater management objectives. In cases where objectives are conflicting, the practitioner must review each site on its own merits and set priorities such that the overall impacts are minimized. In addition to local policy frameworks, design information for these measures can be found in numerous technical documents relating to stormwater management.(*334*)

Table 9: BMPs for Minimization of Salt-Related Impacts - Transportation Association of Canada

Management Practice	Purpose
1 Sheet Flow	Runoff conveyed across grass buffer strips or embankments.
2 V-ditch	Runoff conveyed by roadside ditch to receiving watercourse.
3 Storm Sewer	Runoff conveyed away from sensitive areas using storm sewer system (negligible infiltration potential).
4 Flat Bottom (Trapezoidal) Ditch	Runoff conveyed by roadside ditch with flat bottom ditch.
5 Flat Bottom (Trapezoidal) Ditch with Storage	Runoff conveyed by flat bottom ditch which includes on-line storage to trap sediment and reduce velocities and runoff rates.
6 Dry Basin (Pond)	Runoff directed to stormwater management basin designed to reduce runoff rates and promote sedimentation.
7 Wet Basin (Pond)	Runoff directed to stormwater management basin designed to reduce runoff rates, promote sedimentation and enlarge biological uptake.
8 Buffer Strip and Containment Berm	Berm designed to contain runoff within buffer strip, with positive outlet provided to prevent flooding and sustained water levels.

From Transportation Association of Canada, “Syntheses of Best Practices: Road Salt Management.”

Table 10: BMP Characteristics and Impact on Minimization of Salt-Related Impacts - Transportation Assoc. of Canada

Management Practice	Characteristics	Feature that May be Impacted: Ground-water	Aquatic Habitat	Agriculture	Wetlands	Wildlife
Sheet Flow	Disperses runoff	-	+	0	0	0
V-Ditch	Channels runoff	+	-	+	+	+
Storm Sewer	Channels runoff with little opportunity for infiltration	+	-	+	+	+
Flat Bottom Ditch	Channels runoff Some attenuation of flow rate Some sediment trapping Some potential for infiltration	0	-	+	+	0
Flat Bottom	Channels runoff	-	+	+	+	-
Ditch with	Attenuates flow rate Some sediment trapping Some potential for infiltration					
Dry Basin (Pond)	Attenuates flow rate Sediment trapping Potential for infiltration	-	+	0	0	0
Wet Basin **(Pond)**	Attenuates flow rate Sediment trapping Potential for infiltration	-	+	0	0	-
Buffer Strip and Contain-ment Berm	Contains and disperses runoff	-	+	0	+	-
Legend:	+The identified management measure may reduce the level of impact from salt-laden runoff (i.e. The level of impact potential for a feature may be decreased from high to medium, medium to low, etc.). - The identified management measure may increase the level of impact from salt-laden runoff (i.e. The level of impact potential for a feature may be increased from low to medium, medium to high, etc.). **0** The identified management measure will have minimal effect on the level of impact potential.					

From Transportation Association of Canada, "Syntheses of Best Practices: Road Salt Management."

Snow Disposal and Snow Storage Site Design

At high latitudes, snow plowed from streets accumulates rather than melts. As plowed snow accumulates and exceeds available storage space along streets, it is hauled to central storage areas and placed as a compact snowfill. A portion of the applied grit and salt, as well as fugitive pollutants from vehicles, becomes incorporated into hauled snow. Heavy metals, inorganic salts, aromatic hydrocarbons, litter, debris, and suspended solids accumulate on road surfaces along with oil, grease, rust, hydrocarbons, rubber particles, and other solid materials deposited by vehicles. Runoff, snow, and melt water collect these pollutants, along with debris, and chloride, sodium, and calcium from winter road operations.(*335*) Such contaminants become pollutants when they interfere with the normal life cycle functions of organisms living in or dependent on the water source.(*336*)

The Alaska Department of Transportation and Public Facilities (ADOT&PF) is synthesizing best management practices (BMPs) for handling and treating the melt water snow storage areas, including performance requirements for runoff treatment in the various water quality management jurisdictions and climatological regions, potentially applicable technologies/BMPs that have been used successfully in other locations and jurisdictions, the applicability of available technologies/BMPs, cost effectiveness of various potentially applicable BMPs, and research and development needs for BMPs.(*337*) The Municipality of Anchorage (MOA) conducted a four-year study of snow disposal sites from 1998 through 2001, sponsored by the MOA Street Maintenance Department and the ADOT & PF, Central Region Maintenance and Operations that revealed three important factors related to how pollutants are released during melting: initial source of hauled snow, melt processes of stored snowfall, and shape of storage areas and the snowfills).(*338*) The study concluded that: (*339*)

- Chloride can be controlled passively only through detention and dilution.
- Mobilization of metals and polynuclear aromatic hydrocarbons relates to chloride concentration, but a large fraction can be controlled with particulate capture.
- Particulate loading in meltwater relates to the shape of the snowfill and the pad on which it is situated and can be controlled by manipulation of these elements.

Control of Chloride through Detention and Dilution

Chloride is not readily treated by simple technologies. Passive (non-chemical) treatment of chloride is best addressed through: (*340*)

- Control of street treatment processes (i.e., reducing use of salt).
- Dilution of early meltwater discharges. The necessity for dilution and the potential for impact to other local resources from elevated chloride requires careful consideration to facility siting.
- Application of snow disposal site location criteria. Analysis of Anchorage salt application practices suggested that total chloride loading could be reduced by as much as 60 percent through use of heated sand sheds.

Control of Particulates and Subsequent Mobilization of Metals and PAHs

As noted in the Alaska study, mobilization of metals and polynuclear aromatic hydrocarbons (PAHs) relates to chloride concentration, but a large fraction can be controlled with particulate capture. Furthermore, particulate loading in meltwater relates to the shape of the snowfill and the pad on which it is situated and can be controlled by manipulation of these elements. Turbidity of meltwater is a function of meltwater exposure to fine sediment:

- Turbidity in snow disposal site flows is generated as meltwater exits and cascades off a snowfill, gathering sediment from the surface of the deflating mass.
- Turbidity may be further increased as meltwater crosses a pad surface, particularly if pad surface soils are unprotected, waste soils are exposed, or flow velocities are increased.

Environmental Stewardship Practices in Design and Operation of Snow Storage Sites

The Transportation Association of Canada (*341*), the NHDOT(*342*), and the ADOT&PF (*343*) have each compiled snow storage guidelines for design and operation, which are combined below.

Needs Assessment

- Review potential sites considering:
  - Surface water quality and quantity (including potential assimilative capacity).
  - Site hydrogeology.
  - Location of groundwater recharge areas.
  - Location and nature of salt vulnerable areas including wetlands, sensitive vegetation, agricultural areas, drinking water supplies, shallow ponds, etc.
  - Location of sensitive land uses such as residential, institutional and recreational areas.
- Review public, agency and staff concerns with existing sites and develop a list of potential concerns that should be resolved during the planning and design process.
- Involve the public and government agencies in the site selection process.
- The identification of potential temporary, contingency or emergency sites may focus on smaller more remote sites with natural features supporting basic siting criteria such as:
  - Soils with a low permeability
  - Natural slopes with a ponding area
  - Discharge to a high volume surface water receiver or sanitary sewer

Assessment and Evaluation

The assessment and evaluation process is iterative with increasing level of detail being used as sites are narrowed down. Many of the same criteria are used for the evaluation of existing and new snow disposal sites. The following criteria should be considered as part of the assessment and evaluation process.

- Snow hauling distances
  - Snow hauling routes and site access
  - Past and current site land use
  - Current and future surrounding land use
  - Zoning
  - Size of the site
- A snow disposal site must have an area sufficient to accommodate:
  - Anticipated volumes of snow
  - Site access/control facility
  - Drive paths for the heavy trucks allowing for simultaneous arrivals and departures
  - Parking and re-fueling area for bulldozers, blowers, etc.
  - Temporary storage for large debris
  - Berms around the perimeter
  - Meltwater collection/retention/settling ponds
  - Maintenance access

    - Monitoring stations/sites
    - Consideration for other uses if included or desirable
- Sub-surface conditions. Preference should be given to sites with low permeable soils with sufficient bearing capacity to handle year-round operation of heavy equipment.
- Protection of water quality may be the most important and difficult of issues to address. Map local and site hydrogeology within 300-meter (m) of site. Consideration should be given to:
    - Proximity to drinking and irrigation water sources (avoid possible contamination).
    - Proximity to surface water, downstream effects and the type of aquatic species present (avoid or minimize impacts).
- Meltwater discharge location. If ultimate discharge is into municipal sanitary system, ensure the treatment system can handle the additional flow and contaminants. When discharging meltwater into a surface water body the receiver must provide enough dilution all year round to protect the aquatic eco system. The potential receiver should be evaluated both on its historical flow rate and volume fluctuations and potential for future fluctuations, particularly lower flow periods. Meltwater should not be discharged to salt vulnerable areas, including ground water recharge areas, and areas over shallow aquifers.

Base Construction

- A good solid base is required to allow heavy trucks and graders to drive repeatedly over the wet ground without getting stuck or creating deep ruts that could divert or hold meltwater.
- The base should have low permeability to protect groundwater resources.
- The base must remain firm enough to support vehicle loads even after the frost has gone out of the ground.
- The base should slope downwards to the north to take advantage of the sun melting the pile from south to north. The snow on the high (south) end melts first running under or around the piles to the meltwater collection facility. In this way, contaminants (sand, silt, litter, etc) will remain up-stream of the pile and meltwater will not continuously flow across the materials previously released from the pile.
- The Municipality of Anchorage and the Alaska Department of Transportation and Public Facilities have designed the base with “V” ditches under the pile to channel meltwater to a collection pond to take advantage of the melting process and inherently low-energy environment of a melting snowfall. The V-swale configuration promotes meltwater movement as saturated flow within a snowfill so that particulates are not mobilized during the early and middle stages of melt, providing as much as ten times the particulate control over conventional fl at pad configurations. Flow directed along the trough of the V-swale ensures a single predictable discharge point so that flows can be further managed and directed to minimize erosion of pad and waste soils. The design also limits late-stage sediment mobilization by helping to short-circuit flows to armored channels.

Restriction of off-season pad use will minimize disturbance of pad soils and to allow revegetation.(*344*)

Siting Criteria

- Avoid meltwater discharge to potable water aquifers. The snow storage area should be at least 75 feet from any private water supply wells, at least 200 feet from any community water supply wells, and at least 400 feet from any municipal wells. Prohibit snow storage areas in wellhead protection areas.
- Optimize opportunities for infiltration to shallow nonpotable groundwater systems.
- Avoid meltwater discharge to 'closed' lakes and wetlands.
- Avoid reduction of functionality of receiving wetlands.
- Avoid meltwater discharge to streams having winter base flows less than 85 L/sec.
- Optimize opportunities for a site orientation sloping down from south to north.
- Snow disposal locations should allow melt water to flow at a low velocity to a water body.
- Disposed snow should be stored near flowing surface waters, but at least 25 feet from the high water mark of the surface water.
- Locate and operate snow disposal sites to minimize impacts to the natural environment and control nuisance effects, including noise, dust, litter and visual intrusion on adjacent landowners.

Design Criteria

- A snow handling, storage and disposal design must be practical and must not impose undue maintenance requirements.
- Drainage designs need to consider runoff and snow melt while snow is in the storage area. If snow is piled over the top of drainage inlets, the inlets will not function. Rain or melting snow runs down the outside of the snow pile to low areas, forming ponds or flowing across the road.
- Clearly delineate the actual snow disposal area in a manner that is clearly identifiable under adverse winter conditions, to ensure that the snow is placed in the proper location on the site.
- Construct pad with a single or multiple V-swale configuration (minimum 45 m crest-to-crest swale width, 2 percent sideslope to central trough, and 1 to 2 percent longitudinal slope).
- Orient V-swale longitudinal axes downhill from south to north.
- Establish and flag setbacks from swale crests and facility perimeter.
- Armor swale troughs and crests and all facility drainage channels and containment berms.
- "Trackwalk" (imprint with crawler tractor treads trafficking directly upslope and downslope) and vegetate all nonarmored pad surfaces with a mix resistant to an annual 2 to 5 cm sediment burial.

- Construct dry detention ponds or other treatment to control chloride and sediment releases.
- Install flow dispersion and energy dissipation controls at all outfalls to receiving waters.

Drainage and Meltwater Management

- Manage the discharge of meltwater to comply with local water quality regulations and protect surface and groundwater resources.
- Site meltwater should be directed away from the snow piles and dumping area to reduce ponding/rutting.
- Use of setback staking and armored channels (oversized to provide room for icing) to direct and contain pad meltwater flows and limit turbidity.
- Where local regulations permit dilution to meet regulated contaminant levels, uncontaminated site drainage and precipitation may be directed to the collection pond to provide dilution of the impacted meltwater. Otherwise, uncontaminated drainage should be isolated from the meltwater. The meltwater collection pond should be designed large enough to handle the expected meltwater volume, other site drainage, and the periodic additional load from precipitation events.
- Incorporating shallow collection reservoirs reduces pad erosion and turbidity by effectively transporting meltwater over significant horizontal distances in a low-turbulence (pooled) environment. The meltwater collection pond should be designed with an impermeable base, a forebay to collect litter and settle coarse sediments and a larger secondary area to settle finer particles. An absorbent boom can be placed in the forebay to capture any oil and grease in the site drainage. The outlet should be controlled to regulate the release to the receiving water body. The point of discharge should be protected to prevent scour. Adequate access to the pond needs to be provided to allow for periodic cleanout of sediments.
- A silt fence or equivalent barrier should be securely placed between the snow storage area and the high water mark.
- All required federal, provincial, regional and municipal approvals, permits and licenses will have to be applied for, obtained, and complied with.
- A baseline condition evaluation (benchmarking) of the site and surrounding areas should be conducted for future monitoring comparisons.
  - Contaminant levels recorded once the site is operational will have to be compared to levels prior to the site opening to give a true indication of any environmental impacts.
  - Test sites and holes drilled to benchmark the site could be made permanent allowing future comparison data to be collected from the same locations.

3.11. Designing to Minimize Air Quality Problems

Air quality and pollution have been concerns in the United States for many years, especially in metropolitan areas. AASHTO's Center for Environmental Excellence provides brief summaries of federal air quality requirements applicable to the transportation community including background information on National Air Quality Standards, Developing State Implementation Plans, Emissions Inventory, Control Strategies, Transportation Control Measures, Motor Vehicle Emissions Budget, Sanctions, Conformity, FHWA Resources, EPA Resources, and Links to air quality laws and regulations, guidance and Related Information. Recent Developments are provided as well as Documents and Reports, Success Stories, and Related Links. Most of these air quality resources are focused on the planning process.

The following practices briefly review design measures to promote air quality and congestions mitigation and air quality (CMAQ) and sources of funding.

Tree Shading for Emissions Reduction

While cars sit in the sun, gasoline evaporates from fuel tanks and worn hoses. These evaporated materials are principle components of smog. In 1999, the U.S. Forest Service and the University of California at Davis completed a pilot study to measure the difference in parking lot microclimate and parked vehicle emissions resulting from the presence or absence of shade tree cover. Results indicated that shade tree cover in parking lots reduced motor-vehicle hydrocarbon and nitrogen oxide emissions from cars parked in those lots. In this study, conducted in Sacramento California, interior vehicle temperatures averaged 45ºF cooler in the tree-shaded vehicle when compared with temperatures inside unshaded vehicles. Furthermore, increasing parking lot canopy cover from 8 percent to 50 percent would reduce total vehicle-generated hydrocarbon emissions by two percent and nitrogen oxide emissions by just under 1 percent in similar climates. In addition, this study noted that there was a user preference for shaded parking spaces.

Shade also extends the life of asphalt pavement. Trees in parking areas provide shade, visually reduce the impact of large pavement areas, and reduce heat gain.(*345*)

- Use perimeter trees and shrubs to screen the parking area from nearby residential uses, while allowing for visibility by security personnel.
- Design for a minimum of 50 percent canopy cover over parking areas.
- Select tree species that do not drip pitch or attract aphids.
- Where trees are planted near a bus route, or bus parking, limb trees to eight (8) feet above the ground.
- Use planting areas to divide paved surfaces into smaller, more defined parking areas.
- Consider end islands to delineate aisles and intersections and to protect the end vehicles. End islands should have raised curbs.
- An alternative to planting in linear parking islands is the design of large concentrated planting islands within parking lots. This can allow plant communities to establish in these islands. They can also be stormwater infiltration areas.
- Keep landscaping as low-maintenance as reasonably possible.
- In high snow load areas, end islands may cause difficulties with snow removal. In these areas, large central planting islands may be more appropriate. Consider snow storage needs and adjacent vegetation in high snow load areas.
- In arid climates, irrigation may be necessary for plant survival.

- These areas benefit most from tree shading of parking stalls in the summer due to higher temperatures.
- Consider the use of structural soils under paved surfaces to allow root penetration without damage to the pavement and to retain parking spaces while increasing soil volume for trees in parking islands. This will benefit both the tree and long-term maintenance of the parking lot. Additional information can be found at the Department of Horticulture at Cornell University.
- Interior planting islands should have drainage provided and depth to allow tree root growth at least 3 feet deeper than paving grade.
- Plant trees to align with the painted parking stall lines to prevent their damage by car bumpers.
- Car bumpers overhang tire stops and curbs. Consideration should be made in the design of sidewalks and planting areas for this overhang.

Promoting Carpooling and Transit

Urban air pollution is a major and continuing concern for transportation agencies. Motor vehicles are a major contributor to this pollution. One possible means of mitigating the pollution caused by motor vehicles is to shift travel to alternate modes. Some states are very active in promoting alternate modes; in other, especially rural, states promotion of mode switching is minimal. Arizona DOT has a research project underway, with results due in late 2004, to compile practices in use by other state DOTs.(*346*)

DOT and MPO carpool and transit promotion activities are often funded under the CMAQ program. Sample CMAQ projects include those of the Georgia Department of Transportation (GDOT) in the Atlanta area, where priorities will focus on HOV lanes and park and ride lots over lanes widening and another beltway.(*347*) GDOT conducted a statewide kickoff of the media campaign to increase awareness of HOV lanes under construction in Gwinnett County, and to increase use of the existing HOV lanes and metrorail. The event attracted significant media coverage, including three Atlanta television stations. GDOT also ran radio ads on several stations throughout the year and has a campaign highlighting the need for and benefits of carpooling.(*348*)

The Virginia Department of Transportation has been praised by the EPA and the USDOT for its "Commuter Choice" program and contribution to improving air quality. VDOT has offered its employees bus, vanpool and carpool options since 1993 with its own "Commuter Incentive Program" (CIP), and is not only Richmond's largest employer with such a program, but also the employer with the highest commuter participation. VDOT reports that the program is a very successful recruitment factor. To illustrate the benefits of joining its program, the EPA estimates that an employer with 1,000 employees could help take 175 cars off the road, which would save 44,000 gallons of fuel per year and reduce global warming emissions by 420 metric tons. The same employer also could reduce its parking expenses by $70,000 and save participating employees $13,000 in taxes and $160,000 in fuel, parking, and vehicle costs every year – employees pay no federal income tax or payroll tax on commuter benefits. For VDOT's headquarters office, it's estimated that the program saves more than 93,500 gallons of vehicle fuel per year, and reduces air pollution by 4.25 metric tons of volatile organic compounds, 4.25 metric tons of nitrogen oxides, and 31 tons of carbon monoxide. VDOT's CIP has grown from

196 participants in August 1993 to 373 participants in 2003 - 27 percent of its headquarters office workforce (69 vanpoolers, 262 bus riders and 42 carpoolers) - at an annual cost to VDOT of $151,680. Eight percent (110 employees) of its Northern Virginia work force participate (82 vanpool, 11 bus, 7 Metro train riders, and 10 Metro/bus) at an annual cost of $124,080.(*349*)

NC DOT is studying feasibility of intercity rail from eastern to western NC, through the state's Triad of largest cities.(*350*) Transit promotion activities of other state DOTs can be found through links to these sections online.

ITS Facilitated Air Quality Improvement in Ohio and Kentucky

In the Cincinnati, OH, metropolitan area the Ohio Department of Transportation and the Kentucky Transportation Cabinet developed the Advanced Regional Traffic Interactive Management and Information System (ARTIMIS) to help with incident and congestion management. Using fiber-optic cable and telephone lines, 80 closed-circuit television cameras and 1,100 loop detectors, installed along 142 kilometers (88 miles) of freeway, relay information about traffic congestion and incidents to a control center. Through 40 changeable message signs, ARTIMIS distributes information on traffic problems and alternate routes from the control center to motorists. The system also includes a traveler advisory telephone service and a motorist assistance program with five service patrol vans. Estimates show that the system saves $15.9 million per year in reduced traffic delays, fuel consumption, and crashes.(*351*)

Funding for Air Quality Improvement: The Congestion Mitigation & Air Quality Program (CMAQ)

The most well known program supporting air quality improvement is the Congestion Mitigation and Air Quality Program. In 1990, Congress amended the Clean Air Act (CAA) to bolster America's efforts to attain the National Ambient Air Quality Standards (NAAQS). The amendments required further reductions in the amount of permissible tailpipe emissions, initiated more stringent control measures in areas that still failed to attain the NAAQS (nonattainment areas), and provided for a stronger, more rigorous linkage between transportation and air quality planning. In 1991, Congress adopted the Intermodal Surface Transportation Efficiency Act (ISTEA). This law authorized the CMAQ program, and provided $6.0 billion in funding for surface transportation and other related projects that contribute to air quality improvements and reduce congestion. The CAA amendments, ISTEA and the CMAQ program together were intended to realign the focus of transportation planning toward a more inclusive, environmentally-sensitive, and multimodal approach to addressing transportation problems. The CMAQ program, jointly administered by the FHWA and the Federal Transit Administration (FTA), was reauthorized in 1998 under the Transportation Equity Act for the 21st Century (TEA-21). The TEA-21 CMAQ program provided over $8.1 billion dollars in funds to State DOTs, MPOs, and transit agencies to invest in projects that reduce criteria air pollutants regulated from transportation-related sources over a period of six years (1998-2003).

The percentage of CMAQ funds obligated for transit was higher than that of any other category in FY 1999, the last year for which a report is available. The total CMAQ funds obligated toward transit accounted for 51.6 percent of the total amount of funds obligated nationwide, a 70 percent increase in CMAQ share from FY 1998 (from 30.1 percent to 51.6 percent). Traffic flow improvement projects were the second largest category at 23.3 percent, a 50 percent decrease in CMAQ share from FY 1998.(*352*)

3.12. DESIGN AND SPECIFICATION FOR RECYCLING

The Growing Need for and Importance of Waste Minimization and Recycling

Recycling means reintroducing waste material into the production process, to supplement primary resources. The use of waste as a raw material saves resources and primary raw material, reduces air and water pollution, and extends limited landfill life. Recycled products can also save financial resources through lower material costs and lower disposal costs. In some cases, using recycled products can improve material performance as well. Consequently, using recycled materials is a key aspect of more efficient and environmentally sensitive highway design and construction.(*353*)

Recycling also saves energy. A quantitative assessment of environmental impacts on life cycle of highways found that most energy is consumed in the manufacturing stage of construction materials, with consumption of 1,525 tons of oil equivalent (TOE)/functional unit (1 km and 4 lanes of highway).(*354*) Energy consumption in the maintenance and repair stage was also fairly high among the life cycle stages; the next highest consumption was for the construction and demolition stage. Through the whole life cycle of 20 years, 2,676 TOE of energy/functional unit was consumed, and this corresponds to SO2, NOx, and CO2 emissions of 62.1 tons, 17.1 tons, and 2,438.5 T-C, respectively.(*355*)

The United States spends approximately $13 billion annually (1999 dollars) on highway construction and repairs, requiring nearly 350 million tons of both natural and manufactured construction materials.(*356*) Approximately 4.1 billion metric tons of non-hazardous solid waste materials are generated annually. The majority of these materials are being landfilled in many states; however, landfills and access to materials are increasingly limited by growing environmental regulations and permitting requirements, restrictive zoning laws, land uses, and other economic considerations. Community opposition has restricted the expansion of and forced the closure of existing landfills, quarries, and gravel pit operations. The latter has created localized shortages of construction aggregates and borrow materials in some areas, further adding incentive to explore alternatives in order to alleviate such shortages and to conserve natural resources.

Common Recycling Applications in the U.S. and Europe

Research into new and innovative uses of waste materials is continually advancing. Many highway agencies and private organizations have completed or are in the process of completing studies and projects concerning the feasibility, environmental suitability, and performance of using recycled products in highway construction. Reduction of waste material at its source and resuse of construction waste complement recycling efforts.

Recycled materials are typically used in such applications as bituminous pavements, Portland cement concrete (PCC) pavements, road base, embankments and fills, flowable fills, landscaping, bike paths, parking lots, and appurtenances such as signs, fencing, barriers, traffic delineators, etc. Some of the most notable uses of recycled materials in the highway environment over the last 20 years have included recycled asphalt pavement (RAP), reclaimed concrete pavement, coal fly ash and blast furnace slag. A few states and local governments have passed legislation to promote recycling in road construction. In some case beneficial use determination processes (BUDs) evaluate uses though a wide range of approaches are used;

California, Illinois, Massachusetts, New Jersey and Pennsylvania are working to standardize the BUD process and create reciprocity. State DOTs and state environmental protection agencies (State EPAs) are also trying to balance the desire for increased use of recycled materials with concerns about potential environmental impacts of leaching from recycled materials.

FHWA produced a review of the use of recycled materials in highway construction in the early 90s, a summary of which is included below.(*357*)

Table 11: FHWA Summary of Known Uses in Waste Applications

Waste Material	Millions of Metric Tons Annually		Current and Past Highway Uses				
	Produced	Recycled Reused	Asphalt Pavement	Concrete Pavement	Base Course	Embankment	Other
Blast Furnace Slag	??	14.1	Accepted use as an aggregate in base and surface (friction) coarse, research indicates good performance	Accepted use as a cement additive in granulated form, research is ongoing	Accepted use, good, hard, durable aggregate	Limited but accepted use	Research in Roller Compacted concrete, accepted as ice control abrasive
Carpet Fiber Wastes	2	??	Experimental stages in HMA and SMA no field data	Experimental Stages, no field data	No known use	No known use	No known use
Coal Fly Ash	45	11	Past use as a mineral filler, research ongoing	Accepted use research ongoing	Used in soil stabilization	Used in flowable fills, embankment	Used in all types of PCC
Coal Bottom Ash or Bottom Slag	16	5	Combined ash as a fine aggregate, performance data limited	Use unknown	Use unknown	Used as a sub-base material, embankment	Lightweight concrete, abrasives
Flue Gas Desulfurization Waste	18	??	Use unknown	Used as a set retarder	Used with cement in soil stabilization	Used as an embankment material	No known use
Glass	12.0	2.4	Accepted use, long-term performance research under way	Past research indicated performance problems	Used in dense and open-graded bases	Some research projects under way	Limited use as a paint bead, pipe backfill
Mill Tailings	432	<1 percent	Accepted use, research indicates good performance	Limited but accepted use	Use unknown	Accepted use	Use unknown
Municipal Waste Combustion Ash	7.3	<10 percent	Past research indicated good performance - Environmental questions	No known use	Used in cement-stabilized bases	Used in soil stabilization	No known use
Plastic	14.7	0.3	Used as a binder additive	Experimental stage	No known use	No known use	Fence or delineator posts,

Waste Material	Millions of Metric Tons Annually		Current and Past Highway Uses				
	Produced	Recycled Reused	Asphalt Pavement	Concrete Pavement	Base Course	Embankment	Other
							guardrail blockouts
Reclaimed Concrete Pavement	3	??	Limited use, long-term performance research under way	Limited use, research under way	Accepted use	Accepted use	Used as rip-rap
Reclaimed Asphalt Pavement	91	73	Variety of accepted uses	Experimental stages	Accepted use	Accepted use	Used as shoulder material
Roofing Shingle Waste Industry-Produced Re-roofing Waste	0.4 7.7	<1 percent	Limited use, research under way	No known use	No known use	No known use	Used as a pothole patching material
Scrap Tires	2.3	0.4	Accepted use, extensive research being conducted	Experimental Stages	Used as an insulator	Used with some success - research continuing	Being marketed for use as noise or retaining wall, molded posts, many minor uses
Steel Slag	7.5	6.9	Past research indicates good performance	Extensive research, poor performance	Limited use	Accepted use	Ice control
Waste Rock	954	<1 percent	Accepted use, research indicates good performance	Limited but accepted use	Use unknown	Use unknown	No known use

NCHRP Synthesis of Highway Practice 199, *Recycling and Use of Waste Materials and By-Products in Highway Construction*.(*358*) developed a methodology for assessing the suitability and practicability of specific waste resource materials in transportation applications, determining appropriate uses, developing design and construction guidelines, and evaluating long-term in-service performance and applied the methodology to a spectrum of waste resource materials. The project developed a comprehensive CD-database including material and engineering properties; environmental information; legislative, regulatory, and litigation information; history of past use and performance; references to existing specifications and guidelines; information on material generation (source, quantity, existing inventory); and information on ongoing research and demonstration projects.(*359*)

Congress has supported development of a Recycled Materials Resource Center (RMRC) at the University of New Hampshire to perform research and outreach to reduce barriers to recycling in a highway environment. FHWA and RMRC produced a 2001 manual to provide guidance to assist transportation agencies in the maintenance of high-quality roads that perform to high engineering standards over their design life, without future problems, and to promote cooperative efforts with environmental agencies to ensure that present and future environmental problems do not arise when recycled materials are used in highway infrastructure. Read Document Online(*360*). The private sector is also developing innovations in processing and applications.

In 1999, FHWA, AASHTO, and NCHRP sponsored an international scan tour to Denmark, Sweden, Germany, the Netherlands, and France to review and document innovative policies, programs and techniques in Europe and make recommendations that would lead to the reduction of barriers to recycled material use. In particular the scanning team sought applications in highway construction in the ROW (e.g., roads, shoulders, medians, bridges, culverts, swales, appurtenances) though activities associated with highway construction can also result in use of recycled materials outside the highway ROW. In Europe, government policies and regulations such as bans on landfilling, landfill taxes, and natural aggregate taxes support recycling. Generally, clear and unambiguous engineering and environmental test methods and performance standards help to reduce uncertainty and allow recycled materials to compete with natural materials. Where tests and standards do not exist, governments often support recycling by sharing risk.

In the U.S. there are widespread needs for clear engineering and environmental test methods and performance standards. The owner or contractor generally assumes risk. The States, academia and the private sector are conducting significant research. In the U.S. some recycled materials like RAP, coal fly ash and blast furnace slag are widely used in a true free market situation because of their excellent performance and competitive costs. Other materials are used more locally in response to more specific local market forces. There is little federal government involvement, except for construction procurement guidelines for materials like coal fly ash. Rather, the situation is driven at the state level. For example, the State of Pennsylvania has adopted legislation to promote recycling in the highway environment. RMRC's Report for the International Scan Tour on Recycling Techniques, is available on-line.(*361*)

General Recommendations for DOTs with Regard to Recycling and Waste Management

The International Scan Tour Report generated a number of recommendations for AASHTO's Standing Committee on the Environment and Subcommittee on Materials that are pertinent to recommended practices for state DOTs: (*362*)

- Include a recycling strategy in the sustainability aspect of strategic plans and long range research priorities.
- Create a framework to consider the use of recycled materials in project planning, alternatives analysis, and mitigation analysis.
- Encourage long term materials supply plans and recycled materials availability plans.
- Develop clear engineering and environmental guidelines at the State and Federal level that are available for suppliers and decision-makers.
- Develop courses on recycling.
- Evaluate contractors with respect to use of recycled materials or environmental protection during contract performance reviews.
- Develop and implement the use of warranty and performance based specifications.(*363*)

The following practices are also recommended to facilitate environmental stewardship in materials management: (*364*)

- Materials should be used in the most effective way possible.
- Structures should have long lives.
- Materials should be recyclable.
- Consumption of energy in the construction development should be optimized.
- Alternatives for conventional resources should be considered.

Life Cycle Cost-Benefit Analysis

The most recent TRB research needs meeting called for an expansion of life cycle analysis to reduce waste, prevent pollution, and encourage recycling.(*365*)

FHWA's Highway Economic Requirements System (HERS) is an example of a tool that supports tradeoffs between preservation and improvement projects. The HERS application is based on the Highway Performance Monitoring System (HPMS) database, and is intended to replace HPMS as the source of biennial federal needs studies submitted to Congress. The HERS algorithms address both highway capacity and pavement preservation needs. Thus, state application of HERS or HERS/ST are uniquely suited to asset management studies that are more comprehensive than those addressed by individual management systems (e.g., pavement management and congestion management) and can explore tradeoffs between system preservation and system improvement or expansion.

Specifications for Recycled Materials in Transportation Applications

Available AASHTO or DOT specifications for the recycled materials covered in ensuing sections are included as weblinks within those sections, and more specifications are being developed all the time. The Recycled Materials Resource Center (RMRC) has a project underway to Develop and the Prepare Specifications for Recycled Materials in Transportation Applications. Participants in the project—Caltrans, FDOT, Illinois DOT, Mass Highway, Michigan DOT, Mn/DOT, NHDOT, NJDOT, NYSDOT, NCDOT, Ohio DOT, PennDOT, TxDOT, and WisDOT— identified the recycled materials of greatest interest to DOTs and assisted in the development of specifications. Six material/application combinations are underway. The first of these, a specification for glass cullet use as an aggregate base course, was published in 2001 (M-318-01). This past year, a second specification, "M-319-02, Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course," was published in the 22nd edition of the AASHTO's *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*. A third specification, "Use of Recycled Concrete as an Aggregate Substitute in PCC Pavements," is under review by the AASHTO Technical Section. A specification for coal fly ash in embankments has been tabled by the Technical Section, while a draft specification for reclaimed asphalt pavement as an aggregate in asphalt concrete has been prepared for submission to the Technical Section. The last specification on the use of roofing shingle scrap as an aggregate for asphalt concrete is in preparation.

- Final Glass Cullet specification - AASHTO Designation: M 318-01 (*366*)
- Final Specification for Recycled Concrete as Aggregate in PCC Pavements (*367*)

- Final Specification for Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course: AASHTO Designation: M 319-02 (*368*)
- Draft Coal Fly Ash Specification (*369*)

See also:

- AASHTO Standard Spec for Compost for Erosion/Sediment Control - *Compost Blankets* (*370*)
- AASHTO Standard Spec for Compost for Erosion/Sediment Control - *Filter Berms* (*371*)

As of February, 2004, specifications under development via RMRC projects include the projects listed in the Appendix. RMRC keeps an updated list at their RMRC Resources and Specifications site.(*372*)

3.13. Designing to Minimize Noise

Noise may be defined as unwanted or excessive sound that is bothersome to human beings and wildlife. The 1998 International Labor Office encyclopedia lists the construction industry as the fourth noisiest industry sector.(*373*)

State and federal agencies and the transportation industry as a whole have employed a wide variety of methods to minimize noise from construction and highway operations. Though some noise regulation exists, many of the most innovative and comprehensive noise control practices have evolved outside of the regulatory context.

Noise Effects and Regulation

Noise levels affect the quality of life in neighborhoods and communities and therefore affect the degree of public satisfaction with the transportation system. Fish and wildlife are also affected by noise.

Any type of rehabilitation that adds lanes, significantly changes alignment or increases capacity requires a noise study. The key component of the study is the modeling of the new acoustical landscape by using actual project design data and plugging it into a noise modeling software package that predicts the changes to the acoustical environment caused by the rehabilitation. The generally accepted definition of excessive noise is an increase of 10 dBA or greater. A 3dB reduction approximates doubling the distance from a line source (i.e. traffic) noise source. FHWA Noise Abatement Criteria establishes 67 dBA "not (as) an absolute value or design standard, (but) only a level where noise mitigation must be considered."(*374*)

Effects of Highway Noise on People

Noise can disturb sleep and relaxation, interfere with an individual's ability to perform complicated tasks, be a source of annoyance, influence mood and stress levels, and otherwise detract from the quality of life.(*375*) Economic effects of noise include impacts to property values, impaired health, and lowered working efficiency.(*376*) Recent studies have concluded that day-night average sound level is still the most adequate noise descriptor for use in environmental impact analyses to assess the annoyance and overall impact of noise from general transportation, including civilian and military aircraft operations.(*377*)

In Europe, a substantial amount of research has been performed on effects of noise on people and the European Union has begun to take the topic very seriously. European researchers say most of the high burden by environmental noise arises from transportation on road, on rail and in air and estimate the costs of noise pollution as up to 2 percent of the European gross domestic product.(378) Adverse effects of roadway or traffic noise have been determined to include interference with communication, noise-induced hearing loss, annoyance responses, and effects on sleep, the cardiovascular and psychophysiological systems, performance, productivity, and social behavior.(379) It was found that in the European Union about 40 percent of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) daytime, and 20 percent are exposed to levels exceeding 65 dB(A). When all transportation noise is considered, more than half of all European Union citizens are estimated to live in zones that do not ensure acoustical comfort to residents. At night, more than 30 percent are exposed to equivalent sound pressure levels exceeding 55 dB(A), which are disturbing to sleep.(380)(381) The same researchers determined that noise pollution is an important issue in cities of developing countries as well, where traffic and alongside densely-traveled roads equivalent sound pressure levels for 24 hours can reach 75–80 dB(A). In contrast to many other environmental problems, noise pollution continues to grow and can result in direct, as well as cumulative, adverse health effects, according to the World Health Organization.(*382*)(*383*) As a result of these concerns, the European Union has developed a Noise Research Strategy Plan with goals for 2020 to halve the perceived level of noise from road traffic. To this end, the EU is examining new or improved solutions and system approaches to deal with the following forms of roadway noise: (*384*)

- Rolling noise (the predominant issue at mid and higher vehicle speeds), and in particular low noise tires and quiet, maintainable road surfaces. In this report, rolling noise is addressed under "Roadway or Traffic Noise Control."
- Propulsion noise comprising engine, transmission and exhaust noise (a significant element during acceleration of heavy trucks, especially in urban traffic). In this report, vehicle/equipment operating noise is addressed under "Construction Noise Control."
- Traffic management, i.e. sophisticated management systems, (to make possible road traffic with reduced noise emission). (Not addressed in this report.)

An overview of European activities and working groups related to noise research and policies can be found at www.europa.eu.int/comm/environment/noise/.

Effects of Noise from Roads on Birds and Terrestrial Wildlife

Over 75 percent of roads and streets in the United States are under the jurisdiction of local governments. The Federal jurisdiction is mainly limited to National Parks, National Forests, and other government-owned land. FHWA has taken the view that "generally in these areas, there are no permanent residents and, therefore, no noise problem of any extent."(*385*) While roads on federal lands are lower in density, and thus may have lower effects on people, the effect of roadway noise on wildlife is beginning to be explored.

In general, animals respond to noise pollution by altering activity patterns and with an increase in heart rate and production of stress hormones.(*386*) Sometimes animals become habituated to increased noise levels, and apparently resume normal activity; however, birds and other wildlife that communicate by auditory signals may be at a disadvantage near roads.(*387*) Highway noise can also disrupt territory establishment and defense and communication, with Endangered

Species Act implications in a few cases. The greatest effects of transportation on wildlife have been documented from off-road vehicles(*388*)(*389*) and overhead flights. (*390*)(*391*)(*392*) A wider list of [Scientific Literature References for Anthropogenic Noise Impacts to Wildlife]() was recently posted on Re:NEPA, FHWA's knowledge exchange listserv.

The effects of highway noise on bird populations have been studied in the U.S., particularly in California, and with regard to multiple species' breeding success in the Netherlands. Three papers published in the *Journal of Applied Ecology* describe changes in breeding patterns and densities for 43 species of birds in the Netherlands. Researchers examined pairs of nesting sites, with one near a busy road and one distant from it. Sixty percent of the species analyzed showed evidence of reduced densities close to the roads. The distance over which the effect was observed depended how busy the roads were: 10,000 cars a day affected birds up to 1.5 km from the roads; 60,000 cars a day affected birds up to 2.9 km from the road. For a zone of 250 m from the road the reduction of the density varied from 20 to 98 percent. When noise conditions were held constant, however, there was no difference in bird densities between plots with high and low visibility of cars. Visibility of cars, direct mortality and air and water pollution were considered unimportant.(*393*)(*394*)(*395*)

A California study on traffic noise impacts on Least Bell's Vireo Habitat recommended speed reductions and temporary noise barriers for approximately 600 m (2,000 ft) on each side of CA-83.(*396*) Both New Jersey and Nevada had successfully employed simple plywood tilted away from the road at a ten-degree angle to lessen noise reverberation between the barriers. The FWS rejected the proposed noise barriers but offered a mitigation alternative unrelated to the noise impact and the highway agency agreed to fund a project to control the arundo plant within the expected noise-impact area. Also known as giant reed, the arundo plant invades and destroys the native willow riparian habitat of the least Bell's vireo. FWS indicated this measure would provide more long-term benefit to the vireo.

The California Least Bell's Vireo roadway noise study revealed that neither Caltrans nor the FWS had a centralized list of noise-mitigation projects for endangered species. Nonetheless, the issue of noise mitigation for endangered species has been considered on at least one temporary and seven permanent noise-mitigation highway projects in California. The CA-83 study also brought into question the validity of the FWS's loudest-hour noise-impact criterion of 60 dB. Biologist John Rieger developed the criterion for a California highway project in 1987-88. Rieger assumed that if he found an area where least Bell's vireo nests existed near the highway, the noise level on that stretch of roadway must be acceptable to the bird. Finding ten least Bell's vireo nests along Route 76, he calculated the loudest-hour sound level at the location of each nest. The highest and lowest numbers were discarded, and the remaining were averaged—yielding a result of 61 dB. Rieger never intended this number to set a precedent or become a standard for noise-impact mitigation for endangered species, yet both resulted. In fact, with each noise-impact study that has used it, a 60-dB criterion has become more firmly established as the standard of use. This noise analysis relies on sound-level and loudest-hour equivalent sound level computations, both of which were developed in relation to human hearing. Current noise analysis procedures and criterion may not accurately estimate the impact of noise on the least Bell's vireo and other songbirds. In addition, the CA-83 study raised the issue of money—how much should be spent on noise mitigation projects for endangered species. Rieger, now a manager at Caltrans, has estimated that $9 million has either been spent on or committed to noise mitigation projects for endangered birds in Caltrans District 11.(*397*)

Effects of Noise from Pile Driving during Construction

While pile driving effects on some bird species, such as marbled Murrelets, have been explored, the primary concerns of pile driving during construction have been effects on people. Pile-driving is one of the noisiest construction operations. As an integral component of many overwater and in-water structures, pilings provide support for the decking of piers and docks, function as fenders and dolphins to protect structures, support navigation markers, and are used to construct breakwaters and bulkheads. Bridges, ferry terminals, and other structures commonly have driven-pile foundations. Piles are usually driven into the substrate using one of two types of hammer: impact hammers and vibratory hammers. Impact hammers consist of a heavy weight that is repeatedly dropped onto the top of the pile, driving it into the substrate. Vibratory hammers utilize a combination of a stationary, heavy weight and vibration, in the plane perpendicular to the long axis of the pile, to force the pile into the substrate. The type of hammer used depends on a variety of factors, including pile material and substrate type. Impact hammers can be used to drive all types of piles, while vibratory hammers are generally most efficient at driving piles with a cutting edge (e.g., hollow steel pipe) and are less efficient at driving displacement piles (those without a cutting edge that must displace the substrate). Displacement piles include solid concrete, wood, and closed-end steel pipe. While impact hammers are able to drive piles into most substrates (including hardpan, glacial till, etc.), vibratory hammers are limited to softer, unconsolidated substrates (e.g., sand, mud, gravel). Since vibratory hammers do not use force to drive the piles, the bearing capacity is not known and the piles must often be "proofed" with an impact hammer. This involves striking the pile a number of times with the impact hammer to ensure that it meets the designed bearing capacity. Under certain circumstances, piles may be driven using a combination of vibratory and impact hammers. The vibratory hammer makes positioning and plumbing of the pile easier; therefore, it is often used to drive the pile through the soft, overlying material, after which an impact hammer may be used to finish driving the pile to final depth. Overwater structures must often meet seismic stability criteria, requiring that the supporting piles are attached to, or driven into, the underlying hard material. This requirement often means that impact driving is necessary.

Injuries associated directly with pile driving are poorly studied, but include rupture of the swimbladder and internal hemorrhaging.(*398*) Sound pressure levels (SPL) 100 decibels (dB) above the threshold for hearing are thought to be sufficient to damage the auditory system in many fishes.(*399*) Impact hammers may be more harmful than vibratory hammers because they produce more intense pressure waves and because the sounds produced do not elicit an avoidance response in fishes, which exposes them for longer periods to those harmful pressures. Small fish are more prone to injury by intense sound than are larger fish of the same species (Yelverton et al. 1975)(*400*). Of the reported fish kills associated with pile driving, all have occurred during use of an impact hammer on hollow steel piles.(*401*)(*402*)(*403*)(*404*). SPLs are positively correlated with the size of the pile, as more energy is required to drive larger piles. Wood and concrete piles appear to produce lower sound pressures than hollow steel piles of a similar size, and wood, concrete and small diameter steel may not present a problem.

The degree to which an individual fish exposed to sound will be affected is dependent upon a number of variables, including: species of fish, fish size, presence of a swimbladder, physical condition of the fish, peak sound pressure and frequency, shape of the sound wave (rise time), depth of the water around the pile, depth of the fish in the water column, amount of air in the water, size and number of waves on the water surface, bottom substrate composition and texture, effectiveness of bubble curtain sound/pressure attenuation technology, tidal currents, and presence of predators. Most of the work relating to noise impacts on fish has been done with explosives, which produce pressure waves with different shapes and intensities and frequencies than pile-driving. In 2005, NCHRP will undertake research to determine by laboratory work and field validation the nature and degree of impacts to fish over the potential range of sound pressure levels that can occur during aquatic pile-driving operations. This research will also develop and validate sound pressure guidelines for protecting sensitive Atlantic, Pacific and fresh-water fish species over the potential range of sound pressure levels that can occur during aquatic pile-driving operations in fresh and salt water. For the time being, DOTs rely on conservative assumptions and guidelines provided by the National Marine Fisheries Service, now called NOAA Fisheries, which provided the referenced information in this section on pile-driving and effects on fish species.(*405*)

Noise Regulation

The National Environmental Policy Act (NEPA) of 1969 provides broad authority and responsibility for evaluating and mitigating adverse environmental effects including highway traffic noise. NEPA directs federal agencies to use all practical means and measures to promote the general welfare and foster a healthy environment. The Federal Aid Highway Act of 1970 specifically addresses abatement of highway traffic noise and mandated FHWA to develop noise standards for mitigating highway traffic noise. Under this mandate, FHWA has promulgated noise-level criteria for various land use activities. The law further provides that FHWA not approve the plans and specifications for a federally aided highway project unless the project includes adequate noise abatement measures to comply with the standards. FHWA has developed and implemented regulations for the mitigation of highway traffic noise in federally-aided highway projects, but states retain significant discretion in deciding what is reasonable and feasible. The regulations contain noise abatement criteria which represent the upper limit of acceptable highway traffic noise for different types of land uses and human activities; however, they do not require that the abatement criteria be met in every instance. Rather, they require that every reasonable and feasible effort be made to provide noise mitigation when the criteria are approached or exceeded. Noise descriptors are used to describe the time-varying nature of noise and are used in abatement procedures. The L10 is the noise level exceeded 10 percent of the time in the noisiest hour of the day. Leq is the constant, average sound level, which over a period of time contains the same amount of sound energy as the varying levels of the traffic noise.

The FHWA noise regulations give each state department of transportation flexibility in determining the reasonableness and feasibility of noise abatement and, thus, in balancing the benefits of noise abatement against the overall adverse social, economic, and environmental effects and costs of the noise abatement measures. The state DOT must base its determination on the interest of the overall public good, keeping in mind all the elements of the highway program (need, funding, environmental impacts, public involvement, etc.). FHWA developed a Method to Determine Reasonableness and Feasibility of Noise Abatement at Special Use Locations, which outlines a procedure that employs a systematic approach to the determination of reasonableness of abatement for special land uses. The development process for a Reasonableness Matrix for special land uses is explained and an overview of a finalized policy, along with details of the policy development methodology, is presented.

FHWA and state DOTs have advocated a three-part approach to effective control of the undesirable effects of highway traffic noise: control of land use near highways on a local level, quieter vehicles, and mitigation of noise on individual highway projects.(*406*) Expected noise reduction performance benefits of proposed mitigation measures are weighed against cost implications, and noise mitigation measures are implemented only when justified based on careful consideration of all relevant technical, cost, and policy issues.

Designing for Roadway/Traffic Noise Source Control

Roadway or traffic noise is generated by the vehicle engine and emission of exhaust, aerodynamic sources, and tire/pavement interactions. For vehicle speeds over 50 miles per hour, the tire pavement interaction dominates this mix and the source level is dependent on the vehicle type, tire type, and speed.

Sound walls are the only solution currently approved by FHWA for addressing noise impacts; however; a sound wall attenuates noise only within the acoustical shadow of the wall and benefits only those directly behind it. Caltrans has built more than 600 miles of sound walls at an average annual cost of $60 million.(*407*) As of 2004, sound walls cost more than $1,300,000 per mile.(*408*) Noise walls also tend to be very expensive per residence. For example, the 1990 construction cost for a noise wall on I-40 in Knoxville, TN was estimated at $25,000/affected home, as walls would have needed to be over 20 ft. high to be effective.(*409*) More recently on I-285 in Atlanta the criteria for a noise wall was $50,000 or less per affected home and a noise level of 69 dB(A) or more.(*410*) For U.S. 441 in West Boca, FL, the requirements to construct a noise wall included a noise level of 67 dB(A) or more, a cost of less than $30,000/affected home and a noise reduction of at least 5 dBA.(*411*)

Pavement Alterations to Reduce Roadway Noise

The only component of traffic-related noise under the control of DOTs is the acoustical property of the pavement. Quieter highways have the potential to reduce noise levels at the source, reducing the need for expensive sound walls, and benefiting a larger percentage of the community; however, more scientifically based criteria for designing quiet pavements are still needed. A 2005 NCHRP study will undertake the development of adequate quiet pavement design criteria by performing a nationwide survey of both asphalt concrete (AC) and Portland cement concrete (PCC) pavements, using innovative sound measurement technology to develop a nationwide index that ranks various pavement acoustical properties from the quietest to the loudest.(*412*)

NCHRP Synthesis 268: Relationship Between Pavement Surface Texture and Highway Traffic Noise presented a comprehensive synopsis of pavement/tire noise as it relates to roadways along with detailed information on acoustical definitions and concepts, the theory of tire/pavement noise generation and current mitigation practice, measurement techniques, interior vehicle noise, reported noise emission results for pavement type and texture, effects of pavement wear, surface friction, and maintenance and safety considerations.(*413*) The study concluded that, "In general, when dense-graded asphalt and PCC pavements are compared, the dense-graded is quieter by 2 to 3 dB(A)," a reduction that corresponds to doubling the distance from the noise source or reducing the traffic speed by 25 percent.(*414*) In particular the report found that, "open-graded asphalt show(ed) the greatest potential for noise reduction for passby noise. Reduction when compared to dense-graded asphalt ranged from 1 to 9 dB(A)." A 9dB(A) reduction corresponds to a reduction in traffic noise by almost 50 percent. Even dense graded hot mix asphalt surfaces (DGAC) have been found to be quieter than PCC pavements.(*415*) Stone-matrix asphalt (SMA) has also been found to be a relatively quiet surface.(*416*) England is moving forward with a 10-year plan to install quieter surfaces (SMA or OGFC) on 60 percent of main trunk roads(*417*).

Open Graded Asphalt Concrete (*OGAC*) *for Noise Reduction*

Caltrans and TxDOT are actively involved in quiet pavement studies focusing on open graded asphalt concrete. TxDOT refers to these as Porous or Permeable Friction Course (PFC). TxDOT's first PFC was placed in 1999, and, since that time, approximately 25 PFC projects have been constructed in Texas. PFC mixtures are gaining popularity due to their ability to reduce the risk of hydroplaning, reduce the amount of splash and spray, reduce pavement noise, improve visibility of traffic striping in wet weather, and improve ride quality.

In research supported by the U.S. DOT Volpe Research Center Acoustics Facility (VCAF), near-field measurements (at the tire) and wayside measurements are each being used to evaluate AC and PCC pavements on California State Route 138. This study, unique in scale and scope, has placed commonly utilized AC pavements (30mm DGAC, 30mm OGAC, 75mm OGAC, 30mm Rubberized OGAC, and 30mm Bonded Wearing Course) in one location, exposing them to the same environmental and traffic conditions. All tested pavement courses will be placed over a 30 mm DGAC leveling course. VCAF is measuring noise pressure levels at 25 ft, 50 ft, and 200 ft from the edge of the pavement for 5 years, with existing traffic and a controlled test vehicle and applying a modified Statistical Pass-By (SPB) to evaluate the different pavements and account for multiple vehicle types, tires, and speeds. So far, Volpe has found that the quietest pavements are OGAC and RAC type O, though noise suppression effectiveness of pavements is vehicle dependent, with a lower effect shown for heavy trucks.(*418*)

Caltrans recently completed a three-year study to determine if the noise attenuation benefits of open graded asphalt concrete (OGAC) decreased over time. A 9-kilometer portion of pavement on Interstate-80 near Davis California was rehabilitated in June 1998. The new pavement cross section consisted of a 60 mm dense graded asphalt concrete (DGAC) leveling course that was overlaid with 25 mm of OGAC. Noise measurements a month prior to the pavement rehabilitation established the baseline condition. Additional measurements were made immediately after placement of the DGAC leveling course, and after the completion of the OGAC overlay. Immediately after application of the DGAC base, roadside noise levels declined by 3 to 4 dBA from the baseline condition. After application of the OGAC, roadside noise levels declined by about 5 dBA over the baseline condition. Noise levels continued to be 4 to 6 dBA lower than the baseline condition over the entire period of the study.(*419*)

NCHRP has research planned for FY 2005 on cold weather performance of new generation open-graded friction courses (NGOGFC).(*420*) While there are numerous reported benefits of NGOFC or PFC mixtures, safety and winter maintenance concerns are often cited as the primary objections to increased use. The research will examine whether attributes of new generation OGFC (NGOGRC) will translate into better performance in winter conditions. In addition to the safety issues, concerns have also been raised about the increased maintenance cost of these mixtures due to the need for additional salt and/or sand treatment. Many agencies, particularly the European ones, have adopted innovative methods of maintaining NGOGFCs to ensure free drainage to surface water. It is also known that several agencies are revising their design criteria to improve the performance of NGOGFC. The use of modified binders and additives has improved the durability of NGOGFCs, but has not solved the potential icing problem. Research is needed to determine the liability versus benefit of using NGOGFC in geographic regions that are susceptible to numerous freeze/thaw cycles. Although no performance problems such as raveling have been reported with NGOGFC, there are still concerns that these mixes could experience the performance problems associated with the old OGFC mixes if the NGOGFC mixes are used in climatic regions susceptible to numerous freeze/thaw cycles. The concerns are the most likely reason that NGOGFC mixes are predominately used in warmer, more arid climates such as the southern and western regions of the United States.(*421*)

There are numerous differences between NGOGFC (or PFC) and first generation OGFC. NGOGFC contains approximately 20 percent more asphalt (by volume) than conventional OGFC. NGOGFC is designed to have a minimum of 18-percent air voids, whereas conventional OGFC was not designed based on air voids. Conventional OGFC mixture typically contained between 10- and 15-percent air voids. At the lower air void range, moisture could get trapped within the void matrix of the conventional OGFC. The void structure of NGOGFC allows the mix to be more permeable and less likely to trap water, which could potentially freeze. NGOGFC contain fibers and is heavily modified with polymers unlike conventional OGFC mixes. In addition, NGOGFC mixtures are more open graded than the conventional OGFC mixtures. The open texture allows NGOGFC to get flushed out by high-speed traffic, therefore reducing the potential to get clogged over time. NGOGFC mixtures are typically placed more thickly than conventional OGFC (1.5 to 2.0 inches as opposed to 1.0 inch). The thicker, more open matrix allows the NGOGFC to drain more water off the roadway more quickly than conventional OGFC. Research on NGOGFC indicates that the mixes typically last between 10 to 14 years, which is significantly longer than the first generation OGFC mixtures, which typically lasted between 5 and 7 years. The NCHRP project will provide recommendations for DOTs on how to maintain NGOGFC in different environmental zones, including the issue of how to avoid clogging or unclog voids due to sanding operations, provide recommendations on design requirements for NGOGFC, and identify topics that should be studied further.(*422*)

Rubberized Pavements

Acoustics tests on Asphalt-Rubber open graded mixes or Porous Friction Course (PFC)are occurring in Arizona, California, and Texas. As described above, Asphalt-Rubber OGFC is part of Caltrans five year study of noise reduction from various pavement types. In Arizona, resurfacing of the old concrete US 60 with AR OGFC during a major design/build widening project generated a 9.5 dBs reduction and much public feedback, including requests for further resurfacing efforts.(*423*) ADOT has committed to undertake a $100 million AR OGFC resurfacing effort if the public extends a special freeway tax. ADOT is currently running noise studies on many of its older AR pavements to determine the reduction capabilities of the material over time.

As part of the state's "smoothness" campaign for the state's roadways, TxDOT undertook a noise study as part of a resurfacing of the I-35 in San Antonio, where a 1.5 inch Porous Friction Course that was placed over the existing concrete surface. PaveTex Engineering conducted noise measurements prior to and after the new surface was applied and documented an average reading on the new PFC surface of 10dB quieter than an adjacent section of the old concrete pavement.(*424*)

A joint study prepared for the Sacramento County Public Works Agency, Transportation Division by the Sacramento County Department of Environmental Review and Assessment and consultants in acoustics and noise control engineering found an average four decibel reduction in traffic noise levels as compared to the conventional asphalt overlay used elsewhere. This noise reduction continued to occur six years after the paving with rubberized asphalt, at which time the study was concluded. The sponsors found this degree of noise attenuation to be significant, as it represented a 60 percent reduction in traffic noise energy, and a clearly perceptible decrease in traffic noise. This degree of traffic noise attenuation from rubberized paving has similar to the result documented in several non-related studies conducted in recent years at various other locations, both nationally and internationally.(*425*)

The Netherlands has five years of experience with second generation porous asphalt surface courses with rubberized asphalt binders, ranging from test sections to large scale use. The new concept consists of a double-layered porous asphalt construction, made up of a bottom layer of coarse porous asphalt (single-grained gradation, aggregate size 11 - 16 mm) and a top layer of fine-graded porous asphalt (aggregate size 4 - 8 mm). The binder in both layers consists of rubberized asphalt. The fine texture of the top layer causes a reduction of traffic noise, from 3 to 4 dB(A) at 50 km/h up to 5,5 dB(A) at 100 km/h (and 7 to 12 dBA quieter than PCC pavements). The bottom layer has a higher discharge capacity compared to conventional porous asphalt, which makes the sideways drainage of water, even on wide roads, considerably better. Pollution, dirt and silt on the road surface are kept from entering into the construction due to the "sieve" behavior of the top layer. In the Netherlands, a vacuum cleaning method consisting of water under pressure (up to 120 bar) is sprayed onto the surface to remove nearly all of the accumulation. The rotating movement of the spray nozzles makes sure that water enters the top layer from all directions. Directly behind the spray bar the water, containing dirt, is sucked up and recycled before again entering the circuit. Cleaning the two-layered porous asphalt in this way is much more effective compared to conventional porous asphalt, because the dirt is concentrated in the upper part of the top layer. On the older road sections with Twinlay, the bottom layer appears to be clean after being in use for several years, which assures the horizontal drainage of water through this layer. Depending on the severity of pollution, cleaning is required once or twice a year.(*426*) Like conventional porous asphalt the two- layered construction requires adjusted salting operations, as salt can more easily be carried off with meltwater.(*427*)

Further information on recycling rubber into pavement technologies, and the performance thereof, is reviewed in the Pavement and materials recycling section of this report.

Portland Cement Concrete Treatments for Noise Reduction

The United States has experience with tined (Arizona, California, Colorado, Iowa, Michigan, Minnesota, New Jersey, North Dakota, Virginia, and Wisconsin) and textured (Michigan) surfaces of PCC pavements to address roadway noise. For PCC pavements, Caltrans is partnering with the Western States-American Concrete Pavement Association on the Interstate-280 pavement rehabilitation project in San Mateo County. In this project the noise production from the old longitudinally tined pavement will be compared to noise production from a PCC pavement with diamond grinding, a PCC pavement with texture grinding, and a PCC pavement overlain with 30 mm of open graded rubberized AC. Noise measurements will be made for three to five years to assess the longevity of noise reduction. As of June 2002, several AC pavements had been placed on a test section of the roadway; plan sheets of the study location are available here. In a comparison study, Volpe has helped Caltrans compare 3 PCC test sections (longitudinal tining, burlap dragged, and broomed tining) and helped Arizona DOT compare three as well (uniform longitudinal tining, uniform transverse tining, and randomly spaced transverse tining) finding that the quietest surface treatments are CA burlap dragged, CA broomed, and AZ uniform longitudinal tining. Again, the percentage of heavy vehicles should be considered in determining overall effectiveness of surface treatments.(*428*)

New Research Areas in Noise Source Reduction

New noise research areas being considered include: developing a better understanding of the attributes of pavement that reduce noise generation for different types of vehicles, evaluating pavement performance with age, and developing maintenance techniques that preserve the noise reducing characteristics of the pavement and developing quieter tires without compromising safety.

To date, little data have been developed on how the transmission of pavement noise will be influenced by the porosity and/or rigidity of the internal pavement structure, though the Recycled Materials Resource Center is supporting research in this area.(*429*) Several recent European research projects examining the issue of the high pitched whine and/or low-pitched rumble commonly associated with PCC pavements have indicated that the construction of porous pavements may provide one method for absorbing noise. While many of these pavements have shown significant initial noise reductions when installed, the propensity of these pores to 'clog' with debris over time is a cause for concern as this may lead to a reduction in performance with time. Preventative anti-clogging measures may be required. Two approaches for increasing the porosity of PCC and its noise reduction properties exist. The first approach (used in some applications in Europe) involves increasing the porosity of the hydrated cement paste component of the material (typical techniques include the use of air-entraining/entrapping agents, gap-graded aggregates, or mixtures with low sand content while the second involves the use of "aggregate" with a higher than typical porosity. In addition to dissipating the noise that is generated by tire-road interaction by increasing the energy dissipated by moving air (friction), it is anticipated that the use of a low stiffness 'aggregate/fiber' inclusions may provide an effective means to reduce the stiffness of the pavement and increase the viscous-dampening capacity of the concrete. This is similar to the methodology that is used in machinery vibration isolation pads. By increasing the impedance incompatibility between the concrete components, the sound transmission path can be interrupted which could possibly increase the dampening capacity of the pavement. While little has been reported on the use of inclusions to absorb sound, some work has been performed to investigate the influence of lightweight aggregates and rubber particles on the elastic modulus. With around 280 million tires being dumped annually in the U.S., scrap tires may be a potential source of flexible inclusions for PCC. This project has been funded by the Recycled Materials Resource Center and research results are due in the next year or two.(*430*)

The substantial variation found with pavement type/treatment has also prompted FHWA initiation of the Quiet Pavement Pilot Program (QPPP), which will evaluate quiet pavements in terms of noise reduction benefits and longevity, while ensuring safety, and identify pavement specifications and maintenance requirements necessary to maintain the noise reduction benefits. The program will also help introduce quiet pavements as a feature in highway noise prediction models.(*431*) States with preliminary quantification of quiet pavement benefits qualify for the program. ADOT has already completed an agreement with FHWA and enrolled in the program. Caltrans is working on an agreement. QPPP will collect data over the life of quiet pavement applications included in the program, including pavement parameters and specifications, pavement control parameters, noise data near roads and in communities, and proper noise reductions to include in a noise prediction model. The program will also determine the need for FHWA policy change and key factors that would be included.

Traffic Noise Barriers

Noise emanates directly from primary noise sources such as exhausts and encased engines and from tires, where noise emissions depend upon the pavement type. Secondary noise sources arise due to reflections from pavement and vertical surfaces such as highway noise barriers. Noise barriers can be quite effective in reducing noise for receptors within 120 feet of a highway and are still effective in providing noise reduction beyond that distance. Ten decibel sound reductions are considered attainable, but noise barriers must be high enough and long enough to block the view of a road. Noise barriers do little residences on hillsides extending above a barrier. Also, openings in noise walls for driveway connections or intersecting streets greatly reduce the effectiveness of barriers.(*432*)

Drawbacks of noise walls include cost, impacts to viewsheds, shading, and the ability of noise barriers to reflect sound energy from an elevated location and spread the highway noise over a wider area. Absorptive sound barriers offset this effect. A number of new sound barriers made with polycarbonate or molded or molded crumb rubber panels have been developed to increase absorption. While such materials exhibit a much better performance than concrete with respect to sound absorption and transmission loss, at this point polycarbonate or rubber sound barriers are performing less well in terms of other criteria including cost-effectiveness, technology maturity, durability, cost and convenience in installation, cost and convenience in maintenance and repair, and aesthetics. Crumb rubber coating retrofit options are discussed below under retrofit practices. In the meantime, some states dealing with strong public criticism regarding noise increase at a distance from new wall installations has led to temporary suspension of Type II programs.

Sound refraction is influenced by the effective sound speed as a function of height above the ground surface. Current highway prediction methods assume a neutral, homogeneous atmosphere; however, prevailing atmospheric conditions can cause receivers beyond those adjacent to a highway to be exposed to highway noise otherwise considered inaudible using standard prediction methods. This effect may not only increase audibility of highway noise but can produce noise levels that exceed the applicable noise impact criteria. When the effective sound speed increases as a function of height, as is the case for downwind and temperature inversion conditions, sound refracts downwards. When the effective sound speed decreases as a function of height, as is the case for upwind and temperature lapse conditions, sound refracts upwards.

Arizona DOT is conducting research, due in 2005, to determine the extent of variations in highway noise propagation and the impact on noise exposure attributable to atmospheric conditions, and recommend procedures to ensure that state agencies base their respective noise mitigation studies and decisions on the best noise measurements possible.(*433*)

Current Noise Wall Expenditures and Materials

State and local governments spend more than $100 million each year on noise walls and other methods to avoid or mitigate the noise impacts of highways. California has built more than 600 miles of sound walls costing more than $60 million. In July 2000, $226 million was allocated to deliver 63 sound wall projects located throughout the state. FHWA has developed increasingly accurate models that enable States to reduce their costs substantially through better modeling and prediction of noise impacts and better design of noise walls and other mitigation. A detailed listing of noise barrier data may be found in FHWA's "Summary of Noise Barriers Constructed by December 31, 2001."(*434*)

Noise Wall Retrofit Practices

Most highway sound barriers are built with pre-cast concrete or concrete blocks and have very high acoustic reflectivity (90 percent and above) and low sound absorption for the frequency band of highway noise between 125 Hertz and 400 Hertz. Consequently, the effort to develop new materials for building better noise-reduction sound barriers has increased in recent years, though progress has been limited.

Noise Reducing Noise Wall Coatings

Arizona DOT is exploring crumb rubber based coating, a porous mix of multi-sized crumb rubber particles "glued" with certain polymers/paints, which can be sprayed on to new or existing concrete sound barriers. With near zero porosity, molded rubber has good acoustic absorption capacity. Due to the frequency content of highway traffic noise, changing the size distribution of rubber particles may provide a mechanism to better achieve the noise reduction effect. Crumb rubber is durable, and most industrial polymers/paints can have a minimum life of years and above. Crumb rubber is low cost. Spraying provides a quick, inexpensive and easy way to "manufacture" the coating layer. The repair of coating layers should also be simple because of the spray nature.(*435*)

Innovative Top Treatments for Noise Walls

ADOT is also exploring retrofitting existing noise walls with innovative top treatments, such as angled tops, irregular top edge, T-top treatments, and other applications that can reduce noise levels and eliminate the need for costly wall height increases or wall replacement. ADOT is exploring these strategies to avoid some of the undesirable impacts of noise walls such as blocked views, large shadows, and upward noise refraction. Innovative noise barrier designs and treatments have been successfully utilized in Europe for a number of years. This report is also due in 2005.(*436*)

Receptor Controls

In circumstances where source and path noise control measures are not feasible or sufficient, receptor control measures may be necessary.

Local and State Land Use Planning

FHWA and federal agencies have tried to address receiver controls proactively by recommending that local governments use their power to regulate land development in such a way that noise-sensitive land uses are either prohibited from being located adjacent to a highway, or that the developments are planned, designed, and constructed in such a way that noise impacts are minimized. Some State and local governments have enacted legislative statutes for land use planning and control. As an example, the State of California has legislation on highway noise and compatible land use development. This State legislation requires local governments to consider the adverse environmental effects of noise in their land development process. In addition, the law gives local governments broad powers to pass ordinances relating to the use of land, including among other things, the location, size, and use of buildings and open space.

To aid in the consideration of highway traffic noise in land use planning activities, the FHWA has produced the following report: The Audible Landscape: A Manual for Highway Noise and Land Use**.** Entering the Quiet Zone: Noise Compatible Land Use Planning is a brochure issued by FHWA that can be used by DOTs. It 1) summarizes the general nature of highway traffic noise, 2) provides examples of Noise Compatible Land Use strategies either constructed or planned, and 3) encourages a proactive posture by local decision makers, developers and citizens to share in and actively influence land use next to highways.

Physical and Procedural Receptor Controls

Window openings are typically a building's weakest link for noise infiltration. For this reason, acoustical window treatments can significantly reduce the outside-to-inside noise contribution. In some cases (factors include numbers of affected residents, the configuration of work sites, and the proximity of nearby abutters), window treatments may be more cost-effective and viable than noise barriers or curtains. FHWA has published a resource on "Insulation of Buildings against Highway Noise;" the Full Document is available on-line. Effective public outreach and participation are also a best practice for receptor noise control, as it can greatly increase the community's understanding and tolerance of noise.

The following receptor controls were used on the Boston Central Artery project, and are considered best practices in the field:(*437*)

- Community Participation — open dialog to involve affected residents
- Window Treatments — reinforcing the building's noise reduction ability
- Noise Complaint Process — ability to log and respond to noise complaints
- Temporary Relocation — in extreme otherwise unmitigatable cases

Window Treatments

The most extensive example of window treatment controls in the literature comes from Boston's Central Artery Project.(*438*)(*439*) In response to the need for more noise mitigation than accomplished with only source and pathway controls, in 1997 the Central Artery Project elected to implement an acoustical window treatment program. The program was initially intended to reactively address continuing nighttime noise complaints for which the Project developed an Off-Site Noise Mitigation Policy establishing eligibility criteria for abutters to receive window treatments. In 1998 however, as a direct result of community suggestions, the Project expanded the acoustical window treatment program to proactively treat bedroom windows in residences that were likely to be adversely affected by nighttime construction noise. Noise models were used to predict which residences would be eligible based on anticipated work schedules and established criteria policies.(*440*) As a result, some 300-400 bedroom windows were proactively approved and treated, at a cost of about $400,000. This window treatment program continues to this day, and is expected to treat another 200 windows in anticipation of future work at an additional cost of $100,000.(*441*)

Noise Reduction Resources, Research, and Research Needs

*T*he national pooled-fund study, HP&R 0002-136, Evaluation of Performance of Experimental Highway Noise Barriers summarizes the findings of the multiyear study and presents some additional analyses of previously collected data. The other two reports in the study are FHWA-

RD-90-105, Parallel Barrier Effectiveness, Dulles Noise Barrier Project, and FHWA-RD-92-068, Parallel Barrier Effectiveness Under Free-Flowing Traffic Conditions.

AASHTO has produced a *Guide on Evaluation and Attenuation of Traffic Noise,* containing guidelines for the abatement of traffic-generated noise through highway design procedures and techniques. It discusses 1) the nature of noise, 2) a systems approach for addressing noise, 3) the highway noise study, 4) noise attenuation measures, and 5) noise barrier design considerations.(*442*)

The Organization for Economic Cooperation and Development (OECD) produced a *Roadside Noise Abatement report* reviewing current state-of-the-art and national experience with noise abatement techniques for new and existing roads. It presents the regulations and limits prevailing in the different OECD countries and provides the criteria used in measuring, evaluating, and predicting noise. Low-noise road pavements and noise barriers, walls and screens are assessed in detail. The report also describes the impact of road layout -tunnels, cuttings, embankments on noise levels.(*443*)

To reduce adverse noise impacts on communities, researchers are developing analysis techniques, abatement methods, and land use tools to better evaluate the effects of highway traffic and construction noise. Major issues requiring research are 1) ways in which atmospheric conditions impact traffic noise prediction, 2) relationship of pavement type and texture to noise, and 3) multi-modal transportation noise prediction methodology.(*444*)

Future research will provide additional model validation and improvements to the model's graphical user interface. Existing traffic noise prediction models, including the FHWA Highway Traffic Noise Model, do not account for atmospheric variations. Information related to the problems of highway construction noise and the consideration of visual quality during noise barrier design will also be updated and enhanced.

3.14. LIGHTING CONTROL/MINIMIZATION

Roadway lighting is an important part of a highway system. It contributes to a safe environment and facilitates traffic flow for the traveling public during evening or nighttime driving. Lighting shows drivers changes in direction, obstacles, and roadway surface conditions. Exterior lighting may also have a significant impact on economic development. At present, roadway lighting standards are based almost exclusively on traffic safety.

The impact of roadway lighting practices on the surrounding environment is of increasing concern to the public and DOTs, out of concern for impacts on wildlife as well as energy efficiency and cost. Light pollution is an unwanted consequence of outdoor lighting and includes such effects as skyglow, light trespass, and glare. "Sky glow" is a brightening of the night sky caused by natural and human-made factors. "Glare" is an objectionable brightness or reflection of light and a driving hazard especially bothersome for older drivers. "Light trespass" is the actual light that falls off the right-of-way and can be measured and quantified. In fact, many professional lighting designers have been obliged to go out at night and take measurements of the light that is falling off the right-of-way and onto a concerned citizen's property. Cities and states in some cases have responded with lighting ordinances and requirements regarding certain types of fixtures, minimum and maximum lighting levels, lumen/acre limits, and lighting eliminater in some cases. Legislation has been adopted in Arizona, California, Connecticut, Colorado, Maine, New Mexico, Texas, Georgia, and New Jersey. Such legislation has been proposed or introduced in New York, Iowa, Massachusetts, Michigan, New Hampshire, Maryland, Pennsylvania, Rhode Island, Virginia, and Wyoming.

Environmental impacts of lighting are of increasing concern to biologists and members of the public concerned about wildlife. In the 1970s, research into light's effect on organisms' "biological clocks" and nocturnal behavior patterns led biologists to take a closer note of artificial lighting's effect on a range of organisms. Over the past 25 years, much of this work has focused on small amphibians, reptiles, and birds.(445) Many animals rely on celestial light for visual orientation and/or the timing of periodic behavior. Artificial light that interferes with these essential behavioral systems is termed photo-pollution.(446) It has been estimated that between 35-50 percent of atmospheric light pollution is caused by roadway lighting.(447) Unlike chemical pollutants, errant artificial light is not toxic. Nevertheless, it can have profound effects on the survival of animals that rely on accurate light information to initiate or guide critical biological activities.(448) For example, trees under streetlights have been observed to retain leaves longer into the fall in temperate climates(449) and disruption of plant growth by sodium vapor lights has been recorded in several studies.(450)(451)

European research results reveal that road illumination has a statistically significant negative influence on the breeding habitat quality of certain birds, reaching over several hundreds of meters; in particular, the research suggested that the negative influence of illumination exceeded the attractiveness of favorable habitat or the negative influence of roadway noise.(*452*) Nocturnal insects are also extremely sensitive to outdoor lighting because they have evolved special adaptations of photoreception. In many cases insects become disoriented by the effects of outdoor lighting and are no longer able to perform their basic functions of nutrition and reproduction, leading researchers to conclude that outdoor lighting may be a serious threat to insects, though newer alternatives to the high pressure mercury vapor lamps are better for insects.(*453*) Light cues also figure prominently in the reproductive behavior of sea turtles. Errant lighting on or near nesting beaches introduces misinformation to turtles during vital phases of the reproductive process.(*454*) Large predators such as wolves and mountain lions are reported to avoid illuminated areas.(*455*)

Common Lighting Approaches and Deciding How Much Light Is Enough

High pressure sodium (HPS) lights are the most commonly used type of roadway lighting in the U.S. They have the inherent advantages of long life, and hence less maintenance, low cost, energy efficiency and good long range optical control. Low pressure sodium (LPS) and metal halide (MH) are also used to provide roadway lighting. All of these sources are energy efficient. Newer sources such as inductive fluorescent, compact fluorescent and light emitting diodes may be practical sources in the future.

In the last two decades, research into lighting concepts, along with major advancements in computer simulation and design software, has led to the development of new techniques and methodologies for the design of efficient, effective, safe and environmentally responsive roadway lighting systems. These advancements were acknowledged in the millennium edition of the *Lighting Handbook* of the Illuminating Engineering Society of North America (IESNA).(*456*) In addition, the United States Federal Highway Administration has completed a study on lighting design concepts and the American Association of State Highway and Transportation Officials is currently updating its *Informational Guide for Roadway Lighting.* The AASHTO guide provides guidelines for when lighting should be installed, traffic volumes, and other criteria for locating lighting. IESNA has also recently approved a revision to its *American National Standard Practice for Roadway Lighting* (RP8). The National Standard primarily deals with appropriate levels of lighting for different installations.(*457*)(*458*)(*459*) The revision includes three methods for designing continuous lighting systems for roadways: illuminance, luminance and small target visibility (STV). Advanced technologies in lighting hardware have been applied in most of the industrialized countries of Europe.(*460*)(*461*) Some DOTs have updated their own manuals based on these new standards and resources. For example, Oregon DOT produced a Traffic Lighting Design Manual in January 2003, which drew on RP8 and implemented some lighting reductions, including a study on whether light removal would be possible.

There are many valid reasons where lighting is not only needed, but required. It is important to understand the lighting objectives and how much is enough, in order to balance the need for lighting while minimizing light pollution and increasing energy efficiency. A number of social and economic benefits are attributable to roadway lighting, including but are not limited to:

- Facilitation of traffic flow,
- Reduction of nighttime accidents,
- Aid to police protection,
- Promotion of roadside businesses, and
- Safety for pedestrians and bicyclists.

Initial practices in assessing lighting needs include:

- Identification of community objectives and whether the street in question needs lighting.
- Identification whether other ways exist to accomplish the goals without installing lighting (including marking, mechanical structures, etc.)

Once lighting is deemed necessary, the following inquiry is recommended practice:

- Are minimum lighting levels being used to accomplish the objectives?
- Is the current or proposed lighting installation energy efficient?
- Are all attempts being made to minimize light pollution? One of the most common recommended practices in terms of minimizing light trespass has been use of full cut-off fixtures. A “full cutoff luminaire” is one that allows no direct light emissions above a horizontal plane through the luminaire’s lowest light-emitting part.
- Have maintenance and component life been considered? Have easy mechanisms for opening, removing lamps and ballasts, and cleaning been considered? Will special tools or equipment be needed?
- Is the lighting installation cost effective?
- Have lighting controls such as motion sensors or timers been considered?
- Is a lighting curfew (turning lights off after a certain time) appropriate?
- Are pole heights and pole spacings appropriate? Use an appropriate light for the location. In different locations, different pole heights are appropriate.
    - The “cobra head” type of luminaire seen on many streets and roadways is often found on a higher pole, spreads light further, and is often not fully shielded

- Architectural or decorative types of luminaires might have a scale that requires shorter pole heights.
- When existing utility poles are used, careful attention to luminaire selection is important so that it is suitable for the pole heights
- The height of street lighting poles will impact how uniform the light levels are in the street and surrounding area. This issue can be especially important in a retrofit installation where existing pole mounting locations are going to be used with no additional poles.

- Almost all lamps used in street lighting require a ballast to provide the proper voltage and current to the lamp. Are efficient ballasts going to be used? Even the most efficient lamp and ballast can be made very inefficient by using luminaires that trap light inside. A luminaire that emits less than half of the light generated by the lamp and ballast should be avoided.

Further recommendations by biologists investigating the impacts of lights on wildlife include the following: (*462*)(*463*)

- Lighting should be restricted where protection of biodiversity is a high priority, such as in unusual ecological habitats, and in certain agricultural and horticultural settings.
- To limit artificial lighting, light sources should be turned off whenever illumination is not essential.
- Lamp housings should be sealed tight, and located away from structures that may trap insects.
- Low-pressure sodium lamps should be used in preference to other kinds of lamps.

Arizona DOT Research to Improve Lighting Practices

ADOT has undertaken research on whether it is possible and desirable to improve lighting design practices, with particular attention to observers greater response to the yellow light portion of the spectrum. Nighttime visibility has been shown to be influenced by the lamp type used for roadway lighting, because the lamp's spectral output can influence sensors in the retina that are active at night. ADOT undertook a research project to determine the status of the subject and to find what can be done or needs to be done to better define the issues of useful lighting and to assess potential benefits. Both IESNA and CIE have established committees to review available knowledge of the subject and develop related technical publications.(*464*)

ADOT outlined the following questions with regard to current roadway lighting practice:

- Do different lamp color (or spectral power distribution) characteristics affect visibility and safety in a real roadway environment in a way that has a meaningful or measurable effect on driver performance?
- If a different choice in light source spectral distribution from that most commonly used now does result in potential driver performance improvement, what would be the tangible benefits be: reductions in crashes, light pollution, energy use?
- What would the drawbacks be: increased light pollution, more maintenance, higher initial costs?

- Certain local regulations require the use of a specific lamp type, which has raised controversy. Can ADOT conform to regulations requiring the use of a particular lamp type while meeting desired goals?
- Can and should ADOT make a change from its current designs to light sources with different color rendering characteristics, such as metal halide, or low pressure sodium?
- Can and should ADOT recommend changes to standards writing bodies from their current design standards to lower lighting levels, or to higher lighting levels?
- What maintenance issues are involved in changing lamp type?
- Does the current state of research justify an immediate change to lighting design practice or is more research needed to see if the current results are in fact meaningful?

Comparison of Lighting Sources, Issues, and Costs

The Arizona DOT developed a side-by-side comparison for the three sources for the lighting of a major roadway, using identical design specifications or each of the three. Each design was optimized for maximum pole spacing. The results by lamp type and pole spacing were:

- 400 watt High Pressure Sodium (HPS) 276 ft.
- 180 watt Low Pressure Sodium (LPS) 176 ft.
- 400 watt Metal Halide (MH) 246 ft.

Primarily as a result of these pole spacings, HPS provided the lowest initial system cost. MH had a 7 percent higher initial cost than HPS, while LPS was 41 percent more expensive than HPS. Power costs for HPS and MH were essentially identical, but were 24 percent lower for LPS. Considering overall operating costs, including maintenance, MH was 7 percent more expensive than HPS, while LPS was 12 percent less expensive. These values were based on a cost of 8 cents per kilowatt hour. Life cycle costs, based on a 30 year life, were 7 percent higher for MH versus HPS, and were 17 percent higher for LPS versus HPS.(*465*)

Florida DOT also investigated (LPS) lighting, as an alternative to (HPS), which is the most widely used type of lamp for street lighting. However, other drawbacks were noted by FDOT:(*466*)

- The large fixtures required for LPS typically did not meet Florida wind loading criteria, and the fixtures deteriorated relatively quickly in the salt-air environment of coastal roadways resulting in higher maintenance;
- Both initial and operational costs for LPS lights are substantially higher than for HPS lights;
- The distribution of lighting is more difficult to control (more lights are needed for uniform distribution);
- Replacement cycles for LPS lights are more frequent than for HPS lights (i.e., shorter operational life); and
- LPS have environmental concerns that require special disposal procedures.

While initial costs for LPS lights are higher than for HPS lights, electricity costs are generally lower, because LPS lamps are more efficient (more lumens per watt). In practice, operational costs may vary, depending on how the lights are used in a particular utility's lighting system. Regardless of overall costs, there are some drawbacks to LPS usage. Principal among those are the large fixtures required to house the lamps. These fixtures are susceptible to damage during high winds, require more maintenance, and typically have more omni-directional broadcast properties than conventional light fixtures (i.e. more difficult to control light distribution).

Florida DOT's Coastal Roadway Lighting Manual

Florida DOT has undertaken lighting research primarily because the state's beaches serve as important nesting habitat for several species of threatened and endangered sea turtles. Artificial light on or near nesting beaches can negatively affect the nesting process by interfering with normal nocturnal behaviors and spatial orientation of sea turtles, a problem to which streetlights contribute. Consequently, FDOT contributed to development of a Coastal Roadway Lighting Manual. Guidelines and alternative lighting recommendations contained in the manual were the collaborative effort of a Technical Working Group of lighting experts, traffic engineers, public safety personnel, utility customer service managers, biologists, and regulatory agency personnel. The partners had found that the previous lack of basic guidelines for streetlight management often resulted in duplication of effort, inadequate resolution of identified problems, delays in implementation of effective solutions, and/or unnecessary expense and an adversarial climate between those requiring that lighting be modified and those responsible for affecting a solution. The intent of streetlight management was to 1) confine light to the area of its intended use; 2) reduce the amount of light emitted to the minimum required to effectively achieve its intended purpose, and/or, 3) use light sources that minimize the potential for wildlife and hatchling disorientation.

When a lighting system is incorporated into a roadway improvement project, the FDOT Project Design Engineer refers to the Plans Preparation Manual for information on how to justify and design the system to applicable safety standards. Design elements include distance between poles, pole height, light source, wattage, illuminance, and clear zone requirements. The proximity of proposed lighting systems to environmentally sensitive areas is not always considered. However, the Project Design Engineer can request a design exception if variances from minimum safety standards are needed to reduce the potential for lighting impacts. This requires coordination with the Federal Highway Administration. To better address wildlife needs, FDOT lighting specialists now draw from the following list of options to reduce roadway lighting impacts in the following section.

Lighting Environmental Stewardship Practices

Best practices to reduce glare and improve visibility included: (*467*)

- If using cobrahead fixtures, use a flat-glass cobrahead instead of the typical horizontally mounted high-output lamp in the cobrahead-style fixtures, where the glass refractor lens on the lamp-head creates direct glare that is accentuated during extreme weather conditions such as rain, sleet, snow, and fog. This fixture still has bright spots under the pole that create glare, but is a better alternative.
- Install lights at uniform heights, which helps the eye avoid having to adjust to extreme ratios of alternating higher and lower lights.
- Avoid use of "offset fixtures," mounted at an angle, with much of the resulting light wasted, going into the sky where it can affect nearby residential neighborhoods as well as the flight patterns of migratory birds. Some studies suggest that street and roadway lighting cause as much as 50 percent of the skyglow in our major urban areas. Many

cities have already adopted ordinances against light trespass and light pollution from homes and businesses.

- Utilize full cutoff fixtures to direct light and reduce light trespass.
- Ensure lighting is energy efficient.
- Install improved reflector systems and vertical lamps to put light more accurately in areas where light is desired. Vertically lamped fixtures can be mounted in a median and serviced from one side. Usually, one fixture can replace two or more cobrahead fixtures used in traditional designs. With an optimized fixture design, one can lower mounting heights and still meet required lighting levels. This type of installation usually has a lower first cost and, because it mandates fewer poles and fixtures, a much lower maintenance cost. Energy consumption is usually lower.
- Avoid overlighting. Utilize the IES Standard Practice (RP-8) manual on Roadway Lighting, adopted as the American National Standard Practice in 2000.
- Realign the fixture (change angle of mounting arm or rotate fixture head) so the source of light is not directly visible outside the ROW.
- Apply a shield to a drop globe fixture.
- Change an open bottom or drop globe fixture to a cutoff fixture.
- Apply a shield to a cutoff fixture.
- Reduce the mounting height of the fixture.
- Reduce the lamp wattage.
- Change the lamp socket position in the fixture to compress the lighting footprint.
- Change to a fixture with a different type of reflector providing a more favorable lighting footprint.
- In addition to other shielding and light reduction measures: Install a flat 2422 acrylic amber lens in a cutoff fixture with an HPS lamp of 70 watts or less (e.g., GELS 70W M250).
- Turn the light off.
- Remove the fixture.
- Relocate the fixture to block light from extending to sensitive resources.
- Change to an LPS fixture (if the light is customer-owned).
- Create a vegetated berm/buffer or other light shield between the roadway and the sensitive resource.

Electric utilities can generally provide the following options:

- Seasonally turn the lights off.
- Relocate or redirect the light fixture.
- Change a drop globe fixture to a cutoff style fixture.
- Remove the fixture.
- Lower mounting height.
- Reduce wattage.

- Selectively install amber-colored filtering lenses (on cutoff fixtures of 70-watts or less and only in addition to other modifications).
- Install a light shield.

An overview of roadway lighting fixtures is available at the MetroLux Lighting website.(*468*)

FDOT's Embedded Roadway Lighting Study

In order to further study alternative roadway lighting systems, FDOT funded a demonstration project in 2001 that utilized embedded roadway lighting products. Consultants contracted by FDOT researched available lighting products, designed and installed a system, and are currently maintaining it. A roadway section was selected because there was a history of hatchling disorientations on adjacent beaches, there was a vegetative screen between the road and the beach, the roadway is not heavily traveled in the summer months, and the community was particularly sensitive to the needs of sea turtles. The purpose of the project was to determine if innovative lighting techniques could illuminate pavement markings without impacting sea turtles on adjacent beaches. The modification involved deactivating the existing overhead street lighting, placing amber lenses on existing pedestrian pathway lights, and installing low bollard mounted luminaires along the pedestrian and bike ways. As a safety countermeasure, an embedded pavement lighting system was installed in the roadway. In general, area lighting levels and uniformity were reduced by the elimination of the overhead lighting. The remaining pedestrian area lights provided adequate illumination levels along the pedestrian pathway. Visibility in the travel lanes and in the bike lanes appeared to have been adequate for the traffic conditions of the roadway. The embedded roadway lighting and the low bollard luminaires served principally as delineation aids.(*469*)

Caltrans Light Minimization Efforts

In response to the energy crisis in California, Caltrans voluntarily adopted requirements for lighting controls by zones, maximum lighting power, and shielding of luminaires. Luminaires were required to be off during the day and all luminaires greater than 100 watts to be IESNA cutoff type or full cutoff.(*470*) Caltrans is exploring designs that yield peak candlepower in the range of 65°to 72° yield, as those are the most economical roadway/outdoor layout. Avoidance of light above 80° from vertical was also recommended, as such light never reaches the ground, causes direct glare, and generates the most number of complaints.(*471*)

Tennessee DOT Light Reduction and Maintenance Cost Savings

Tennessee DOT recently took a closer look at lighting opportunities and tradeoffs and found opportunities for significant payoff. A value engineering proposal for a new intersection designed with off-set style cobrahead lighting mounted in the right-of-way outside the safety shoulders was revised to use a vertically mounted lamp in an optimal, architecturally designed roadway fixture directed from a 40-ft. pole placed on the median barrier. True cut-off fixtures were installed, eliminating light trespass and light pollution; power consumption stayed the same in terms of first-cost dollars and cents. The change provided the state with several important benefits: (*472*)

- Skyglow and light trespass were greatly reduced. People in surrounding residential neighborhoods were pleased with the reduction in stray light and fewer impacts to the natural environment were likely.

- Lighting levels on the roadway were increased, creating a safer highway and a safer intersection.
- Fewer fixtures and poles were required, reducing anticipated maintenance costs.
- Savings included more than 5 miles of trenching and backfilling and more than 5 miles of cable that no longer needed to be provided.
- Sixty-one pole foundations, poles, and fixtures were eliminated. The new median lighting system involved installation of 26 poles and fixtures mounted on median barrier walls.
- Considering maintenance, the cost of the lighting project was considerably reduced.

Tennessee DOT implemented alternatives to traditional roadway lighting practices that created visibility, maintenance, and safety problems, as well as escalating installation costs.(473) TennDOT used many of the best practices listed in the earlier section on roadway lighting fixture options.

3.15. Safety Rest Areas, Traveler Services, and Parking Area Design

Washington State Roadside Manual describes environmental stewardship practices for roadside facilities such as safety rest areas, roadside parks, points of interest, and traveler information centers. Recommended practices include:(*474*)

- Use context sensitive design principles in planning and funding of projects. See the FHWA Context Sensitive Design website for more information on context sensitive design.
- Preserve existing landscape features to the greatest extent possible.
- Select vegetation to minimize water usage.
- Encourage the use of recycled materials and offer recycling opportunities to the greatest extent practical.
- Encourage nonprofit groups to coordinate recycling programs for aluminum cans and newspaper whenever possible.
- Consult Maintenance personnel during the design phase of any parking facility to determine their concerns and respond to their suggestions.

Planning for Conservation in Rest Area Design

An Environmental Management System roadmap (RMS) developed for AASHTO's EMS Workshop for State DOTs recommends the following stewardship practices in rest area planning. The main objective of the process is to consider environmental issues and opportunity areas in the design process and then to establish a process to routinely and consistently identify and implement pollution prevention and energy efficiency (P2/E2) opportunities in the operation and maintenance of rest areas. To do this, it is helpful to identify environmental issues and opportunity areas and prioritize. For example, desired environmental benefits and fiscal gains could include the following objectives: (*475*)

- **Reduce energy costs.** Rest areas average around $10,000/year for electricity and $7,000 for natural gas.

- **Control chemicals/materials used in maintenance (e.g., cleaning products) and switch to "green" cleaners wherever possible**. Each rest area requires 500 gallons per year of cleaners and 1,000 pounds per year of herbicides and pesticides.
- **Reduce water consumption.** Each rest area (lavatories,drinking water, and cleanup) uses an average of 1,000,000 gallons per year of water, DOT cost for treating well water or purchasing water averages $1.75 per 1,000 gallons.
- **Reduce the number of and the potential for wastewater treatment upsets** per month at each area's treatment facilities(e.g.,discharge parameters not met).

A substantial amount of pollution prevention and energy efficiency (P2/E2) information has been developed by USEPA and Defense Department agencies. Among the DOTs, PennDOT has prepared a P2/E2 Guide identifying and characterizing the costs and benefits of various P2/E2 options.

The Washington State Roadside Manual describes environmental stewardship practices for parking area design as such: (*476*)

- Provide areas for snow storage requirements in parking area design.
- Adjust design to comply with local regulations and requirements.
- Design aisles and breaks in planting strips to provide for easy maintenance. Aisles should be wide enough to allow access by street sweepers. High points in corner areas will allow water to drain away from these locations so they do not collect water and leaves.
- Ensure environmental quality by addressing air, drinking water and noise concerns, watershed restoration, and preservation of habitats and public green spaces.
- Use transportation facilities to enhance community aesthetics by incorporating unique local features (scenic views, community neighborhoods, historic districts, cultural and natural resources, etc.) and providing focal points for communities through those facilities such as multimodal stations, pedestrian plazas, and parkways.

Vegetated/Bioinfiltration Swales in Parking Facility Design

- Integrate vegetated/bioinfiltration swales into the facility to collect and detain stormwater. These can be designed within planting islands and around the perimeter. These swales also serve as water quality filtration strips and can be an amenity on the site. Long, linear swales break up the large expanse of pavement, collect stormwater, and allow for tree planting. A minimum width of 10 feet is recommended for these planted swales. If curbing is not placed around the swale, stop blocks should be used for each parking space surrounding the swale to prevent vehicles from entering the swale. Rip soils in planting islands before adding soil amendments and plant materials and/or install subsurface drainage. See the EPA Bioretention website for information on design of planting islands within parking areas.
- Use on-site stormwater drainage to provide water for plants. For example, plant trees on the edges of swales in parking islands. Trees should be spaced a minimum of every 75 feet on center within the parking lot, and aligned with stall lines. If curbing is used around swales, regular gaps in the curbing should be provided to allow stormwater runoff to drain into the swale. The elevation of the swale in relation to the pavement should be

low enough for water and debris to drain into the swale without continuous maintenance. However, these locations will require periodic maintenance to clear debris build-up.

Permeable Pavements

Consider vegetated pervious open grid-type parking stalls to allow infiltration of stormwater. These are most effective for peripheral or overflow parking. Alternative modular paving systems that can support long-term parking are available.

Porous Concrete Pavement

No-fines porous concrete pavement is an emerging technology that has been used in the eastern United States and in Europe for years. Costs are slightly higher (approximately 25 percent more) than for conventional Portland cement concrete pavement. However, because porous concrete pavement infiltrates water at 270 to 450 inches per hour per square foot (3-5 gallons per minute per square foot), stormwater detention facilities are usually not needed to mitigate those surfaces, thereby reducing costs for stormwater mitigation.

Porous concrete pavement uses large aggregate and Portland cement with an additive to slow the rate of evaporation of the mix during placement. The thickness of the pavement is greater than conventional concrete and is laid over an aggregate subbase in order to provide structural stability. Because of the large pore spaces (15 to 25 percent of the total volume), porous concrete pavement is more resistant to frost heave than conventional concrete pavement. With regular (4 times per year) vacuuming or blowing to remove fine materials that can clog the pore spaces, these systems can continue to infiltrate stormwater and last as long as conventional concrete pavement systems. Higher installation and maintenance costs might be balanced by savings in stormwater storage and treatment costs. Because these systems infiltrate water at high rates, they are not appropriate where pollutants, such as fluid drips are likely to occur and where ground water tables are close to the surface.

The large pore spaces may cause problems with people in spiked heels, or people with pointed-tip canes. For this reason the use of this system may be more appropriate on outlying areas. Information on pavements can be found in WSDOT's online engineering publication, the WSDOT Pavement Guide.(*477*)

CHAPTER 4: CONSTRUCTION PRACTICES FOR ENVIRONMENTAL STEWARDSHIP

Much environmental stewardship practice in construction over the past thirty years has focused on erosion and sedimentation controls and protection of water quality. Virtually every DOT now produces guidance for design engineers on design of stormwater pollution prevention plans and implementation and maintenance of stormwater best management practices (BMPs). The cutting edge in stormwater protection is now focusing on ensuring 100 percent compliance with these practices at construction sites; Maryland State Highway Administration and Caltrans, many of whose practices are included in this Chapter, lead the way in this regard. While links to some of the best on-line resources in water quality protection are included herein, this Chapter focuses on the wider range of environmental stewardship practices in construction, which are less common than erosion and sedimentation control and for which resources are sometimes harder to find.

4.1. GENERAL CONSTRUCTION SITE STEWARDSHIP PRACTICES

These general practices have been collected from multiple DOTs and from requirements by federal land management agencies to protect the environment in the course of construction:

- Select the right equipment for the job.
- Establish an emergency notification program.
- Before beginning a project, conduct an on-site meeting. At a minimum, include team members with vegetation, local climate, and soils knowledge.
- Avoid earthwork in saturated soils. When possible, schedule heavy equipment work during periods of low precipitation.
- Develop and implement BMPs for mobile operations common to the construction of a project as well as the earthwork: include asphalt recycling, concrete mixing, crushing and the storage of materials, as appropriate to control the individual situations these mobile operations can create.
- Inspect project work daily.
- Consider the following often overlooked erosion and sedimentation control areas:
    - Round the top edge of a slope failure, which is often a vertical face. For project success, it is critical to address this “initiation point” or persistent source of erosion by removing or rounding off the slope overhang.
    - Smooth all eroding areas such as rills or gullies. In addition, prepare a seed bed by slightly roughening Do this by raking across the slope face, not downhill.
    - Create terraces when slopes exceed 35 percent. Dig these terraces 10 to 14 inches deep across the slope face. Horizontal spacing usually varies from 14 to 10 feet depending on conditions. The steeper the slope, the closer the terraces should be to one another. The objective is to accelerate establishment of plants by reducing the slope angle of the planted locations.

4.2. Preparing Access and Staging Areas

Several principles should guide design, placement, and construction of site access to ensure environmental stewardship:

- Avoid any sensitive wildlife habitat or plant areas or threatened and endangered species and their designated critical habitat.
- Avoid crossing streams if at all possible; where crossing is unavoidable, use bridges.
- Minimize slope disturbance since effective erosion control is difficult on a sloped roadway that should be heavily used.
- Construct roadways with low gradients; ensure that stormwater runoff drains to outlets; install an adequate roadbed; and, if possible, set up a truck-washing station at the entrance of the construction site to reduce offsite transport of mud and sediment by vehicles.
- Every effort should be made to minimize and, where possible, avoid site disturbance. Emphasis should be placed on addressing protection of existing vegetation and sensitive habitat, erosion and sediment control, protecting air and water quality, protecting cultural resources, minimizing noise, and providing for solid waste disposal and worksite sanitation.

4.3. Construction Sequencing, Timing, and Acceleration

There are a variety of reasons for construction sequencing. On environmental, restoration, or bioengineering projects, sites often require earthwork as part of site restoration and/or before installing a soil bioengineering system. It is important to plan for and manage timing conflicts that can occur between scheduling heavy equipment, hand labor work, plant collection, and plant use.

Construction Phasing and Sequencing

One of the largest and most common environmental stewardship concerns that can be addressed by construction sequencing is minimization of unprotected soil and resultant erosion and sedimentation. Construction sequencing should be scheduled to minimize land disturbance at all times, but especially during the rainy or winter season. Scheduling should be considered when establishing permanent vegetation (appropriate planting time for specified vegetation). The following environmental stewardship practices are recommended:

- Minimize the extent and the duration of exposure of bare ground surface to be opened at any one time, to prevent erosion at the source.
- Plan the phases or stages of construction to minimize exposure. On larger projects, sub-phases should be used to minimize the area of exposed soil. Before site disturbance occurs, perimeter controls, sediment traps, basins, and diversions should be in place to control runoff and capture sediments. Prioritize disturbed areas in the vicinity of water bodies, wetlands, steep grades, long slopes, etc. for effective stabilization within seven days of disturbance.
- Schedule land-disturbing activities during periods of low precipitation.

- Complete grading as soon as possible after it is begun.
- Establish permanent vegetative cover immediately after grading is complete. Graded areas that will not be worked on should be seeded and mulched immediately, rather than waiting until all project grading is done.
- Monitor work to ensure progress according to the schedule and adjustments if necessary. When changes are warranted, amend the sequence scheduling in advance to maintain sediment control.

EPA has developed a Fact Sheet on Construction Sequencing, available on-line.

Preserving Local Fish and Wildlife through Attention to Timing Restrictions

Timing restrictions might be imposed on the project due to the presence of nesting, migrating, or wintering threatened or endangered species. Restrictions are dependent upon the distance from the species' activity center, the type of activity proposed, and the time of year the activity is proposed. Pile driving, blasting, and other noise generating activities (addressed in the Noise Minimization section of this Chapter) are of the greatest concern.

Timing restrictions might also be placed on projects involving construction in or over water, such as culvert or bridge installation or pile driving. Sensitive times include winter periods, migratory periods, and breeding seasons.

- During construction, clearly flag or place construction fencing around all habitat areas and features that are to be saved or avoided in the field, and include those locations in the plans of the project. This will minimize confusion and will help avoid impacting these areas and/or features.
- Projects near stream or wetland habitat areas must have their erosion control measures carefully implemented and maintained during construction to avoid impacting aquatic species.
- Occupied migratory bird nests may not be removed; however, nests can be covered prior to seasons when nests would be re-occupied.
- See Bridge Construction and Maintenance Section for further discussion of timing restrictions.

Accelerated Construction

Though accelerated construction is often driven by increasing traffic demand, this practice is also highly useful to minimize environmental impacts on certain projects as it focuses on "getting in and getting out" as quickly as possible. Sponsored by the American Association of State Highway and Transportation Officials' (AASHTO) Technology Implementation Group (TIG) and the Federal Highway Administration (FHWA), the Accelerated Construction Technology Transfer process begins with a 2-day workshop in which a multidisciplinary team of 20–30 national transportation experts works with an equal number of their local counterparts to evaluate all aspects of a project and develop recommendations for reducing construction time and enhancing safety and quality.(*478*)

Transportation Research Board Task Force A5T60 on Accelerating Innovation was formed in 1999 to promote accelerated construction in the highway infrastructure. In 2002, the task force completed two ACTT pilot workshops in Indiana and Pennsylvania. AASHTO-TIG and FHWA are continuing the effort, and workshops in Texas, Louisiana, and California were conducted in 2003. Interest among State highway agencies has been very high, and six workshops already are occurring in 2004. Recent workshop recommendations have included using design-build contracting; coordinating with utility companies early in the project planning process; using long-life pavements with a 50-year design lifespan; improving general materials specifications; establishing a dedicated incident management system at the project site; and introducing various traffic flow strategies. In some cases project construction times have been cut in half.(*479*)

4.4. DISCOVERY OF ARCHEOLOGICAL OR HISTORIC SITES IN CONSTRUCTION

Prior to construction, any potential cultural resources should be identified in compliance with Section 106 of the National Historic Preservation Act. An archaeological record search should be conducted during the planning process in accordance with the State Historic Preservation Officer (SHPO).

Mitigating a project's impact on historical and archaeological sites during construction may require the recovery of artifacts. Mitigation may also require Native Americans, archaeologists, architects, and historians to monitor and coordinate the recovery process. Normally, archaeological work is done in advance of construction, but occasionally, finds are made during construction.

- If human remains or previously unknown historic or archaeological artifacts are unearthed, work should be suspended in the vicinity until the find can be evaluated and properly treated. Procedures and responsibilities are usually detailed in a DOT's environmental handbook. Typically, all activity that might adversely affect the historic property must cease, and the responsible agency official must notify the SHPO. Upon notification, the SHPO determines whether the activity will cause an irreparable loss or degradation of significant data. This might require on-site consultation with a 48-hour response time for determining significance and appropriate mitigation actions so as not to delay implementation activities inordinately. If the property is determined not to be significant or the action will not be adverse, implementation activities may continue after documenting consultation findings. If the resource is significant and the on-site activity is determined to be an adverse action that cannot be avoided, implementation activities are delayed until appropriate actions can be taken (i.e., detailed survey, recovery, protection, or preservation of the cultural resources).
- Data recovery should collect information through scientific investigation in accordance with the Secretary of the Interior's Standards and Guidelines.
- Include specifications to the effect that the contractor will: (*480*)
    - Involve archaeologists in project planning and pre-construction meetings to develop preservation plans that minimally disrupt the construction schedule.
    - Contact the DOT archeologist five days prior to pavement removal in the area of archaeological concern, to ensure that both a DOT archaeologist and an archaeological contractor could be onsite quickly to monitor construction.
    - Saw cut and lift out existing pavement, instead of using air-driven machinery, to minimize disturbance.

- Minimize the typical section of construction within the area of archaeological concern.
- Construct no stormwater systems in the area associated with the site.

4.5. Construction in Streams, Wetlands, and Other Environmentally Sensitive Areas

Riparian areas and wetlands make up a small percentage of total land area in the United States, but are essential for maintaining water quality and quantity, ground water recharge, and dissipating stream energy. They also provide tremendous community benefits in the form of wildlife, fisheries, and recreation, along with other uses, and are indicators of watershed health, as they are among the first landscape features to reflect damage from improper management. Due to their sensitivity, special attention is in order, including the following environmental stewardship practices:

Pre-Contract and Pre-Construction Activities

- **Emphasize sensitive areas during precontract meetings.** Note the kinds of activities that are not allowed in the sensitive areas and designated lands (such as clearing, grading, stockpiling materials, construction equipment, vehicle parking, etc.). This will help to minimize confusion and also help contractors and construction personnel avoid the sensitive areas. Items that should be specifically addressed at the prework meeting include: (*481*)
- Access — Equipment access points that minimize disturbance, especially to less stable areas should be located.
- Protection of Water Quality – Prevention of direct runoff of sediment containing water into streams, proactive prevention of erosion, qualitative design expectations relating to construction area drainage and treatment, preparation and protection of the site from potential storms during the work period.
- Protection of Habitat – Preservation of riparian habitat, minimization of damage to existing vegetation, preservation and use of cleared large wood with stumps.
- Dewatering Method Performance - Expectations of erosion control methods, sediment trapping and turbidity treatment of runoff, expectations of possible subsurface flow in the excavation and the method for handling it, including payment method. Capture and rescue of aquatic organisms may be an important part of dewatering that could be the responsibility of the contractor. Discuss expectation and coordination with other specialists (fish biologist).
- Quality of Stream Bed Simulation Rock Placement – Emphasize that the intent is to reconnect the channel and create as natural a channel inside the pipe as possible. Photos of the site showing stream segments with similar channels to what is in the contact plans can be helpful. Discuss the proposed method of placing of bed material; this often requires hand labor and specialized equipment. The quality of labor and effort put into fitting and interlocking individual pieces of rocks together can have a substantial effect on their durability. Material dimensions, gradation, and permeability are vital to the simulated streambed's performance. Special specification and pay items are vital to

describe and administer this area of work. These items may be a minor cost item in the overall contract, but they have a major impact on the effectiveness of the structure.

- **Perform construction surveys if needed for bioengineering projects.** Additional surveys by the contract administrator may be helpful before excavation to help locate any additional specific features or objects not in the contract drawings or original survey. Surveys performed during construction to determine specific locations of the structure and details are extremely important and are in a larger sense verifying that the design meets the site geometry. Contractor survey accuracy should be checked. Contract administrator should be skilled in survey methods and able to verify contractor surveys. Survey errors can lead to costly construction mistakes and, therefore, should be caught as soon as possible. For instance, if the structure is placed at the wrong elevation, when the stream channel is constructed and reconnected to the adjacent channel, slopes into or out of the pipe may cause channel scour or passage problems that are difficult to mitigate. A structure placed in the wrong location may create road alignment problems later on.
- **Confine construction and staging areas to the smallest area necessary.** Construction area boundaries, including staging areas, should be clearly marked to ensure and all construction activity and storage of construction materials should occur within these marked areas.
    - Use disturbed or developed areas for staging whenever possible.
    - Keep right-of-way for watercourse crossings as narrow as possible within the constraints of safety and construction requirements. Limit removal of vegetation to the width of the right-of-way.
    - Where possible, plan instream work to occur as a single event.
    - Restrict instream work to low flow periods where possible.
    - Limit machinery access to a single point on one bank.
    - Limit distance between machinery access point and work site.
    - Utilize new technologies such as prefabricated materials and Geosynthetic Reinforced Soil abutments and walls to minimize the access needed for large equipment.
- **Install construction fencing or flagging to protect sensitive areas** from encroachment by construction activities, if appropriate. As in delineating work zones, fencing should be placed around all protected areas during initial site preparation, even before the access road is fully constructed, if possible, but certainly before wholesale earthmoving begins. Fencing material should be easy to see, and areas should be labeled as protection areas.
- **Delineate and mark wetland areas.** Adjacent or nearby wetland areas not in the construction area should be fenced to reduce potential impacts from construction activities. Consider the following as indicators of possible wetland presence, and a potential "red flag" until the area is delineated by a trained wetland biologist:

  Wetland Hydrology Indicators
    - Areas that have standing water at any time of the year.
    - Topographical low areas.
    - Areas near streams, lakes, or other shorelines.

- Areas with water seeping out of a hillside.
  - Ditches that hold water long after rain events.
  - Ditches that flow to other water bodies such as streams, lakes, ponds, and the like.

Wetland Soil Indicators

  - Areas where vehicles get stuck or leave ruts.
  - Areas with dark, sticky soils.
  - "Unsuitable soils" for construction or foundation.
  - Highly organic soils.
  - Clay soils that are pale gray or mottled.
  - Sites within floodplains.
  - Soils that give off a rotten egg smell when disturbed.

Wetland Vegetation Indicators

  - Obvious wetland plants such as rushes or cattails.
  - Trees such as alders or willows dominating low-lying areas.
  - Shrub Thickets in low-lying areas.

- **Isolate the work area from other jurisdictional waters.**
- **Prevent discharge of water from the work area prior to treatment.** All runoff from the work area should drain through a Sedimentation Control BMP or a Dewatering Device BMP prior to entering jurisdictional waters.
- **Maintain a buffer area along streams and other waters of the state or waters of the US.** Buffers are areas along jurisdictional waters such as streams, lakes, ponds and estuaries that often have legal protection. A typical riparian buffer is a 50-foot wide vegetative strip along each side of a jurisdictional stream measured from the top of bank or the mean high water line. The riparian buffer typically cannot be disturbed unless specific conditions are satisfied. Existing drainage ditches and roadside ditches are typically exempt from the buffer rules provided that they are managed to minimize sediment, nutrients and other pollution that enters jurisdictional waters. Existing drainage ditches may not be deepened beyond original pre-construction depths. New ditches through a riparian buffer are typically not allowed unless specific conditions are satisfied.(*482*)

Vegetation Protection

Protection of vegetation is a particularly important part of construction activities near or in streams, wetlands and environmentally sensitive areas. Consequently, environmental stewardship practices such as the following, should be employed:

- **Avoid native vegetation removal and disturbance** on streambanks unless absolutely necessary.
- **Maintain a vegetated buffer strip between the work site and watercourse** except at the actual crossing location.

- **Mark large trees, where present, with colored and labeled flagging** to ensure that the field crew understands what is to be cut and what is to remain and be protected from damage. Temporary barriers to protect existing trees, plants, and root zone should be provided, if necessary. Trees and other vegetation should not be removed, injured, or destroyed without prior written approval. Ropes, cables, or fencing should not be fastened to trees.
- **Clear vegetation from unstable or erodible banks by hand** instead of using heavy machinery.
- **Remove undesirable plant species** such as nonnative and invasive species that might threaten the survival of native species.
- **Retain as much understory brush and as many trees as feasible, emphasizing shade** producing and bank stabilizing vegetation.
- **Minimize soil compaction by using equipment with a greater reach** or that exerts less pressure per square inch on the ground, resulting in less overall area disturbed or less compaction of disturbed areas.
- **Decompact disturbed soils at project completion as the heavy equipment exits the construction area.** Heavy equipment may use various routes to reduce severe compaction in any one area. Conversely, using fewer haul routes may result in less overall compaction. After use, haul routes may be ripped or subsoiled to reduce compaction and promote infiltration.
- **If riparian vegetation is to be removed with chainsaws**, consider using saws currently available that operate with vegetable-based bar oil.
- **Revegetate disturbed and decompacted areas with native species** specific to the project location that comprise a diverse community of woody and herbaceous species.
- **Allow at least four weeks of growing season** when using seeding to stabilize erodible soils.

Fish and Aquatic Species Protection

Fish passage design practices are detailed in Chapter 3, Designing for Environmental Stewardship in Construction; however, the following practices are important to review and implement during construction:

- **Disturbance of the bed and banks should be limited to disturbance necessary to place the culvert**, embankment protection and any required channel modification associated with the installation. All disturbed areas should be protected from erosion within seven (7) calendar days of completion of the project using vegetation or other means. The banks should be revegetated within one year with native or other approved woody plant species. Live stakes should be planted at a maximum interval of three feet (on center) and maintained as necessary to ensure 80 percent survival.
- **Approved structures should be constructed in the dry whenever possible.** Where significant live flow exists, isolation of the construction site from stream flow should be accomplished by techniques such as:
    - The installation of a bypass channel, a flume or culvert

  - The installation of a sheetpile or sandbag wall
  - The use of a water-filled cofferdam
  - By pumping the stream flow around the site if siltation or turbidity cannot be reduced to acceptable levels by other means.
- **Any wastewater from project activities and dewatering should be routed to an area outside the ordinary high water line** in a location that will not drain directly into any stream channel, to allow settling of fine sediments and other contaminants prior to being discharged back into the subject stream.
- **The work area should be fully restored upon completion with a mix of native, locally adapted, riparian vegetation.** Use of species that grow extensive root networks quickly should be emphasized. Sterile, non-native hybrids may be used for erosion control in the short term if planted in conjunction with native species.
- **If target species are likely to be present, fish clearing or salvage operations should be conducted by qualified personnel prior to construction.** If these fish are listed as threatened or endangered under the federal or state Endangered Species Act, consult with FWS, NMFS, and/or state biologists to gain authorization for these activities. Care should be taken to ensure fish are not chased up under banks or logs that will be removed or dislocated by construction. Return any stranded fish to a suitable location in a nearby live stream by a method that does not require handling of the fish.
- **If pumps are used to temporarily divert a stream to facilitate construction, an acceptable fish screen should be used** to prevent entrainment or impingement of small fish.

Erosion control receives particular attention in environmentally sensitive areas. Properly chosen, installed, and maintained sediment control measures can provide a significant degree of filtration for sediment-bearing runoff. For further detail on erosion control stewardship practice, see the section of this document on Erosion and Sedimentation Control, and the related section on Bioengineering, in the Chapter Designing for Stewardship in Construction:

- Use environmentally sensitive bank and erosion control measures or bioengineered designs.
- Develop sediment control plans and install sediment control measures before starting work.
- Minimize the length of time that unstable erodible soils are exposed.
- **Isolate the construction area from flowing water until project materials are installed** and erosion protection is in place. Erosion control measures should be in place at all times during construction. Do not start construction until all temporary control devices (straw bales, silt fences, etc.) are in place downslope or downstream of project site.
- **Stockpile topsoil removed from the right-of-way** outside of the active floodplain and use measures such as silt fences and holding ponds to prevent stockpile runoff from entering the watercourse.
- **Use erosion controls to protect and stabilize stockpiles and exposed soils** to prevent movement of materials. Use devices such as plastic sheeting held down with rocks or

sandbags over stockpiles, silt fences, or berms of hay bales to minimize movement of exposed or stockpiled soils.

- Direct runoff containing sediment away from the stream into a vegetated area.
- **Construct suitably sized settling ponds** to precipitate suspended sediment before water is discharged into the watercourse.
- **Stabilize erodible soils as soon as practical** by seeding, spreading mulch or installing erosion control blankets.
- Inspect sediment control measures regularly and make necessary repairs immediately after damage has been discovered.
- **Maintain a supply of erosion control materials onsite**, to facilitate a quick response to unanticipated storm events or emergencies.
- When needed, utilize instream grade control structures to control channel scour, sediment routing, and headwall cutting.

Other Stewardship Considerations

- **Prevent vehicle fuels and fluids from contaminating the watercourse.**
- Refuel machinery at locations well removed from the watercourse (recommended minimum 100 m or 300 ft. separation)
- Wash and service vehicles and machinery at locations well removed from the watercourse.
- Use bio-friendly hydraulic fluids in equipment operating in or adjacent to watercourse.
- Store fuel, lubricants, hydraulic fluid and other potentially toxic materials at locations well removed from the watercourse.
- Isolate storage areas so that spilled fluids cannot enter the watercourse.
- Prepare a spill contingency plan.
- Ensure operators have spill clean-up supplies on site and are knowledgeable in their proper use and deployment.
- Report all spills. In the event of a spill, operators must immediately cease work, start clean-up, and notify the appropriate authorities.
- **Perform in-stream work in low flow conditions**, to the maximum extent practicable.
- **Prevent any construction debris from falling into the stream channel.** Any material that does fall into a stream during construction should be immediately removed in a manner that has minimal impact to the streambed and water quality.
- **Where feasible, the construction should occur from the bank**, or on a temporary pad underlain with filter fabric.
- **Temporary fill must be removed in its entirety** prior to close of work-window.
- **Begin reclamation and site cleanup as soon as construction has been completed**. Remove all waste material from the active floodplain as well as all temporary facilities and structures.

- **Recontour, stabilize, and revegetate disturbed areas to suit original conditions**; it is especially important to stabilize all slopes leading directly to the watercourse.

State Resources and Fact Sheets

States have developed the following fact sheets outlining environmental stewardship practices with respect to stream crossings:

- Ford Crossing, MD
- Temporary Fording, NCDOT, p. 97
- Utility Crossing, MD
- Small Bridge Installation, MD
- Temporary Access Bridge, MD
- Temporary Access Bridge, NCDOT, p. 101
- Temporary Stream Crossings, Caltrans
- Temporary Piped Crossing, NCDOT, p. 99
- Cofferdams, Alberta Transportation
- Instream Silt Barriers, Alberta Transportation
- Sensitive Area Isolation, Alberta Transportation

The Maryland Department of the Environment developed the following Temporary Instream Construction Measures and Guidance as part of its Waterway Construction Guidelines. Each fact sheet contains descriptions, effective uses and limitations, installation guidelines, and drawings.(*483*)

- Ford Crossing
- Utility Crossing
- Culvert Installation
- Multi-Cell Culverts
- Depressed Culverts
- Culvert Baffles
- Small Bridge Installation
- Temporary Access Bridge

4.6. Erosion and Sedimentation Control

Erosion is a natural process that can be greatly accelerated by human activities, especially those that change or remove vegetation or that disturb the soil. All construction activities have the potential to cause soil erosion, a contributor to the excessive loss of topsoil nationwide. Environmental stewardship practices for erosion prevention reduce both the need for costly sediment controls and the risk of environmental damage.

Federal, state, and local water quality regulations prohibit the discharge of turbid water from construction activities into adjacent water bodies and require DOTs to use approved Best

Management Practices (BMPs). Generally, highway construction projects and any activities involving earthwork require a Temporary Erosion and Sediment Control (TESC) Plan, Management or Stormwater Pollution Prevention Plan (SWMP) and may require a Stormwater Site Plan (SSP). A well-planned and well-maintained construction entrance with stabilized construction roads can prevent offsite sedimentation, keep sediments off of roads, minimize complaints from neighbors, and reduce future expenses and aggravation.

Temporary sediment control practices include those practices that intercept and slow or detain the flow of stormwater to allow sediment to settle and be trapped. These practices can consist of installing temporary linear sediment barriers (such as silt fences , fiber rolls, sandbag barriers, and straw bale barriers); providing fiber rolls, gravel bag berms, or check dams to break up slope length or flow; or constructing a temporary desilting basin, sediment trap, or sediment basin. Linear sediment barriers are typically placed below the toe of exposed and erodible slopes, downslope of exposed soil areas, around temporary soil stockpiles and at other appropriate locations along the site perimeter. Permanent control measures are installed in the course of construction and left in place to continue to provide water quality benefits after construction is complete. Permanent control measures generally require ongoing maintenance.

General recommendations for preventing erosion include: (*484*)(*485*)

- **Keep slope lengths short and gradients low and preserve natural vegetative cover** to lower stormwater velocities and erosion hazards. Place terraces, benches, or ditches at regular intervals on longer slopes. Project drainage design should consider water generated both on and off of the site that can impact erosion potential.
- **Clear the smallest practicable work zone to minimize erosion.** All possible measures should be taken to minimize clearing and grading which exposes the site to erosion.
- **Use slope roughening on the contour or tracking with a cleated dozer to minimize erosion during grading.**
- **Protect water quality through the use of best management practices** including silt fences , sedimentation basins, **and other control measures to reduce erosion, surface scouring, and discharge to water bodies.**
- **Apply perimeter control practices (BMPs) prior to construction**, to protect the disturbed area from off-site runoff and to prevent sedimentation damage to areas below the construction site. This principle relates to using practices that effectively isolate the construction site from surrounding properties, and especially to controlling sediment once it is produced and preventing its transport from the site. Diversions, dikes, sediment traps, and vegetative and structural sediment control measures are classified as either temporary or permanent, depending on whether or not they will remain in use after construction is complete. Generally, sedimentation can be prevented by two methods: a) filtering runoff as it flows through an area and b) impounding the sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion. Installation of initial controls should be discussed at the pre-construction conference. The contractor and the inspector should understand the inspection and maintenance requirements of the specified BMPs, as well as the location and proper installation procedures.
- **Ensure inspection and maintenance of BMPs by the contractor weekly and/or after significant rain events.** Any failures should be analyzed to prevent recurrence.

Substantial changes to the approved plan should be made or reviewed by the designer and approved by the appropriate regulatory agency.

- **Maintain low runoff velocities in channels by lining with vegetation, riprap, or using checkdams at regular intervals,** in addition to minimizing steepness and slow length.
    - Trap sediment on-site. Many conventional BMPs available, in addition to always evolving new ones.
    - Use native grasses and plants in reseeding and planting
    - Use temporary vegetation to provide immediate ground cover until permanent landscaping is in place
- **Convey runoff from developed areas to a stable outlet using storm drains, diversion structures/techniques, stable waterways, or similar measures if stabilized areas, adequate conveyance, and/or protected inlets are available.** Design conveyance systems to withstand the velocities of projected peak discharges, and make these facilities operational as soon as possible. Use diversion structures to divert surface runoff from exposed soils and grade stabilization structures to control surface water.

Manuals for Stormwater and Erosion & Sedimentation Control

Almost 30 percent of state DOTs have developed manuals for construction (AR, CA, FL, GA, IH, IA, IN, LA, MI, MO, MT, NM, OH, WA). (*486*) Almost every state DOT has a guide to development of such plans and design of stormwater BMPs, though such BMPs are often combined and categorized in very different ways. The practices presented in this section are a compendium of highlights from these manuals, focusing on environmental stewardship practice and how to get to available resources on selection and implementation for best environmental effect. Following is list of highway runoff and construction BMP manuals available on-line:

California

- California Stormwater Quality Association Stormwater BMP Handbooks
- Los Angeles Stormwater Program (click "Publications")
- California Department of Transportation (Caltrans) Stormwater Quality Handbooks
- Stormwater Quality Handbook - Project Planning and Design Guide
- Caltrans Construction Manual includes details for a wide array of construction drawings and standard water quality best management practices.

Georgia

- Georgia Stormwater Management Manual

Idaho

- Idaho Department of Transportation (IDT) Design Manual (July 2001)

Illinois

- Illinois Department of Transportation. Erosion and Sediment Control NPDES for Standard Specifications for Road & Bridge Construction.

Maine

- Erosion & Sedimentation BMP Manual

Maryland

- Maryland Stormwater Design Manual, Volumes I & II

Massachusetts

- Massachusetts Department of Environmental Protection Stormwater Handbooks

Michigan

- DEQ Index of BMPs/Individual BMPs
- Michigan DOT Drainage Manual

Minnesota

- Protecting Water Quality in Urban Areas: A Manual
- Urban Small Sites Best Management Practice Manual

Missouri

- Protecting Water Quality: A Construction Site Water Quality Field Guide

Montana

- Montana Department of Water Quality – Stormwater Program – BMPs and Erosion Control Plans

New Hampshire

- Innovative Stormwater Treatment Technologies Best Management Practices Manual

New Jersey

- Revised Manual for New Jersey: BMPs for Control of Nonpoint Source Pollution from Stormwater

New York

- New York State Stormwater Management Design Manual
- NYSDOT Highway Design Manual

North Carolina

- North Carolina Department of Environment and Natural Resources

Ohio

- Ohio EPA Stormwater Program Index

Oregon

- Department of Environmental Quality Guides
- Oregon Department of Transportation. Field Manual for Erosion and Sediment Control (2000). The reference for the field guide is the ODOT Hydraulic Manual Volume 2 entitled Erosion and Sediment Control, which provides a source of more in-depth information.

Pennsylvania

- Pennsylvania Handbook of Best Management Practices

South Carolina

- NPDES Stormwater Program Guide
- Sediment, Erosion and Stormwater Management Program Index to Guides

Tennessee

- Tennessee Department of Environment and Conservation Water Pollution Index to Guides
- City of Knoxville, Best Management Practices Manual

Texas

- Texas Nonpoint Sourcebook
- TxDOT "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002)

Utah

- Utah Department of Environmental Quality Stormwater Program Index to Guides
- West Valley City Stormwater Utility Best Management Practices
- Utah DOT Roadway Drainage Manual of Instruction

Virginia

- Northern Virginia Regional Commission Best Management Practices
- Virginia Department of Conservation & Recreation BMP Guides
- Virginia DOT Drainage Manual

Washington

- WSDOT 2004 Standard Specifications for Erosion Control (Section 8-01)
- WSDOT Standard Plans Section I - Erosion Control
- WSDOT Temporary Erosion Sedimentation Control (TESC) Plan Template
- WSDOT When is a TESC plan needed?
- WSDOT 2004 Highway Runoff Manual

- WSDOT Hydraulics Manual

Wisconsin

- Wisconsin Construction Site Erosion Control and Stormwater Management Procedures

Wyoming

- Urban Best Management Practices for Nonpoint Source Pollution

The Stormwater Manager's Resource Center also maintains List of Acceptable Practices, Construction Specifications, and Checklists for Construction Inspection.

In addition to extensive design guidance available in both manual and on-line formats, a number of BMP evaluation systems are emerging. MDSHA has developed an evaluation system for all stormwater facilities and criteria for improvements. In the late 1990s WSDOT and FDOT also developed systems for categorizing outfalls and, in the case of WSDOT, assessing which projects provide the best return on investment in terms of environmental effectiveness and pollution reduction. WSDOT's system included a condition indexing methodology and support program that enables users to quickly evaluate and compare projects and generate benefit-cost ratios for projects.(*487*)

Procedural Management Practices for Water Quality

Procedural BMPs affect how and when a project is built and can greatly affect the potential for erosion. Sequencing and scheduling are some of the most important aspects of erosion control planning. Construction sequencing should minimize the duration and extent of soil disturbance. Whenever possible, major soil disturbing activities should be done in phases to minimize exposed areas. Likewise, major grading operations should be limited to the dry season. An effective schedule prevents the site from becoming overexposed to erosion risks. The construction schedule should tie the installation of erosion control BMPs to the order of land disturbing activities. The types of activities that should be included in the schedule are:

- Installation of perimeter control and detention BMPs prior to soil-disturbing activities.
- Phasing and timing of clearing, grubbing, and grading.
- Interim BMP strategies.
- Installation of permanent BMPs and a description of how temporary BMPs have been coordinated with the development of permanent measures.
- Erosion control inspection and maintenance schedule.

Dewatering and Managing the Watercourse

Dewatering

Dewatering methods are temporary measures for filtering sediment-laden water, managing the discharge of pollutants or to keep water away from a worksite. Dewatering operations are used to manage removal of water from excavations, cofferdams, diversions, barges, and areas of ponding (accumulated precipitation). Sediment is the most common pollutant associated with dewatering operations. Whether the contractor manages dewatering operations by re-using the water on site, discharging it to an adjacent facility or land, or discharging it by NPDES permit to a storm drain or receiving water, the water will often require treatment to remove sediment. Dewatering usually involves pumping water from the location of accumulation to the treatment area on the construction site. Following treatment, the water is discharged or reused on site, in accordance with the authorizing permit.

Suggested stewardship practices for dewatering are summarized in the remainder of this section.(*488*)

- **If the water is free of pollutants other than sediment, consider the following management options** prior to deciding to discharge to a storm drain or water of the U.S.:
- Reuse the water on site for dust control, compaction during earthwork activities, or irrigation.
- Retain the water on site in a grassy or porous area and allow water to infiltrate/evaporate.
- Discharge to a neighboring property (by agreement) that may have irrigation needs or sufficient land for infiltration.
- Discharge (by permit) to a sanitary sewer.
- **If the water contains pollutants other than sediment,** contact the Stormwater Coordinator or environmental support staff for guidance. Water from areas of known or suspected soil contamination, or that has unusual visual features or odor, may contain pollutants other than sediment. If other pollutants are suspected, water quality testing may be required. Depending on the quality of the water, possible management options include:
- Discharge to a sanitary sewer (by permit with or without treatment).
- Transportation off site for disposal at a commercial recycling or disposal facility.
- Sediment treatment requirements depend on the final disposition of the water. For dewatering discharges to a storm drain or water body authorized under a permit, in general, if water is not visibly clear, it should be treated using best management practices prior to discharge. A variety of treatment practices are available for use individually or in combination. Some common primary treatment methods include:
- Desilting basins and sediment traps are traditional sediment removal methods. The site must accommodate a basin of adequate size to provide the time necessary for particles to settle out.
- Weir tanks are steel tanks with interior weirs (or baffles) that allow sediment to settle prior to discharge from the tank. The tanks remove debris, some oils, and particles 0.05 mm in size and larger.
- Dewatering tank are open rectangular steel tanks. The water drains through a filter fabric to a discharge header to remove particles as small as 0.025 mm, depending on the filter material used.
- When water is pumped into a gravity bag filter the sediment forms a soil blanket/filter that removes additional sediment as the water passes through the sides and bottom of the bag. A secondary filter of rock or straw bales is often constructed beneath the bag. Due to the need to form the soil blanket, it is difficult to guarantee particle size removal.

  The following treatment methods remove finer-grained materials and may be useful as secondary treatment methods when needed to meet water quality goals.

- A sand media filter is a portable unit that removes particles larger than 0.01 mm. Water flows through the unit and sediment is captured by the sand particles. This method is cost-effective due to a filter backwashing feature.
- A pressurized bag filter is a unit composed of individual filter bags that are most effective when larger particles have been removed by prior treatment with a weir tank, sand filter, etc. It can remove particle sizes as small as 0.002 mm.
- A cartridge filter provides the highest degree of sediment removal. It is capable of removing sediments larger than 0.002 mm, but is most effective when used for polishing after larger particles have been removed by other treatment methods.

  In addition to sediment, these methods can also reduce some other potential water quality pollutants such as oil and grease and nutrients. However, none remove the colloidal particles natural to some soils that increase water turbidity. Pre-discharge testing for possible pollutants may be required, based on the source of the water, land use history of the construction site, and potential impacts to the quality of the receiving water.
- For discharge to a sanitary sewer or to an adjacent facility/land, sediment treatment requirements are specified in the permit or agreement with the sanitary sewer agency or landowner.
- For infiltration or reusing water on-site, water may require treatment to meet the specific reuse option.

On-line sources for dewatering practices and associated BMPs:

- Dewatering Basins, MD
- Dewatering, WA, p. 2.50
- Dewatering, Caltrans
- Dewatering, FL, p. 113
- Stilling Basin for Pumped Effluent, NCDOT, p. 86
- Special Stilling Basin (Silt Bag), NCDOT, p. 88

Measures to Minimize Impacts to Aquatic Habitat and Species during Dewatering of Project Site

When construction work must occur within a year-round flowing channel, the work site must be dewatered. Dewatering can result in the temporary loss of aquatic habitat, and the stranding, displacement, or crushing of fish and amphibian species. Increased turbidity may occur from disturbance of the channel bed. Following these general guidelines will minimize impacts.

- **Prior to dewatering, determine the best means to bypass flow through the work area** to minimize disturbance to the channel and avoid direct mortality of fish and other aquatic vertebrates.
- **Minimize the length of the dewatered stream channel and duration of dewatering**.
- **Maintain stream flow to channel below construction site.**

- **Capture and relocate fish and amphibian species prior to dewatering to avoid direct mortality and minimize take.** This is especially important if listed species are present within the project site.
- **Coordinate project site dewatering with a fisheries biologist** qualified to perform fish and amphibian relocation activities.
- **Periodically measure air and water temperatures.** Cease activities when water temperatures exceed temperatures allowed by resource agencies.
- **Exclude fish from re-entering work area** by blocking the stream channel above and below the work area with fine-meshed net or screens. Mesh should be no greater than 1/8 inch. It is vital to completely secure bottom edge of net or screen to channel bed to prevent fish from re-entering work area. Exclusion screening should be placed in areas of low water velocity to minimize impingement of fish. Screens should be checked periodically and cleaned of debris to permit free flow of water.
- **Prior to capturing fish, determine the most appropriate release location(s)**. Consider the following when selecting release site(s): similar water temperature as capture location, ample habitat for captured fish, and low likelihood of fish re-entering work site or becoming impinged on exclusion net or screen.
- **Determine the most efficient means for capturing fish.** Complex stream habitat generally requires the use of electrofishing equipment, whereas in outlet pools, fish may be concentrated by pumping-down pool and then seining or dipnetting fish. If fish are abundant, periodically cease capture, and release fish at predetermined locations.
- **Minimize handling of aquatic species**; however, when handling is necessary, always wet hands or nets prior to touching fish.
- **Temporarily hold fish in cool, shaded, aerated water** in a container with a lid. Provide aeration with a battery-powered external bubbler. Protect fish from jostling and noise and do not remove fish from this container until time of release. Place a thermometer in holding containers and, if necessary, periodically conduct partial water changes to maintain a stable water temperature. If water temperature reaches or exceeds those allowed by resource agencies fish should be released and rescue operations ceased. Avoid overcrowding in containers. Have at least two containers and segregate young-of-year (YOY) fish from larger age-classes to avoid predation. Place larger amphibians, in container with larger fish.
- **Visually identify species and estimate year-classes of fish at time of release**. Count and record the number of fish captured. Avoid anesthetizing or measuring fish. If mortality during relocation exceeds 5 percent, stop efforts and immediately contact the appropriate agencies.
- S**ubmit reports of fish relocation activities to resource agencies in a timely fashion.**
- **If feasible, plan on performing initial fish relocation efforts several days prior to the start of construction.** This provides the fisheries biologist an opportunity to return to the work area and perform additional electrofishing passes immediately prior to construction. In many instances, additional fish will be captured that eluded the previous day's efforts.
- **Periodically pump seepage from the work area.** Place pumps in flat areas, well away from the stream channel. Secure pumps by tying off to a tree or stake in place to prevent

movement by vibration. Refuel in area well away from stream channel and place fuel absorbent mats under pump while refueling. Pump intakes should be covered with 1/8" mesh to prevent entrainment of fish or amphibians that failed to be removed. Check intake periodically for impingement of fish or amphibians.

- **Discharge wastewater from construction area to an upland location** where it will not drain sediment-laden water back to stream channel.

Flow Diversion

The normal flow of a stream should be diverted and the work area isolated to allow a project to proceed. The watercourse should be managed to minimize adverse impacts to the jurisdictional waters. All projects should be planned to minimize the time that the watercourse will be diverted. Several methods of diverting a watercourse are provided in this section. There may be certain seasonal components to consider when attempting flow diversion of a stream, such as spawning times of individual fish species.(*489*)

- **Avoid having equipment in streams, wetland, or other environmentally sensitive area.** When necessary in-stream, limit the type and number of equipment to those necessary to accomplish the work at that moment.
- **Design temporary diversion channels to accommodate expected watercourse flow from storm events** (generally 1 in 5 year event, though the 1 in 2 year event may be used for noncritical situations). Leave the existing channels untouched until the temporary diversions are constructed.
- **Construct temporary diversion channels in the dry**, starting from the downstream end.
- **Open diversion channels from the downstream end first.**
- **Use clean, washed material to close existing channels and divert water** to temporary diversion channels.
- **Use gradient controls** to ensure that diversion channel slopes correspond to the existing channel gradients.
- **Protect unstable bends from erosion**.
- **Armor discharge point with clean rock** to prevent erosion.
- **In areas with fish passage concerns, avoid using pumped diversions**, where a channel must be completely blocked to allow work 'in the dry.'
- **Size and screen intakes to prevent debris blockage and fish mortality.**

Environmental stewardship practices for flow diversion BMPs are contained within the following state fact sheets available on-line:

- Fabric-Based Channel Diversion, MD
- Fabric Lined Diversion Channel, NCDOT, p. 71
- Aqua Barrier, WA p. 21
- Pump-Around Practice, MD
- Diversion Pipe, MD

- Piped Diversion, NCDOT, p. 69
- Sandbag/Stone Diversion, MD
- Sand Bags, NCDOT, p. 79
- Stone with Impervious Fabric, NCDOT, p. 77
- Sandbag, WA, p. 109

Cofferdams

Use cofferdams (earth fill, sheet pile or other proprietary designs) to separate instream work site from flowing water. Design cofferdams to accommodate the expected flows of the watercourse. Build rock platforms for equipment needed in-stream for longer periods.

- Use clean, washed material for construction and face berms with clean granular material.
- Limit cofferdams to one side of the watercourse at any one time and ensure that they block no more than one-third of the channel
- Restore the original channel bottom grade after removing cofferdams
- Treat all water pumped from behind the cofferdams to remove sediment before discharge.
- Cofferdam, WA, p. 26
- Continuous Berm, WA, p. 43

Turbidity Curtains

In some instances, the depth of water downstream from a proposed work area may be too deep for an in-stream, silt fence-sediment trap to be effective, such as the outlet of a ponded area. At these times, turbidity curtains prove to work effectively in retaining suspended sediment. The barrier consists of a wire-mesh supported silt fence attached to a floating boom. The boom remains afloat, on top of the water, while the filtration mechanism, anchored to the streambed, retains suspended sediments in the work area.

Even though work is being conducted during months that typically promote low water conditions, seasonal increases in water flow can result from precipitation events. This BMP is used as a precautionary measure should a rise in water and/or flows occur. If water in the work areas were to increase, an in-stream sediment-trapping device would prevent increases in turbidity and sedimentation. This BMP can, and at times should be, used in conjunction with other BMPs depending upon proposed work. Sandbags and/or check dams can be used as a first line of defense with turbidity curtain downstream as a second defense.(*490*) Online implemented guidance and best practice resources for turbidity barriers may be found at:

- Turbidity Curtain, NCDOT, p. 74
- Turbidity Curtain, WA, p. 162
- Turbidity Barrier, FL, p. 117

Other Slope Stabilization and Drainage Techniques

NCHRP project 24-19 lists the following areas in slope stabilization to be discussed in the upcoming publication due in late 2004:

- Diversion Dikes
- Slope Drains
- Live Pole Drains
- Chimney Drains
- Trench Drains
- Drop Inlets
- Fascines with Subsurface Drains
- Flattening
- Stone-Fill Trenches

Managing Excavated Material or Spoil

Excavated material or spoil should either be: (*491*)

- Contained within the work area.
- Stockpiled near the work area and contained by an appropriate Erosion and Sedimentation Control BMP.
- Removed from the site and disposed of properly.
- Spoil material shall not be placed in wetlands, protected riparian buffers, or other jurisdictional areas.
- Used for reestablishing groundcover.

Interception

Reducing Slope Length for Erosion Control

Slope length and inclination are two factors that directly affect the tendency of a slope to erode and introduce sediment into stormwater runoff. Although contractors cannot deviate from embankment and slope inclinations specified in construction plans, there are stormwater friendly methods available for shortening the effective length of a slope.

Best Management Practices (BMPs) for mitigating slope length make use of fiber rolls or gravel bag berms to build erosion control benches at specified intervals down the slope face. This strategy is effective at low surface velocity flows (< one cubic foot/second) for intercepting and filtering sediment from runoff. The decrease in velocity also reduces the concentration of sheet flows that create rills and gullies on slope faces. These measures should be used in combination with others to remove sediment and minimize sedimentation.

Fiber Rolls

A fiber roll consists of straw, flax, or other similar materials wood excelsior, rice or wheat straw, or coconut fibers that are is rolled and or bound into a tight tubular roll and placed on the toe and face of slopes at regular intervals to intercept runoff, reduce its flow velocity, release the runoff as sheet flow, and provide some removal of sediment from the runoff. Fiber rolls are biodegradable materials and prefabricated fiber rolls constructed of rice straw, wheat straw, flax or similar material can be purchased in diameters ranging from 200 mm to 300 mm. Fiber rolls can also be made in the field using erosion control blanket material rolled and bound with jute twine every 1.2 m along the length and at each end. Fiber roles are best suited for longer term protection of non-active disturbed soil areas and completed areas to help stabilize the slope while vegetation establishes. Fiber rolls may also be used for inlet protection and as check dams under certain situations.

- For slope lengths of 30 m or more with inclinations between 1:20 and 1:2, install fiber rolls or an equivalent at intervals no greater than 15 m.
- For slope lengths of 15 m or more with inclinations of 1:2 or steeper, install fiber rolls or an equivalent at intervals no greater than 7.5 m.

Best practices with regard to fiber roll installation and use are available online: (*492*)(*493*)

- Fiber Rolls, MT, p. 87
- Natural Fiber Rolls, MD
- Fiber Rolls, Caltrans

Gravel Bags

An alternative to fiber rolls are berms constructed of gravel bags. Bags made from synthetic woven material or burlap are filled with ½ to 1-inch clean aggregate. The gravel bags are aligned end-to-end, tightly abutted, along a level contour to form a berm that creates the erosion control bench. A gravel bag berm consists of a single row of gravel bags that are installed end to end to form a barrier across a slope to intercept runoff, reduce its flow velocity, release the runoff as sheet flow and provide some sediment removal. Gravel bags can be used where flows are moderately concentrated, such as ditches, swales, and storm drain inlets.(*494*) Installation guidance and stewardship practices for use of gravel bags and gravel bag berms are available online:

- Gravel Bag Berm, MT, p. 90
- EPA Filter Berms
- Gravel Bag Berm, Caltrans

Triangular Filter Dike

Triangular sediment filter dikes can be used to intercept and detain water-borne sediment from unprotected areas of limited extent, where there is no concentration of water in a channel or other drainage way above the barrier and the contributing drainage area is less than one acre. If the uphill slope above the dike exceeds 10%, the length of the slope above the dike should be less than 50 feet. If concentrated flow occurs after installation, corrective action should be taken such as placing rock berm in the areas of concentrated flow. This measure is effective on paved areas where installation of silt fence is not possible or where vehicle access must be maintained. The advantage of these controls is the ease with which they can be moved to allow vehicle traffic and then reinstalled to maintain sediment.(495)

- Triangular Filter Dike, TX, pp. 5-8 – 5-9

Strawbale Barriers

Bale barriers may be the most common mitigation measures illustrated in SWPPPs and found on construction sites.(496) Hay or straw bale dikes, also known as straw bale barriers are used to intercept and detain small amounts of sediment-laden runoff from relatively small, unprotected areas. They bales are often used when it is not feasible to install other, more effective measures or when the construction phase is expected to last less than three months. They work well in conjunction with silt fence.

Although hay bales have been the traditional choice for erosion protection, especially in drainage channels, careful consideration should be taken during the selection process. Runoff waters may not readily seep through the bales. Bales are not an effective method for filtering sediment. Water can pond behind the bale structures and flow around, between, and under the structures causing channel degradation and sediment transportation. Furthermore, bales are often not inspected or maintained and are one of the more costly methods for controlling sediment in runoff waters.(*497*) When roadway median drains are on a grade and bale barriers placed around the inlets, the barriers divert runoff waters to downstream locations and diversion around inlets cause downstream flooding and downstream deposition of sediment and bale structures to experience massive failure. (*498*)

- Only use hay bales as temporary check structures when the following conditions can be maintained:
- Channel receives low volume flows.
- Flow line slopes are less than 2%.
- Installed in a trench, staked, and backfilled.
- Enough bales are used on the channel side slopes to force runoff over the bales, rather than around the structure.
- Bales are inspected and maintained frequently.
- Consider other techniques. Properly sized rock check structures provide an excellent alternative as do some of the new methods (e.g. synthetic barriers) being introduced every year. Silt fence material must not be used unless it is properly supported. If vegetation is to be established, avoid bale check structures. Instead, properly install rolled erosion control products.
- Instead of placing bales around an inlet, install a properly designed upstream sediment containment system. Since medians are long and narrow, they provide ideal conditions for efficient sediment traps. When properly installed and maintained, sediment traps will reduce sediment in runoff waters and allow inlets to function in a manner for which they are designed—as drainage systems.
- If sufficient space does not exist for a containment system, then install a riprap check structure to serve as a sediment trap. Take care to ensure the rock used has sufficient diameter and mass to avoid failure from large flow events.
- Avoid use of straw bales on areas where rock or other hard surfaces prevent the full and uniform anchoring of the barrier.(*499*)

Almost all state DOTs have installation guidance for strawbale barriers; the following DOTs have made such guidance and practice recommendations available online:

- Hale (Straw) Bale Dike, TX, pp. 5-12 – 5-15
- Strawbale Barrier, MT, p. 79
- Strawbale Barrier, Caltrans
- Straw Bale Barrier, FL

Geotextiles, Mats/Plastic Covers and Erosion Control Blankets

Erosion Control Blankets are biodegradable materials that can be used to protect disturbed slope and channel areas from wind and water erosion. The blanket materials are natural materials such as straw, wood excelsior, coconut, or are geotextile synthetic woven materials such as polypropylene. In addition to preventing erosion, erosion control blankets also increase water infiltration into the soil, protect seed mixes from being eroded during heavy rainfall or wind, and increase the retention of soil moisture to promote seed germination.

Testing at the San Diego State University Soil Erosion Research Laboratory (SDSU/SERL) as part of a Caltrans District 7 Erosion Control Pilot Study (ECPS) and the Soil Stabilization for Temporary Slopes study (SSTS) found that all of the blankets or RECPs tested reduced erosion and off-site sediment delivery by 90-100 percent.(*500*) These results are comparable to tests conducted at the Texas Transportation Institute (TTI) and other laboratories. Before specifying an erosion control blanket for a highway site, consider effectiveness, implementation costs, durability, longevity, whether the netting may pose any wildlife hazards, and long-term costs or maintenance considerations, e.g. will nets or staples be a factor if the area will be routinely mowed?

Function is dependent on proper installation and maintenance, including proper soil surface preparation:

- All rocks, clods, debris, and vegetation should be removed to ensure full contact between the blanket and the soil surface.
- Check the special provisions or follow the manufacturer's recommendations for seed application requirements when used with blanket installation.
- The blanket should be anchored to the soil using metal wire staples as specified in the special provisions or recommended by the manufacturer.
- The staples should be driven through the blanket and into the soil, flush with the soil surface.

Inspection and maintenance of Erosion Control Blankets should include the following:

- Inspect the site during installation.
- Inspect the installation before, during and after significant rain events.
- Repair or replace all damaged materials.
- Recompact all soil washout areas.

Inlet Protection Information:

- Storm Inlet Protection, MT, p. 102
- EPA Inlet Protection Fact Sheet

Infiltration - Sediment Basins and Traps

Conventional sediment control BMPs are capable of removing a certain size soil particle, but in most cases it is not enough to bring the runoff in compliance with state water quality standards. Detention time and volume is critical in sediment control. Sand and gravel takes only seconds to trap, but silt and clay can take hours to weeks to settle.

Research has indicated that infiltration can be a viable alternative in the disposal of runoff at low metals concentrations, with appropriate siting criteria, which should include the following: (*501*)

- Identify the presence of background metals in the soil.
- Identify the organic content of the soil, which is likely to a better indicator of potential metal retention, and as such, should be included as a siting condition along with the cation exchange capacity (CAC) and silt and clay content.
- Consider extending the minimum depth to groundwater from the existing value of three feet to ten feet (three meters) or more, particularly in those areas in which background metals are present. Here, geochemical controls are thought to produce effluents beneath the infiltration basins which may lead to detectable quantities (particularly copper and zinc) within underlying groundwater, wherein creating a situation that may violate the anti-degradation laws for groundwater resources.

Sediment Basins

A sediment basin is a basin or barrier constructed within a waterway or at another suitable location to intercept sediment-laden stormwater runoff and to trap and retain the sediment. The purpose of the sediment trap is to intercept sediment-laden stormwater runoff and reduce the amount of sediment leaving the disturbed area. A sediment basin applies where physical site conditions or land ownership restrictions preclude the installation of barrier-type erosion control measures to adequately control runoff, erosion and sedimentation.(502) Stormwater runoff from drainage areas with more than 5 acres disturbed area should pass through a sediment basin or other suitable sediment trapping facility. Sediment basins are more cost effective when most of the area draining to the basin is disturbed area, since their size must be based on total contributing area. Appropriately sized and stabilized conveyance channels will normally be required to funnel runoff to the basins. (503) It is also used for disturbed areas of more than 10 acres within the same drainage basin in order to comply with NPDES requirements. It may be used below construction operations which expose critical areas to soil erosion. Following are BMPs from various states that describe basins, construction and impacts: (504)

- Sediment Basin, TX, pages 5-20 – 5-22
- Special Stilling Basin, NCDOT, p. 94
- EPA Sediment Basins Fact Sheet
- Temporary Sediment Basin, FL, p. 79
- Caltrans attachments-Desilting Basin, Caltrans
- Desilting Basin, MT p. 74.

Sediment Trap

A sediment trap is a small temporary basin formed by excavation and/or an embankment to intercept sediment-laden stormwater runoff and to trap and retain the sediment-laden runoff. The purpose of the sediment trap is to intercept and retain runoff and allow the suspended sediment to settle out. A sediment trap is usually installed at points of discharge from disturbed areas. Constructing traps within ditches can be easy and effective and may require nothing more than a berm to create the volume and an outlet structure. Following are Sediment Trap BMPs from various states: (505)

- Sediment Trap, TX, p. 5-18 – 5-20
- Sediment Trap, Caltrans
- Sediment Trap FL p. 4-67
- EPA Sediment Traps
- EPA Sediment Basins and Rock Dams
- EPA Sediment Filters and Sediment Chambers
- Sediment Trap, MT, p. 80
- Temporary Sediment Trap, FL p. 67

Check Dams

A check dam is a small device constructed of rock, gravel bags, sandbags, fiber rolls, or other proprietary product placed across a natural or man-made channel or drainage ditch.(*506*) Check dams reduce scour and channel erosion by reducing flow velocity and encouraging sediment settlement. Following are various Check Dam BMPs:

- EPA Check Dams Fact Sheet
- Check Dams, TX, pp. (5-23 – 5-30)
- Check Dams, Caltrans
- Log & Rock Check Dams, MD
- Check Dams, FL, p. 105
- Check Dams, MT p. 84
- Temporary Rock Silt Check Dam, NCDOT p. 58
- Check Dams, New Brunswick, p 4-7

Sandbag Barrier

Sandbag barriers or "berms are devices the purpose of which is to detain sediment carried in runoff from disturbed areas. This objective is accomplished by intercepting runoff and causing it to pool behind the sandbag berm. Sediment carried in the runoff is deposited on the upstream side of the sandbag berm due to the reduced flow velocity. Excess runoff volumes are allowed to flow over the top of the sandbag berm.(*507*) Sandbags can be used as a temporary interceptor to slow water velocity. Sandbags placed across access or interior construction roads provide for a means to divert or slow erosive water flows on a construction site.(*508*)

Sandbags work well as diversion structures, temporary cofferdams, sediment control devices and temporary flow dissipaters during any number of routine roadway maintenance activities. When appropriately designed and used as a cofferdam, these sandbags are stable enough for water to pond behind them. The ponded water behind the dam structure can then be pumped to a sediment retention basin or filter bag to allow work to be performed in-the-dry. When used in conjunction with other BMPs, sandbags can be useful in ensuring that sediment does not enter surface waters or wetlands, helping to retain sediment in a sediment retention basin, and/or diverting and/or dissipating runoff water during roadside ditch maintenance.(*509*)

- Sand Bag Barriers,WA p. 194
- Sandbag/Stone Diversion, MD
- Sandbag Barrier, Caltrans
- Sandbag Barrier MT p. 95
- Sandbags, NCDOT, p. 85
- Sandbag Berm, TX, p. 5-4

Rock Berm

The purpose of a rock berm, or rock filter dam, is to serve as a check dam in areas of concentrated flow, to intercept sediment-laden runoff, detain the sediment and release the water in sheet flow (see Figures 5.6, 5.7 and 5.8). The rock berm should be used when the contributing drainage area is less than 5 acres. Rock berms are used in areas where the volume of runoff is too great for a silt fence to contain. They are less effective for sediment removal than silt fences, particularly for fine particles, but are able to withstand higher flows than a silt fence. As such, rock berms are often used in areas of channel flows (ditches, gullies, etc.). Rock berms are most effective at reducing bed load in channels and should not be substituted for other erosion and sediment control measures further up the watershed.

- Temporary Rock Sediment Dam, NCDOT, p. 60
- Rock Berm, TX, pages 5-10 – 5-12

Maintenance of Sediment Basins and Traps

Sediment basins and traps and associated BMPs depend on maintenance for proper functioning: (*510*)(*511*)(*512*)

- Inspection should look for:
- Sediment accumulation in front of checkdams.
- Erosion/scouring behind checkdam.
- Proper checkdam configuration.
- Erosion in contributing drainage area.
- Periodically remove debris and litter.
- Remove sediment when it reaches 50 percent of checkdam height.
- Repair/replace checkdams if necessary.

- Stabilize eroding soils on DOT right-of-way in the contributory drainage area by seeding and mulching or other appropriate means.

Vegetative Erosion Control

Providing such detention time is not always possible. Thus, preventing erosion in the first place makes sediment control more effective. Vegetative erosion control is based on the assumption that soil can be kept in place with a vegetative cover. The reasons to keep soil in place include:

- Protection of engineered grades
- Reduction of maintenance on buildings, structures, and other man-made objects
- Maintenance of surface water quality
- Visual enhancement

Filter strips, also known as vegetated buffer strips, are vegetated sections of land similar to grassy swales, except they are essentially flat with low slopes, and are designed only to accept runoff as overland sheet flow. They may appear in any vegetated form from grassland to forest, and are designed to intercept upstream flow, lower flow velocity, and spread water out as sheet flow. The dense vegetative cover facilitates conventional pollutant removal through detention, filtration by vegetation, and infiltration.

Filter strips cannot treat high velocity flows, and do not provide enough storage or infiltration to effectively reduce peak discharges to predevelopment levels for design storms. This lack of quantity control favors use in rural or low-density development; however, they can provide water quality benefits even where the impervious cover is as high as 50 percent. WSDOT undertook a 17-month sampling campaign to investigate the potential for vegetated highway shoulders to retain suspended solids, metals, and total petroleum hydrocarbons. The data indicated that TPH and suspended solids were effectively removed. Metal concentration reduction was also effective when consideration was given to inadvertent pretreatment afforded by the highway runoff collection system. The study concluded the vegetated highway shoulder, located along hundreds of miles of highway can afford a cost effective means of contaminant retention.(*513*) Another WSDOT study found that the overall best Service Level for water quality benefits was excavating the first three quarters and retaining vegetation in the remainder. The ditch treated in this manner was capable of reducing TSS by approximately 40 percent, total phosphorus by about 50 percent, and total and dissolved Cu and Zn each by roughly 20 to 25 percent.(*514*) Analysis of survey data showed that biofiltration swales with broad side slopes, wide bases, and total storage volumes equivalent to 3 inches of runoff from the impervious drainage area consistently supported good vegetation cover and showed few signs of damage. For assisting grass growth, straw held in place with stapled jute mat had a clear advantage in effectiveness over the alternatives and a slight economy advantage over the coconut mat. (*515*)

The primary highway application for vegetative filter strips is along rural roadways where runoff that would otherwise discharge directly to a receiving water, passes through the filter strip before entering a conveyance system. Properly designed roadway medians and shoulders make effective buffer strips. These devices also can be used on other types of development where land is available and hydraulic conditions are appropriate.

Flat slopes and low to fair permeability of natural subsoil are required for effective performance of filter strips. Although an inexpensive control measure, they are most useful in contributing watershed areas where peak runoff velocities are low, as they are unable to treat the high flow velocities typically associated with high impervious cover. The most important criteria for selection and use of this BMP are soils, space, and slope. Further guidance and stewardship practices for installation and use of vegetated buffer strips are available online. Also, see the section of this document on Vegetation Establishment in Construction.

- EPA Vegetated buffer Fact Sheet
- Vegetative Filter Strips, TX, pp. 5-30 – 5-31

Wind Erosion Control

Wind erosion control consists of applying water and/or other dust palliatives as necessary to prevent or alleviate erosion by the forces of wind. Dust control should be applied in accordance with standard practices. Covering of small stockpiles or areas is an alternative to applying water or other dust palliatives.(*516*) Following are stewardship guidance resources from EPA and state DOTs:

- EPA Wind Fences and Sand Fence Fact Sheets
- Wind Erosion Control, Caltrans
- Wind Erosion Control Fact Sheet, MT

Sediment Tracking Prevention

Stabilizing Construction Entrances/Exits

Stabilized construction roads and entrances/exits are designed for the control of dust and erosion during construction and maintenance projects. In wet weather mud tracking occurs and in dry weather dust becomes the issue.

- Stabilize construction exits and roadways with aggregate, asphalt concrete, or concrete.
- Select the material used for stabilization based on the anticipated road longevity, performance, and site conditions.

Sediment tracking BMPs tend to be more effective in combination. BMPs such as limiting exits, stabilizing construction exits, and using existing paved areas should be considered in all sediment tracking control approaches. The following fact sheets from various state DOTs and EPA include construction and implementation guidance and stewardship practice:

- EPA Construction Entrance Fact Sheet
- Stabilized Activity Entrance/Exit, Caltrans
- Temporary Gravel Construction Entrance, FL, p. 7
- Construction Road Stabilization, FL, Ch. 4, p. 11

Inspecting Adjacent Roads

Inspecting and cleaning adjacent public and private roads is an unavoidable obligation at each and every construction site:

- Inspect roads near egress points commensurate with their use. If an exit is used daily, then the adjacent area should be inspected daily.
- Clean roads near egress points before every predicted rain event and when visibly accumulated sediment has been deposited at other times.
- Clean roads upon which dirt is hauled daily.
- Clean roads using proper equipment. Use sweepers equipped with vacuums or a mechanical means of collection and removal. Do not just push the sediment around using only a mechanical broom.
- Do not use a water truck or other hydraulic means to flush accumulated sediment on the roads into the storm drain system.
- Limit egress points on the construction site to greatly reduce the time and effort expended on sediment tracking control. The fewer exits, the fewer areas that will require inspection and eventual cleaning.

Entrance/Outlet Tire Wash

A tire wash is an area located at stabilized construction roadway egress points to remove sediment from tires and undercarriages and to prevent sediment from being transported onto public roadways.

- Construct on level ground when possible, on a pad of coarse aggregate.
- Wash rack shall be designed for anticipated traffic loads.
- Provide a drainage ditch that will convey the runoff from the wash area to a sediment trapping device.
- Ditch shall be of sufficient grade, width, and depth to carry the wash runoff.
- Remove accumulated sediment in wash rack and/or sediment trap to maintain system performance.
- See Caltrans Fact Sheet Entrance/Outlet Tire Wash

Combining Recycling and Effective Erosion and Water Quality Control

Claassen also performed a review of the published literature on compost use and showed widespread use of composts to control erosion and improve soil conditions, with very few negative impacts. Protective mulch eliminates most sediment transport. Large rates of yard waste compost application have been shown to have low leaching rates, making them suitable for regenerating topsoil fertility and biological activity. Use of compost in erosion control applications increases soil organic content and increases microbial activity and populations, in contrast to chemical fertilizers, which do not. A thick compost layer can also improve access onto soft soils and can reduce tracking of mud onto local streets and into storm drains. Compost application also offers nutrient benefits. Long-term improvements resulting from compost application can be expected, but short term results may be variable depending on compost characteristics; considerable variability exists between producers and with different batches from a given producer. Evaluation of each product is needed before application to field sites, but better methods are needed for rapid evaluation of bioavailable nutrients in composts for use in field situations. Claassen's observations and state DOT and municipal recommendations are summarized here:

- **Use mulches in combination with revegetation seeding or planting.** The combination effect of mulches plus revegetation seeding or planting gave the greatest reduction in erosion on decomposed granite (DG) materials in Idaho.(*517*) Although erosion processes during the first year after construction primarily involved mass wasting and slumping, subsequent years were entirely surface erosion processes such as rilling, raindrop impact and splash detachment and dry creep, all of which are effectively treated with mulch covers.(*518*)
- **When soils are compacted during disturbance, treatment by ripping improves hydraulic conductivity and reduces surface runoff and erosion**.(*519*) This type of physical treatment may not restore the natural hydraulic conductivity of an undisturbed slope, however, because the pores formed may not be continuous or may not persist through multiple soil saturation cycles such as with winter rains.
- **Compost and mulch applications can preserve the open soil structure generated by ripping treatments.** Wind tunnel tests indicated that soil surface roughness had little effect on reducing wind erosion or sandy soils (80 percent of particles within 150 to 300 mm), but that application of 5.6 ton/ha (5000 lb/ac) rates of garden and household waste compost (94 percent less than 5 cm length) increased the threshold wind speed for starting of wind transport from 6 m/s to 12-14 m/s. Composts were slurried onto the soil in a hydroseed-like mix using 1 part compost to 4 parts water with continuous agitation and then dried before testing.(*520*)
- **Compost compares favorably to shredded wood with tackifier and synthetic or organic blankets for erosion control.** Texas Transportation Institute's Hydraulics and Erosion Control Field Laboratory Performed a study on compost application, testing three materials on 1:3 slopes with both clay and sand loam textured soils; these materials included co-compost (mixed yard trimming and municipal sewage sludge), shredded wood with polyacrylamide tackifier (6.75 kg/ha), and shredded wood with a hydrophilic colloid tackifier (56 kg/ha). The compost performed better and were cheaper than the synthetic or organic blankets tested by the facility.(*521*)
- **Of various compost methods tested by Portland Metro in nonpoint source pollution reduction "medium" mixed yard debris compost blanket yielded the lowest total suspended solids,** surpassing sediment fence, compost barrier, "leaf litter" compost, hydromulch treatment, and coarse screened compost.(*522*)(*523*) The project used both "coarse" compost materials (containing chunks of wood and branches up to 152 mm [6 in] in length) and "medium" compost materials, the fraction remaining following screening of the coarse compost through a 16-mm (5/8-in) trammel. Results from subsequent Portland Metro demonstration projects suggest the following environmental stewardship practices using compost application:
- **Compost can be used to prevent vehicle and foot trafficking of soil.** A thick compost layer can provide a surface covering for foot or vehicle traffic onto soils that are otherwise too muddy and wet to support traffic. A compost layer at the exit of a site will reduce mud tracking onto local streets and into storm drains. A 76-mm (3-in) layer of compost was found to be effective.

- **Compost screened to 38 mm (1½ in) or less is recommended for erosion control on steeper slopes.** Slopes of up to 35 degrees were effectively treated. The compost layer should be extended over the top of the slope for 0.6 to 1 m (2 to 3 ft) at a 300-to 450-mm (12- to 18-in) depth to diffuse ponded water entering the top of the slope.
- **Compost that has been screened to 19 mm (3/4 in(or less is recommended for slopes that are to be landscaped.** A moisture content of less than 25 percent makes application most efficient and enables the compost layer to readily adsorb larger amounts of rainfall soil more readily than immature compost.

- **Compost may be applied by hydroseeder.** This technique replaces the low-nutrient cellulose or wood fiber amendment with a higher nutrient material. Compost screened to 3/8 inch has worked well in hydroseeders and did not plug the pump or nozzles. Erosion control was excellent with whole compost surface amendments. Hydroseeded compost should be applied with straw in order to provide structural strength. A typical application sequence would be:
- Apply seed, 2000 kg compost/ha, 400-500 kg fiber/ha. (A 20-25 percent fiber mixture is needed to create a pumpable slurry.
- Apply 4 Mg/ha wheat or barley straw (3.5 Mg/ha rice straw) evenly.
- Apply 3000 kg/ha straw, 600 kg/ha fiber, slow release fertilizer (if needed), and 200 – 300 kg tackifier.

  Higher application rates of compost may be more economically amended by dry application methods.

Two draft specifications on the use of compost for erosion and sedimentation control have been reviewed and approved by industry representatives and Technical Section 1a of the AASHTO Subcommittee on Materials. See AASHTO Standard Spec for Compost for Erosion/Sediment Control - *Filter Berms*, AASHTO Standard Spec for Compost for Erosion/Sediment Control - *Compost Blankets*, which specifies compost blanket parameters and application rates. Compost Use is also covered in the Recycling section of this report. Also see discussion of compost in Materials Recycling and Maintenance for a review of the water quality benefits of using compost.

Erosion Control Structure Removal

- When deemed by the Engineer to be no long required, Erosion Control Structures should be removed by use of an excavator, or other acceptable method approved by the Engineer, so that all erosion control materials and any retained sediment are excavated with minimal disturbance of the underlying ditches or slopes.
- Removed materials and sediment should be disposed of at a location approved by the Engineer, at least 100 feet from a watercourse and such that it cannot wash into a watercourse.
- Upon removal of the erosion control structure materials and retained sediment, the affected ditches and slopes should be shaped to match into adjacent final ditch and slope grades and immediately seeded as approved by the Engineer.

New Technologies

California is one of the leading states in developing new technologies. Following is a link that consolidates and standardizes information on new technologies that are part of the Departments BMP identification, evaluation and approval process. It includes fact sheets for identified technologies.(*524*)

WSDOT's New Products Committee evaluates products submitted by vendors for use on WSDOT projects. Products meeting material and installation specifications are automatically added to the Qualified Products List. When no specification exists for immediate approval, the product is thoroughly evaluated by the appropriate material expert(s) on the New Products Committee.

Performance Monitoring Systems and Specifications for Contractors

MDSHA System for 100 Percent Compliance in Construction Erosion & Sedimentation Control

MDSHA believes the agency maintains one of the better DOT enforcement systems in the country. To assess compliance, MDSHA implemented a six-layer system that includes independent quality assurance ratings for each project. Certified Quality Assurance inspectors inspect projects biweekly and rate the sediment controls on a letter grade scale. Projects can be shut down based on these inspections. Ratings for all projects are summarized quarterly and annually to comply with the SHA Business Plan. In the past the agency has pursued ratings of B or better on 95 percent of construction projects annually. As part of a primary agency commitment though, the Chief Administrator is seeking to improve performance to achievement of 100 percent compliance in construction.

NCDOT Delegated Erosion and Sedimentation Control Performance Tracking

NCDOT has its own sediment and erosion control program as delegated by the N.C. Sedimentation Control Committee and the North Carolina Department of Environment and Natural Resources. The Delegation Agreement has a self-monitoring component that requires NCDOT to inspect its projects for compliance with sediment pollution laws. Area Roadside Environmental Engineers (AREE) inspect all TIP and maintenance construction projects and whenever the AREE sees a significant erosion problem on a Department project that could result in issuance of a Notice of Violation (NOV) from DENR, the AREE will issue a Immediate Corrective Action (ICA) report to project personnel. This notifies project personnel that corrective procedures should be performed to resolve identified problems immediately. ICAs and NOVs are tracked and measured electronically and NCDOT has significantly raised environmental stewardship statewide through the program.

Contractor Disincentive Specs for Inadequate/Improper Installation of BMPs

Thirteen state DOTs have implemented contractor disincentive specifications, allowing fines or withholdings in case of inadequate installation or maintenance of erosion and sedimentation control BMPs.(525) One such example is that of the Colorado Department of Transportation, which is available in Section 208 of the department's specifications: CDOT Erosion Control Contractor Disincentive Specification on page 28. Essentially, the specification states that "[t]emporary erosion and pollution control measures required due to the Contractor's negligence, carelessness, or failure to install permanent controls as a part of the work as scheduled or ordered by the Engineer or for the Contractor's convenience, shall be performed at the Contractor's expense. In the case of repeated failures on the part of the Contractor in controlling erosion, sedimentation, or water pollution, the Engineer reserves the right to employ outside assistance or to use Department forces to provide the necessary corrective measures. Such incurred direct costs, plus project engineering costs, will be charged to the Contractor, and appropriate deduction will be made from the Contractor's monthly progress estimate. Accepted work performed to install measures for the control of erosion and sedimentation, and water pollution, not originally included in the Contract will be paid for as extra work in accordance with subsection 104.03."

Utah DOT also has a $500.00 penalty each calendar day during which the project is in non-compliance with permits and regulations. The fine is above and beyond that assessed by regulatory agencies. Furthermore, no extension of contract time is allowed for any project delay resulting directly or indirectly from a violation.(*526*)

WSDOT Application of ISO 14001 to Erosion and Sedimentation Control

The Washington State Department of Transportation (WSDOT) Erosion Control Program has been working on applying the standards of an Environmental Management System (EMS) and ISO 14001 to proactively plan, implement, and monitor effective Temporary Erosion and Sediment Control (TESC) efforts. To do so, the Erosion Control Program performed an inventory and analysis of existing internal policies, procedures, and guidance documents. This allowed the Program to provide clarity and consistency with new regulations and erosion control technologies throughout the entire agency. To date, WSDOT has updated the Plans Preparation Manual, Standard Specifications for Erosion Control (Section 8-01), Standard Plans Section I - Erosion Control, Highway Runoff Manual, Design Manual, Construction Manual, and Roadside Manual, to integrate Program improvements into existing WSDOT directional documents.

The second step involved establishing operational controls to address needs identified in the environmental aspect review process. Analysis revealed inadequate statewide standardization with WSDOT's erosion control plans that address a comprehensive set of thirteen minimum requirements. Internal discussions led to improved best management practice selection, quality of erosion control planning, and consistency with resource agency guidance. A variety of training resources, described in the section on Training and Certification, have been developed.

The WDOT Erosion Control Program's third step involved creating compliance evaluation measures to monitor performance, analyze data, and report the Program's effectiveness. As part of this compliance effort, WSDOT identifies and makes compliance visits to all construction project sites in the state that possess a reasonable potential for erosion problems. Site assessments evaluate the quality of plans, implementation of the contract, and effectiveness of the best management practices. The assessment is viewed as an educational opportunity and the assessor works closely with project staff to solve any problems observed in the field. Program tools include the Daily Data Record Form and Excel Summary and Monitoring Report Forms.

All assessment results are stored in the TESC Assessment Database, providing Environmental Management System document control. The database generates reports for use at the project, regional, and state levels. Project reports provide answers to 150 questions. Recommendations are clearly identified and associated with precise standard specifications to be applied in addressing concerns. This report is the Program's primary technical assistance tool, providing the respective agency managers with a summary of all projects assessed and trends associated with the 13 minimum planning requirements. The state report provides the State Design Engineer and the State Construction Engineer with an overall picture of how the various regions are performing. In addition, the database generates two other reports specifically for use at the Erosion Control Program management level. First, the minimum requirements report determines how well the required planning components are being satisfied, in addition to other key issues that are instrumental in improving the Program. This is accomplished by applying database filters not used with the project, regional, or state reports. Second, the best management practice report reveals the frequency of use, correct application, maintenance, and overall effectiveness of 37 practices.

A recent agency Instructional Letter 4049, entitled *Water Quality Sampling and Reporting for Construction Projects*, established monitoring protocols to document whether WSDOT's most difficult projects meet water quality standards, during the most sensitive parts of construction and under the most challenging weather conditions. WSDOT plans to incorporate the content of this Instructional Letter into the WSDOT *Construction Manual* during its next revision. All construction sites are evaluated and categorized based on their inherent risk of erosion. Risk factors include size; timing and duration of work; soils; slopes; groundwater levels; and the need for in-water work. Runoff water from twenty percent of the projects that meet the risk criteria is tested during storm events and during critical periods of in-water work. Monitoring results are used to both evaluate specific project performance and validate results of the TESC Assessment Database. The results from the TESC Assessment Database and the water quality monitoring are published and widely distributed in WSDOT's *Measures, Markers and Mileposts*, a quarterly document that tracks various agency performance and accountability measures. WSDOT's statewide performance with the 13 erosion control minimum requirements is available on-line in Bar Graph form.

WSDOT found that the most effective method of achieving change in construction is in partnership with the agency Construction Office and with the construction industry and by documenting the necessary changes and required practices in those directional documents that govern the construction process and in individual construction contracts. Applying ISO 14001 Environmental Management System standards provides compliance documentation and a feedback mechanism. The TESC Assessment Program provides an audit component, identifying 1) how well WSDOT is protecting water quality; 2) what specific areas need improvement; 3) what strategies should be used to make improvements. The complete Erosion Control Program approach was developed with input and broad support of multiple stakeholders and reflects agency-wide ownership of the solution. The program has been accepted and institutionalized into the daily activities at all levels of those responsible for designing and building the state's transportations system. As a result, WSDOT expects agency-wide performance to continually improve.(*527*)

NHDOT Stormwater Quality Retrofits

NHDOT staff regularly attend meetings with the Chocorua Lake Association and other partners to monitor past accomplishments, plan and program new initiatives, and to share concerns and solutions with regard to future DOT projects. After installation of Best Management Practices at several highway culverts showed a reduction of phosphorus input by over 80 percent, the partners decided a long term commitment would best serve environmental stewardship goals. The stakeholders developed an agreement to protect and preserve the water quality of Chocorua

Lake for the indefinite future with regard to stormwater management, requiring Best Management Practices in both construction and maintenance activities. The Memorandum of Understanding was the first of its kind between the NH Department of Transportation and a private organization. NHDOT anticipates using this MOU as a model for future partnerships with other similar environmental groups as opportunities become available.

4.7. VEHICLE FLUID, FUEL, AND WASHWATER CONTROL

The potential for contamination of stormwater or flowing waters by vehicle fluids, fuels, or washwater necessitates environmental stewardship practices. To protect on-site watercourses:

- Refuel machinery at locations well removed from the watercourse (recommended minimum 100 m or 300 ft. separation)
- Wash and service vehicles and machinery at locations well removed from the watercourse.
- Use bio-friendly hydraulic fluids in equipment operating in or adjacent to watercourse.
- Store fuel, lubricants, hydraulic fluid and other potentially toxic materials at locations well removed from the watercourse.
- Isolate storage areas so that spilled fluids cannot enter the watercourse.

Construction Vehicle Washing Areas

Vehicle and equipment cleaning procedures and practices are typically used to minimize or eliminate the discharge of pollutants from vehicle and equipment cleaning operations to storm drain systems or watercourses. On-site vehicle and equipment washing are often discouraged, to minimize runoff problems. Caltrans has developed the following construction vehicle cleaning environmental stewardship practices: (*528*)

- When vehicle/equipment washing/cleaning must occur onsite, and the operation cannot be located within a structure or building equipped with appropriate disposal facilities, the outside cleaning area shall have the following characteristics, and should be arranged with the construction stormwater coordinator. Vehicle washing should occur only at designated pre-wash areas, facility wash racks or other designated areas:
- Special areas should be designated for washing vehicles. Whether at pre-wash areas at the maintenance facility or the field, vehicle and equipment wash water should be discharged to a sanitary sewer, or contained for percolation or evaporative drying away from storm drain inlets or watercourses. The latter should be located where the wash water will spread out and evaporate or infiltrate directly into the ground, or where the runoff can be collected in a temporary holding or seepage basin.
    - Locate away from storm drain inlets, drainage facilities, or watercourses. Wash waters should not be discharged to storm drains or watercourses.
    - Pave with concrete or asphalt and bermed to contain wash waters and to prevent run-on and runoff.
    - Configure with a sump to allow collection and disposal of wash water.
    - Use only when necessary.

- Apply sediment control BMPs if applicable. Wash areas should have gravel bases to minimize mud generation.
- Vehicles such as cement or dump trucks and other construction equipment should not be washed at locations where the runoff will flow directly into a watercourse or stormwater conveyance system.
- Minimize use of solvents. The use of diesel for vehicle and equipment cleaning should not be allowed. Cleaning of vehicles and equipment with soap, solvents or steam should not occur on the project site unless the Resident Engineer (RE) has been notified in advance and the resulting wastes are fully contained and disposed of outside the highway right-of-way in conformance with specifications. Resulting wastes and by-products should not be discharged or buried within the highway right-of-way, and should be captured and recycled or disposed according to Liquid Waste Management BMPs or Hazardous Waste Management BMPs, depending on waste characteristics.
- Vehicle and equipment wash water should be contained for percolation or evaporative drying away from storm drain inlets or watercourses and should not be discharged within the highway right-of-way. Sediment control BMPs should be applied if applicable.
- All vehicles/equipment that regularly enter and leave the construction site should be cleaned off-site.
- When cleaning vehicles/equipment with water:
    - Use as little water as possible. High pressure sprayers may use less water than a hose, and should be considered.
    - Use positive shutoff valve to minimize water usage.
    - Facility wash racks should discharge to a sanitary sewer, recycle system or other approved discharge system and should not discharge to the storm drainage system or watercourses.
- When possible, truck beds should be cleaned using a dry cleaning technique (sweep up or shovel out).
- The control measure should be inspected at a minimum of once a week.
- Monitor employees and subcontractors throughout the duration of the construction project to ensure appropriate practices are being implemented.
- Inspect sump regularly and remove liquids and sediment as needed or as directed by the RE.

Vehicle and Equipment Fueling

Vehicle and equipment fueling procedures and practices are designed to minimize or eliminate the discharge of fuel spills and leaks into storm drain systems or to watercourses. These procedures are applied on all construction sites where vehicle and equipment fueling takes place.(*529*)

- Onsite vehicle and equipment fueling should only be used where it's impractical to send vehicles and equipment off-site for fueling
- When fueling occurs onsite, the contractor shall select and designate an area to be used, subject to approval of the Resident Engineer (RE).
- Absorbent spill clean-up materials and spill kits should be available in fueling areas and on fueling trucks and should be disposed of properly after use.
- Drip pans or absorbent pads should be used during vehicle and equipment fueling, unless the fueling is performed over an impermeable surface in a dedicated fueling area.
- Dedicated fueling areas should be protected from stormwater run-on and runoff, and should be located at least 15 m (50 ft) from downstream drainage facilities and watercourses. Fueling must be performed on level-grade areas.
- Nozzles used in vehicle and equipment fueling should be equipped with an automatic shut-off to control drips. Fueling operations shall not be left unattended.
- Use vapor recovery nozzles to help control drips as well as air pollution where required by Air Quality Management Districts (AQMD. Ensure the nozzle is secured upright when not in use.
- Fuel tanks should not be "topped-off."
- Vehicles and equipment should be inspected on each day of use for leaks. Leaks should be repaired immediately or problem vehicles or equipment should be removed from the project site.
- Absorbent spill clean up materials should be available in fueling and maintenance areas and used on small spills instead of hosing down or burying techniques. The spent absorbent material should be removed promptly and disposed of properly.
- Federal, state, and local requirements should be observed for any stationary above ground storage tanks.
- Mobile fueling of construction equipment throughout the site should be minimized. Whenever practical, equipment should be transported to the designated fueling area.
- Protect fueling areas with berms and/or dikes to prevent run-on, runoff, and to contain spills.
- Fueling areas and storage tanks should be inspected regularly.
- Keep an ample supply of spill cleanup material on the site.
- Immediately cleanup spills and properly dispose of contaminated soil and cleanup materials.

Vehicle and Equipment Maintenance

Vehicle and equipment maintenance procedures and practices are used to minimize or eliminate the discharge of pollutants to the storm drain systems or to watercourses from vehicle and equipment maintenance procedures. These procedures are applied on all construction projects where an onsite yard area is necessary for storage and maintenance of heavy equipment and vehicles.(*530*)

- Drip pans or absorbent pads should be used during vehicle and equipment maintenance work that involves fluids, unless the maintenance work is performed over an impermeable surface in a dedicated maintenance area.
- All maintenance areas are required to have spill kits and/or use other spill protection devices.
- Dedicated maintenance areas should be protected from stormwater run-on and runoff, and should be located at least 15 m (50 ft) from downstream drainage facilities and watercourses.
- Drip Pans or plastic sheeting should be placed under all vehicles and equipment placed on docks, barges, or other structures over water bodies when the vehicle or equipment is planned to be idle for more than one hour.
- Absorbent spill clean-up materials should be available in maintenance areas and should be disposed of properly after use. Substances used to coat asphalt transport trucks and asphalt spreading equipment should be non-toxic.
- Use off-site maintenance facilities whenever practical.
- For long-term projects, consider constructing roofs or using portable tents over maintenance areas.
- Properly dispose of used oils, fluids, lubricants, and spill cleanup materials.
- Do not dump fuels and lubricants onto the ground.
- Do not place used oil in a dumpster or pour into a storm drain or watercourse.
- Properly dispose or recycle used batteries.
- Do not bury used tires.
- Repair of fluid and oil leaks immediately.
- Provide spill containment dikes or secondary containment around stored oil and chemical drums.
- Maintain waste fluid containers in leak proof condition.
- Vehicle and equipment maintenance areas should be inspected regularly.

- Vehicles and equipment should be inspected on each day of use. Leaks should be repaired immediately or the problem vehicle(s) or equipment should be removed from the project site.
- Inspect equipment for damaged hoses and leaky gaskets routinely. Repair or replace as needed.

Environmental Impacts of Construction & Repair Materials

Waste and recycled materials (WRM) used in structural systems are required to satisfy material strength, durability, and leachability requirements. These materials exhibit a wide variety of characteristics, due to the diversity of industrial processes that produce them.(*531*)

A proposed methodology for assessing the environmental impact of leachates from pavements and other construction and repair materials on surface water and groundwater was developed and validated by NCHRP Project 4-21, *Appropriate Use of Waste and Recycled Materials in the Transportation Industry*. The researchers also studied the movement (or transport) and eventual fate of the soluble components of highway materials, including materials, preservatives, and additives present in the highway right-of-way. The methodology is intended to help highway agencies protect the environment and explain to the public why they are using—or not using—a particular material (new or recycled) in a construction and repair project. The methodology can be used as a management and decision-making tool for state highway engineers and managers, public interest groups, environmental advocacy groups, and regulatory agencies involved in reviewing new materials for highway construction and rehabilitation. The project delivered several key products:

- Baseline data on conventional (new and recycled) construction and repair materials.
- Laboratory protocols for integrated bioassay and chemical analysis.
- A computer model for screening and evaluating materials in highway settings.
- A recommended practice for screening and evaluating the impact of construction and repair materials on ground and surface waters.

The IMPACT software estimates the fate and transport of leachates from highway construction and repair materials in the environment surrounding the highway right-of-way. The project also contains an extensive, readily accessible database of laboratory test results for materials ranging from common construction and repair products to waste and recycled materials proposed for use in highway construction. A summary document titled *Primer Environmental Impact of Construction and Repair Materials on Surface Water and Ground Water* was published as NCHRP Report 443. The revised final report is made up of five volumes: Volume I, *Summary of Methodology, Laboratory Results, and Model Development*; Volume II, *Methodology, Laboratory Results, and Model Development for Phases I and II*; Volume III, *Methodology, Laboratory Results, and Model Development for Phase III*; Volume IV, *Laboratory Protocols*; and Volume V, *User's Guide, IMPACT*. Volume I was published as NCHRP Report 448. All five volumes, the primer, and the IMPACT software have been distributed on CD-ROM as *CRP-CD-7*.(*532*)

Recycled materials that exhibited greater potential problems in terms of leachates, such as municipal solid waste combustor ash, were not included in the generally recommended practices below, though research on how to stabilize and utilize some of these potential aggregates continues. The RMRC at the University of New Hampshire also has a research project on the subject underway: *Monitoring and Analysis of Leaching from Subbases Constructed with Industrial Byproducts*.(*533*)

4.8. Air Quality Control Practices

Diesel Emission Reduction Strategies

Heavy-duty trucks and buses account for about one-third of NOx emissions and one-quarter of PM emissions from mobile sources. In some urban areas, the contribution is even greater. The fine particles in diesel exhaust (known as particulate matter) can penetrate deep into the lungs and pose serious health risks including aggravated asthma, lung damage, and other serious health problems. In addition, diesel exhaust is a likely human carcinogen. Children are more susceptible to air pollution than healthy adults because their respiratory systems are still developing and they have a faster breathing rate. Diesel exhaust also has environmental impacts. PM from diesel engines contribute to haze, which restricts visibility. In addition, diesel exhaust contributes to ozone formation (a component of smog), acid rain, and global climate change.(534)

Diesel engines, which provide fuel economy and durability advantages for large heavy-duty trucks, buses and nonroad equipment, emit significant amounts of oxides of nitrogen (NOx), particulate matter (PM), and hydrocarbons (HC) that contribute to acid rain, ground-level ozone, and reduced visibility. In addition, there is concern about the adverse human health effects related to exposure to diesel exhaust such as lung damage, respiratory problems, and premature death. Increasing evidence also suggests that diesel exhaust can cause cancer in humans. The severity of air quality issues vary greatly with the region of the U.S. and level of urbanization. Current estimates indicate that emissions from such engines in the Northeast States account for roughly 33 percent of the nitrogen oxides (NOx) and 80 percent of the particulate matter (PM_{10}) emitted by all mobile sources. (*535*) There are new EPA emission standards to dramatically reduce pollution from new engines beginning in 2004, "New Emission Standards for Heavy-Duty Diesel Engines Used in Trucks and Buses.(*536*) However, the diesel engines currently on the road pollute at much higher rates. They can run for 1,000,000 miles and last for 20 to 30 years. Several strategies are being pursued to make existing diesel engines cleaner. In addition to efforts to optimize fuel delivery and air intake systems, after-treatment devices such as particulate traps and catalytic converters offer ways to prevent dangerous emissions from entering the air. Particulate traps collect and burn away particulate emissions. Catalysts convert damaging pollutants to less-harmful products. There are also efforts to improve the emission characteristics of diesel fuel by modifying fuel properties such as sulfur content and through the use of fuel additives. EPA has a fact sheet on Emissions Control Potential for Heavy Duty Diesel Engines that explains the potential for control of pollution from Heavy-Duty Diesel Engines.(*537*)

EPA has issued emission standards for new, nonroad diesel engines, such as construction equipment, but engines within the existing fleet will not be subject to the new regulations, yet may remain in operation for another 25-30 years. Therefore, state DOTs with who are taking seriously stewardship with respect to air quality are retrofitting existing diesel vehicles with pollution controls, implementing emission testing programs for diesel vehicles, creating and implementing anti-idling programs, and promoting cleaner fuels like ultra-low sulfur diesel and compressed natural gas.(*538*)

Idling Reduction

The Environmental Protection Agency is working with the trucking industry, manufacturers of idle control technologies, various states, and other partners to help save fuel and reduce air pollution from idling trucks. EPA is conducting emissions testing on idling trucks under various conditions, surveying trucking fleets to learn more about idling times, implementing demonstration projects to test idle control technologies, and holding workshops to educate affected communities. Truck drivers idle their engines during their rest periods to provide heat or air conditioning for the sleeper compartment, keep the engine warm during cold weather, and provide electrical power for their appliances. Trucks consume up to one gallon of diesel fuel for each hour at idle, using as much as 2,400 gallons of fuel every year per truck. This totals 1.2 billion gallons of diesel fuel consumed every year from idling, costing $1.8 billion (at $1.50 gallon/diesel). On average, each idling truck produces about 21 tons of carbon dioxide (C02) and 0.3 tons of nitrogen oxides (NOx) annually totaling over 11 million tons and 150,000 tons, respectively. Diesel exhaust also contains particulates, sulfur dioxide, carbon monoxide, hydrocarbons, and various air toxics. Idling emissions can contribute to premature mortality, bronchitis (chronic and acute), hospital admissions, respiratory symptoms (upper and lower), and asthma attacks. The vast majority of fuel consumed during long-duration idling can be saved and air emissions reduced by installing one of several idle control technologies that provide heat, air conditioning, and electrical power. These technologies include auxiliary units and truck stop electrification. A list of the currently available idle technologies can be found on-line at EPA.(*539*) Strategies for reducing idling include:

- Auxiliary units: These are small, diesel-powered engines (5 to10 horsepower) that are installed on the truck They range in cost from $1,500 for direct-fired heaters (providing heat only) to $7,000 for auxiliary power units (combined cab heat/AC, electric power, and heat to engine and fuel).
- Truck stop electrification: This technology involves modifications to the truck and to the truck stop parking space to provide electrical power, heat and air conditioning. An advanced truck stop electrification product is also available as a rental without modification to the truck. Costs to implement truck stop electrification vary depending on the company modifying the truck and installing the electrification technology used.

Diesel Engine Retrofits through Fleet Management

An engine "retrofit" includes but is not limited to

- Addition of new/better pollution control after-treatment equipment to certified engines.
- Upgrading a certified engine to a cleaner certified configuration.
- Upgrading an uncertified engine to a cleaner "certified-like" configuration.
- Conversion of any engine to a cleaner fuel.
- Early replacement of older engines with newer (presumably cleaner) engines (in lieu of regular expected rebuilding).
- Use of cleaner fuel and/or emission reducing fuel additive (w/o engine conversion).

Fleet owners should consider the cost and benefits of each of these options. Potential Funding Sources are available for projects meeting certain criteria. It is also helpful to work with air quality planners to calculate the tons of emissions reductions the project can generate. EPA has created an Emissions Reductions Calculator that facilitates investigation of various retrofit scenarios. Recommended practices include the following:

- Consider alternatives with the most advanced emission control systems available in new vehicle purchases. Such alternatives include those equipped with devices that minimize idling and warm-up time automatically, and those that run on cleaner fuels like compressed natural gas.
- Identify and characterize the fleet. EPA's Fleet Assessment web page can assist fleet managers in determining the fleet information needed for proper description.
- Understand which retrofit technologies are good choices for the engines in the fleets. EPA's Verified Technology List provides a table all retrofit technologies verified to produce measurable emissions reductions. New technologies are added to this list periodically.
- Review the New York City Transit Authority or Massachusetts Big Dig retrofit project case studies to note some of the details of existing retrofit projects. Some details of the latter are reviewed in the next section.
- Understand the In-Use Testing Requirements for which retrofit manufacturers are responsible. A retrofit device manufacturer may request that some of the retrofitted engines be tested in the future to confirm that the retrofit technology is performing properly.
- Review EPA's Tampering Concerns web page to understand EPA's policies regarding changes to certified engines.

EPA also maintains lists of Retrofit Manufacturers web page and applicable Engine Manufacturers and additional maintenance requirements, installation procedures, or other factors that may be associated with a retrofit project.

Use of Clean Fuels

Ultra-Low Sulfur Diesel (ULSD) improves the performance of after-treatment technologies such as a particulate matter (PM) filter. The combination of a PM filter and ULSD can reduce emissions of PM by 90 percent. The quantity of emissions reductions from the use of ULSD alone will vary depending on the application, level of sulfur reduction, and other fuel characteristics of the replacement fuel (e.g., cetane number, aromatics, PNA). Some case studies suggest that the use of ULSD alone can reduce emissions of PM between 5 and 9 percent. While ULSD-only emission reductions for PM are relatively modest on a per-vehicle basis compared to aftertreatment retrofit, the emission reductions can be significant if an entire fleet is fueled with ULSD. ULSD will be available nationwide in June 2006, but currently is available in certain parts of the country. The price differential between ULSD and regular diesel fuel varies by location but currently ranges between 8 and 25 cents more per gallon. In 2006, when ULSD is available nationwide, the cost differential will be much less.

Biodiesel is a domestically produced, renewable fuel that can be manufactured from new and used vegetable oils and animal fats. Biodiesel has several advantages over petrodiesel. It has greater lubricity, so it reduces wear between contacting metal engine parts. This attribute will be of greater importance as the levels of sulfur in diesel fuel are lowered from 500 ppm to 15 ppm in 2006. All diesel engines will need lubricity-enhancing agents, and biodiesel is a proven choice in this regard. Also, biodiesel's higher cetane content gives it a higher flash point and greater resistance to premature ignition—a plus for many applications. Perhaps most important, though, is that pure biodiesel reduces sulfates by 100 percent, carbon dioxide lifecycle emissions by 78 percent, and carbon monoxide by 44 percent, due to the higher oxygen level in the fuel. It also reduces particulate emissions by 40–80 percent and cuts unburned hydrocarbons by 68 percent. Blends of 20 percent biodiesel with 80 percent petroleum diesel (B20) can be used in unmodified diesel engines. B20 reduces emissions of PM by about 10 percent. However, B20 also increases NOx emissions by approximately 2 percent. The B20 blend costs about 15 to 30 cents per gallon more than regular diesel fuel. Biodiesel can be used in its pure form (B100), but may require certain engine modifications to avoid maintenance and performance problems. Pure blends of biodiesel may not be suitable for cold climates. B100 reduces emissions of PM by roughly 40 percent and costs about 75 cents to $1.50 more than regular diesel fuel.

Emulsified diesel is a blended mixture of diesel fuel, water, and other additives that reduces emissions of PM as well as NOx. Emulsified diesel can be used in any diesel engine, but the addition of water reduces the energy content of the fuel, so some reduction in power and fuel economy can be expected. Emulsified fuel will stay mixed for a fairly long time. However, if a vehicle sits dormant for months at a time the water can settle out of the fuel and possibly cause problems.

Compressed Natural Gas (CNG), perhaps the most commonly known "clean fuel," is a gaseous fuel that is a mixture of hydrocarbons, mainly methane, and is produced either from gas wells or in conjunction with crude oil production. More information on alternative fuels is available online.

Sample Diesel Emission Controls: The Boston Central Artery/Tunnel (CA/T) and New Haven Harbor Crossing

The diesel emission control programs with the Central Artery/Tunnel (CA/T) Project in Boston, Massachusetts, and the I-95 New Haven Harbor Crossing Improvement Program (I-95 NHIP) in Southern Connecticut entailed add-on pollution control devices with the option of cleaner diesel fuels. Initially started as a pilot program, the CA/T retrofit program was then expanded to include all off-road equipment on more than 20 remaining construction contracts. Based on EPA certification data, it was anticipated that oxidation catalysts would achieve at least 20 percent reductions for PM_{10}, 40 percent reductions for CO, and 50 percent reductions for HC in all heavy-duty engines. The results of the evaluation for 88 pieces of equipment retrofitted during the year 2000 indicated emission reductions of approximately 90 Kg/day of CO, 30 Kg/day of HC, and 7.4 Kg/day of PM_{10}. The cost of these catalysts ranges from $1,000 to $3,000 per unit, depending on the engine horsepower (HP) rating of the unit being retrofitted. The average cost for the CA/T project was $2,500.(*540*)

The CA/T project had also explored the possibility of lowering diesel emissions even further by replacing the diesel fuel with a cleaner alternative, using a low NOx emission blend of diesel fuel consisting of a mixture of diesel fuel, water, and an additive to maintain stability of the emulsified mixture. Demonstration projects have achieved 10-30 percent NOx reductions and 10-50 percent PM reductions. A test performed on one of the CA/T contracts using a Caterpillar excavator for a period of three weeks indicated that this fuel, PuriNOx™, reduced NOx emissions up to 30 percent, and smoke up to 96 percent when compared to No. 2 diesel fuel; however, PuriNOx™ was not applied due to needed reductions in project costs.(*541*)

To help improve air quality in Greater New Haven, the Connecticut Department of Transportation (ConnDOT) is implementing new methods for reducing emissions during the I-95 New Haven Harbor Crossing (NHHC) Corridor Improvement Program. During construction on the I-95 NHHC Corridor Improvement Program, equipment used on highway contracts will be part of a pilot emissions reduction program for the State of Connecticut. ConnDOT is requiring all contractors and sub-contractors to take part in the Connecticut Clean Air Construction Initiative. The following contractor requirements apply: (*542*)

- Emission control devices (such as oxidation catalysts) and/or clean fuels (such as PuriNOx) are required for diesel-powered construction equipment, with engine horsepower (HP) ratings of 60 HP and above, that are on the project or assigned to the contract in excess of 30 days. Based on the CA/T experience PuriNOx™ was considered a good alternative to the use of retrofit equipment to reduce NOx and PM_{10} emissions. The cost of PuriNOx™ was estimated to be 16 cents per gallon above the cost of N°2 diesel fuel in the Northeast. The cost of B-20 Blend was estimated between 15 to 30 cents per gallon above the cost of N°2 diesel fuel.(*543*)
- Truck staging zones will be established for diesel-powered vehicles waiting to load or unload materials. The zones will be located where diesel emissions will have the least impact on abutters and the general public.
- Idling is limited to three minutes for delivery and dump trucks and other diesel-powered equipment (with some exceptions).
- All work will be conducted to ensure that no harmful effects are caused to adjacent sensitive receptors, such as schools, hospitals, and elderly housing. Diesel-powered engines will be located away from fresh air intakes, air conditioners, and windows.
- Initial and monthly reporting by contractors will ensure the proper implementation of the Connecticut Clean Air Construction Initiative. Non-compliance will be enforced with a 24-hour notice to the contractor to improve a vehicle or remove it from a project.

The cost of retrofitting equipment or using clean fuels was included in the general cost of the contract, as bid by each contractor. Whereas a contractor who owns equipment may be more likely to install the retrofit apparatus, one who rents equipment may opt to use clean fuels.

To introduce the program to area contractors including clean fuel vendors and equipment manufacturers, ConnDOT three informational meetings regarding clean fuels and equipment retrofitting were conducted in August and September 2001, which were attended by clean fuel vendors and equipment manufacturers. On Boston's "Big Dig", no adverse operational problems or additional maintenance costs have been reported for construction equipment retrofitted with oxidation catalysts. With proper installation, and as long as a system is not stressed beyond its design limitations, equipment warranties are not affected by installation of retrofit products. It has been estimated that on Boston's "Big Dig," emission reductions amount to 36 tons/year for carbon monoxide, 12 tons/year for hydrocarbons, and 3 tons/year for fine particulate matter. Estimates for reduced emissions during the I-95 NHHC Corridor Improvement Program are 20 tons/year for carbon monoxide and two tons/year for fine particulate matter (with clean fuels or oxidation catalysts) and eight tons/year for hydrocarbons (with oxidation catalysts only).

Dust Control in Construction and Maintenance

Dust or particulate matter (small airborne particles) is a major form of air pollution and can constitute a health hazard and create unsafe driving conditions. Airborne particulate pollution arises from a number of sources, including manipulation of the surface soil during construction activities, bulk material operations on construction sites, and traffic on paved and unpaved roadways. Maintenance activities such as sweeping, sand or chip sealing, ditch cleaning, foreslope shaping, roadside repairs, and sanding for snow or ice conditions present possible sources of fugitive dust. While dust control is an issue on many construction sites, particularly in arid areas, it has become an even more important issue in metro areas with serious non-attainment area designation for both the annual and 24-hr. PM10 National Ambient Air Quality Standards. The Arizona Department of Transportation (ADOT) completed an investigation into construction project PM10 source emissions in 1994, and recommended a variety of control measures for future projects; however, many of these measures are not having the anticipated impacts to address the particulate matter pollution issue, leading to another study underway as of this writing, focusing on development of a project manual to be used for education and outreach.

Wind erosion controls consist of applying water, other dust palliatives or covering material as necessary to prevent or alleviate dust nuisance. Dust control practices should be implemented on disturbed soils subject to wind erosion (including Shoulder Grading, Roadside Stabilization and Minor Slides and Slipouts Cleanup/Repair).

Dust control practices are typically implemented on all exposed soils subject to wind erosion. Covering of small stockpiles or areas is an alternative to applying water or other dust palliatives. Dust abatement involves application of a dust palliative to non-paved road surfaces to temporarily stabilize surface soils, leading to a reduction of dust during the dry season. Palliatives are applied in liquid form and can include water or calcium magnesium acetate, magnesium chloride, emulsified asphalts, or lignon sulfonates. Wind erosion controls should be implemented for stockpiles of loose materials.

DOT recommendations for dust control include the following:

- Evaluate suspending work under windy conditions when loose materials are prone to erosion.
- Materials applied as temporary soil stabilizers should also provide wind erosion control benefits.
- Water should be applied by means of pressure-type distributors or pipelines equipped with a spray system or hoses and nozzles that will ensure even distribution.
- All distribution equipment should be equipped with a positive means of shutoff.
- Unless water is applied by means of pipelines, at least one mobile unit should be available at all times to apply water or dust palliative to the project or maintenance activity site.
- Only potable and nonpotable (uncontaminated) water should be used. If reclaimed waste water is used, the sources and discharge should meet state and local water reclamation criteria. Nonpotable water should not be conveyed in tanks or drainpipes that will be used to convey potable water, and there should be no connection between potable and nonpotable supplies. Nonpotable tanks, pipes, and other conveyances should be marked as non-potable and not for drinking.

- Do not apply excess water. Non-stormwater discharges are prohibited.
- Never use oil to control dust
- During preparation for application of dust palliatives, gravel berms should be constructed at the low shoulders of the roadway to inhibit liquid palliatives from entering waters of the State or waters of the US.
- Dust palliatives will not be applied during rain.
- Methods or materials should be applied in a manner that is not detrimental to either water or vegetation.
- Carry adequate spill protection.
- Use environmentally sensitive cleaning agents.
- Dispose of excess materials at appropriate sites.
- Maintenance: inspect protected areas to ensure proper coverage.

Model Air Monitoring and Dust Control Practices on Boston's Central Artery Project

To minimize air quality dust impacts from CA/T construction activities, the project developed Construction Dust Control Specification 721.561. Before any work can begin on a CA/T site, a contractor must first develop and submit for approval a "Dust Control Plan" which follows the requirements of the dust specification. The requirements contractors followed to control construction generated dust included: (*544*)

- Wet suppression alone, or with approved binding agents, to be used on-site on a routine basis using a water truck.
- Wet spray power vacuum street sweeper to be used on paved roadways.
- Use of calcium chloride instead of wet suppression when freezing conditions exist.
- Use of windscreen fabric or solid wood barriers around the perimeter of construction sites.
- Use of wheel-wash stations or crushed stone at construction ingress/egress areas.
- Covering active stockpiles with plastic tarps, and seeding or using approved soil stabilizers on inactive stockpiles.
- Covering dump trucks during material transport on public roadways.

Due to the unique characteristics of each contract in terms of location and scope of work, particular methods to control dust in addition to the dust control specification were implemented. These methods included: (*545*)

- Reducing the number of truck entrances and exits from a site within the contract;
- Providing a crushed stone base for the dump truck in the on-site loading area;
- Creating embankments between stockpiles and haul roads.

These particular measures were implemented to manage and reduce the dirt that was tracking off work sites and onto city streets. To evaluate the effectiveness of the dust control measures, a PM_{10} monitoring and field dust inspection program was implemented in 1997. The program measured PM_{10} levels and inspected nuisance dust at close to 20 sidewalk locations along the alignment during the summer months for the past five years. The results from the monitoring program indicated that the highest PM_{10} levels decreased almost 50 percent once dust control efforts were implemented.(*546*)

Practices to Minimize Emissions during Hot Mix Asphalt (*HMA*) *Construction*

At the plant, minimize air emissions by employing the following environmental stewardship practices: (*547*)

- Select plant mixing temperature by:
- Contacting the asphalt supplier.
- Using the chart on the back.
- Do not use laboratory mixing temperature as plant mixing temperature.
- Make sure RAP and aggregates are dry.
- Do not use RAP containing coal tar.
- Do not expose RAP to flame.
- Do not over-heat RAP.
- Look for other sources of fumes such as:
- Slag aggregate
- Shingles
- Crumb rubber mixtures
- Other products from construction and demolition waste
- Read the Material Safety Data Sheet (MSDS) for all materials.
- Regularly calibrate thermocouples and other sensors.
- Tune up the burner.
- Contact the manufacturer and find out the limits on CO and O_2.
- When the stack is tested, compare the plant's thermocouple reading to the tester's thermocouple.
- Gather data on aggregate moisture content and fuel usage. If fuel usage goes up for the same or less moisture, find the reason.
- Have stack gases tested to see if they are in limits. If not, contact manufacturer to make adjustments.
- Compare mix temperatures with plant temperatures. Look for changes over time.
- Measure and record the pressure drop in the baghouse. Look for changes over time.
- Keep a record of fuel usage over time. Find the reason for any big changes.
- Keep track of this information and discuss it with co-workers and the manufacturer.
- Do not use diesel fuel and kerosene as release agents.

At the plant, minimize air emissions by employing the following environmental stewardship practices:

- Try increasing the mat lift thickness before calling for a higher plant temperature. Do not use diesel fuel and kerosene as release agents.
- Maintain engineering controls on paving equipment.

Guidance for Plant Mix Production and Field Compaction Temperatures of HMA

High temperatures may cause several problems to occur, including damage of the asphalt binder, generation of unnecessary fumes and odors, and excessive asphalt drain-down may occur with some mix types.(*548*) At this time, a reliable test does not exist for measuring the emissions potential for a given asphalt binder. Research is underway to establish a test to indicate emissions potential for a given asphalt and establish a maximum temperature that will prevent unnecessary emissions generation. Until this research is completed, the following procedure is recommended for selecting the starting point for plant mixing and field compaction temperatures: (*549*)

- Contact the asphalt supplier, describe the mix type, and request the plant mixing temperature recommendations.
- Consider previous field experiences with this asphalt binder grade from this asphalt supplier and current project conditions. Project conditions could include weather or seasonal conditions, lift thickness, haul distance, and mixture considerations. Adjust the supplier's recommended temperatures to suit project conditions.
- Consult the chart "Typical Binder Temperatures" listed by PG Grade.
- Select a plant mix temperature starting point based on the information obtained in items above.
- The starting point should be close to the middle of the range of temperatures for the PG vender grade being used.
- Construct a test strip and monitor both densities and temperatures in accordance with an approved Quality Control plan.
- Determine the laydown temperature at which specification density can be achieved.
- Use available software or graphs to estimate the heat loss during mix transport and laydown, taking into consideration haul distance, ambient temperature, wind conditions and mat thickness.
- Add this temperature loss to the targeted mix temperature obtained from the test strip and this will yield a starting point for plant mixing temperatures at the HMA plant.
- Adjust this temperature as necessary during normal production.

Aggregate, RAP, and Anti-Stripping Environmental Stewardship Practices

- Do not use materials for RAP containing coal tar or other questionable material.
- Do not over-heat.
- Do not expose RAP to burner flame

High moisture contents in aggregate and RAP introduced into the HMA production process may cause unnecessary fumes, emissions, and odors. Further, high moisture contents can waste fuel in the drying process and negatively impact the quality of the HMA. Therefore, to minimize these moisture contents, best management practices should include the following:

- Paved stockpile areas graded to enhance drainage.
- Stockpiling techniques to allow materials to shed rain.
- Use of covered stockpiles in areas of high annual rainfall.
- Procedures to use the driest portion of a stockpile.
- Flighting in the dryer configured to optimize retention time and drying efficiency while at the same time minimizing exposure of RAP and asphalt to the hot air stream.

In addition, anti-stripping additives should be used to enhance mixture durability only when test results indicate the need for them. The antis-tripping additive must be uniformly blended into the asphalt. Non-uniform blending may contribute to unnecessary emissions. To minimize emissions:

- Use "low-odor" formulations of anti-stripping additives. Manufacturers have developed blends that have reduced odor potential.
- Determine the optimal percentage of anti-stripping additive to use. Dosages exceeding 0.5 percent (by weight of asphalt cement) are rarely needed. If high concentrations are required, consider using a higher efficiency formulation. Note that the dosage rate is expressed as a percentage of the weight of asphalt—*not the weight of the mixture.*
- Control the temperature of the asphalt binder and the antistripping additive at the lowest temperatures that produce satisfactory results. Do not overheat since excessive heating may generate unnecessary emissions.

HMA Facility Burner Operation and Maintenance Practices for Reducing Emissions

An HMA facility has the potential to emit various emissions, and it should not operate outside its permit limits. Carbon Monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), and volatile organic compounds (VOCs) are found in the exhaust gas stream. The concentration level of each of these gases indicates the efficiency of the combustion process. It is important to know the burner system specifications and capacities, along with the concentration level of each of these gases.(*550*)

Implementation of a burner maintenance program is necessary to achieve optimum performance of a burner system. Daily monitoring of burner performance is an integral part of effective burner operation. Fuel usage should be tracked in relation to aggregate moisture, mix temperature, and baghouse temperature to create and maintain a database. Then daily burner operation parameters can be compared to this database to indicate when burner efficiency has diminished, and burner maintenance is required. Flighting in the combustion zone should be checked for wear and proper combustion space. In parallel flow plants, particular attention should be given to obtain the proper cigar-shaped flame.

Best practices for reducing emissions in facility burner operation and maintenance include the following mechanisms: (*551*)

- Counter-flow mixing equipment technology can reduce emissions since it keeps the RAP and binder separate from the drying area and flue gases.

- Sealed silo tops and sealed load-out areas may reduce fugitive emissions especially when tied into fugitive emission recapture and destruction systems.
- An asphalt storage tank fugitive emission capture system may reduce fugitive emissions from the vent.
- Exhaust fans should be kept running efficiently.
- Calibration of the thermocouples and other sensors are essential in monitoring plant conditions and mix temperatures.
- Properly maintained engineering controls on the paver will help reduce emissions in the work zone.
- Elimination of the use of diesel fuel and kerosene as release agents throughout the hot mix asphalt production and construction process.

Minimizing Volatile Organic Compounds from Traffic Paint

In recent years, air quality concerns have included the release of volatile organic compound (VOCs) into the atmosphere from traffic paint solvents. A second concern was worker exposure to hazardous materials such as the solvents toluene and Methyl Ethyl Ketone (MEK) and the lead chromate pigments in yellow traffic paint. These materials have the potential to result in adverse health effects and contaminate the environment if not used carefully. NCHRP Project 4-22 performed a comprehensive evaluation of the health and environmental hazards and 1) identified generic products and materials that would meet the EPA 1996 VOC standards for pavement-marking materials and compared VOC emissions from these materials with VOC emissions from a representative, currently used solvent-borne material; 2) identified the material, application, economic, and performance characteristics of 1996 VOC-compliant pavement-marking materials; 3) identified the products and components of 1996-compliant pavement-marking materials and associated operations (e.g., application, clean-up, disposal) that posed potential risks to workers and the environment; and 4) developed a methodology to compile, evaluate, and quantify the benefits and liabilities of VOC-compliant materials, the hazards to workers and the environment, and performance factors. In addition to the final research report, a software package was developed to assist users in applying the technology. The software package, PAMAS, is described in *NCHRP Research Results Digest 222*. PAMAS95.ZIP Download, PAMAS31.ZIP Download.(*552*)

4.9. Noise Minimization

Equipment noise impacts wildlife and people, and is a hazard to workers even more than the general public. Asking contractors to buy quieter equipment when they buy new equipment tops workers lists of requests; (*553*) unions, equipment manufacturers, and contractors are beginning to tackle the issue.(*554*)

Source controls, which limit noise emissions, are the most effective methods of eliminating noise problems. Source mitigation reduces the noise problem everywhere not just along a single path or for one receiver. Consequently, a project's noise mitigation strategy should emphasize noise control at the source. Source controls that limit noise emissions or restrict allowable types or operating times of heavy equipment are the easiest to oversee on a construction project.

The Noise Control Act of 1972 gives the Federal Environmental Protection Agency (EPA) the authority to establish noise regulations to control major sources of noise, including transportation vehicles and construction equipment. In addition, this legislation requires EPA to issue noise emission standards for motor vehicles used in Interstate commerce (vehicles used to transport commodities across State boundaries) and requires the Federal Motor Carrier Safety Administration (FMCSA) to enforce these noise emission standards. The EPA has established regulations that set emission level standards for newly manufactured medium and heavy trucks that have a gross vehicle weight rating (GVWR) of more than 4,525 kilograms and are capable of operating on a highway or street. For existing (in-use) medium and heavy trucks with a GVWR of more than 4,525 kilograms, the Federal government has authority to regulate the noise emission levels only for those that are engaged in interstate commerce. Regulation of all other in-use vehicles must be done by State or local governments.

Underwater Pile Driving Practices and Conservation Measures

NOAA Fisheries provided the following information on practices and conservation measures to reduce the effects of pile driving.(*555*) Systems successfully designed to reduce the adverse effects of underwater SPLs on fish have included the use of air bubbles. Both confined (i.e., metal or fabric sleeve or plastic sleeve) and unconfined air bubble systems have been shown to attenuate underwater sound pressures up to 28 dB.(*556*)(*557*)(*558*)(*559*) When using an unconfined air bubble system in areas of strong currents, it is critical that the pile is fully contained within the bubble curtain. To accomplish this, adequate air flow and ring spacing both vertically and distance from the pile are factors that should be considered when designing the system. Recommended conservation measures to be included in project descriptions and specifications include:

- Install hollow steel piles with an impact hammer at a time of year when larval and juvenile stages of ESA-listed fish species or those with designated Essential Fish Habitat (EFH) are not present.
- If within the in-water work window described above, drive piles during low tide periods when located in intertidal and shallow subtidal areas.
- Use a vibratory hammer when driving hollow steel piles; however, impact hammers may be required for reasons of seismic stability or substrate type or to proof weight-bearing piles. Proofing is usually not required for non-weight bearing piles
- Monitor peak SPLs during pile driving to ensure that they do not exceed the 180 dBpeak threshold for harm to fish (150 dBrms is protective with regard to harassment as defined under the ESA).(*560*)
- If sound pressure levels exceed acceptable limits, methods to reduce the sound pressure levels include, but are not limited to, the following:
- Surround the pile with an air bubble curtain system or air-filled cofferdam.
- Since the sound produced has a direct relationship to the force used to drive the pile, use of a smaller hammer should be used to reduce the sound pressures.
- Use a hydraulic hammer if impact driving cannot be avoided. The force of the hammer blow can be controlled with hydraulic hammers; reducing the impact force will reduce the intensity of the resulting sound.

- Drive piles when the current is reduced (i.e., centered around slack current) in areas of strong current to minimize the number of fish exposed to adverse levels of underwater sound.

Installing bubble curtains takes time and costs more, and can result in increasing the total amount of time the whole project takes to complete. Using a vibratory hammer can increase the amount of time it takes to drive a pile. Currently there is a trend to use fewer and larger piles on projects, requiring larger pile drivers, which in turn require that larger temporary piles be used to support the weight of the larger hammers.

Further research on the effects of noise mitigation measures and effectiveness in protecting fish life is underway and those who established the current thresholds believe thresholds will be raised when better information on pile driving effects is published.(*561*)

Blasting Practices and Mitigation Measures

Instream and offshore blasting are used during bridge or culvert construction to fracture bedrock or free materials that are difficult to excavate. Fish near blast sites may be killed or severely injured as a result of swim bladder rupture, tissue and organ damage or internal bleeding. Fish habitat may be affected by changes in downstream water quality, sedimentation, or the physical destruction of habitat at the blast site. Blasting mitigation minimizes or eliminates the potential for negative effects on fish or fish habitat that might occur as a result of the instream or onshore use of explosives during bridge or culvert construction. The Alberta Transportation in Canada has developed the following best management practices for blasting: (*562*)

- Limit the charge size and detonation velocity. Shock wave intensity and blast radius may be minimized by keeping the weight of individually detonated charges small and by selecting explosives that minimize detonation velocity
- No explosive that produces, or is likely to produce, an instantaneous pressure change greater than 100 kPa (14.5 psi) in the swim bladder of a fish should be detonated in or near fish habitat. Setback distances from the land-water interface or burial depths from fish habitat are included in the Alberta's Construction BMP Fact Sheet on Blasting Practices.
- No explosive that produces, or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed should be detonated during incubation. Setback distance or burial depths are given in Alberta's Construction BMP Fact Sheet on Blasting Practices.
- Increase the delay between charges. For multiple charges, time delay detonators (blasting caps) should be used to reduce the overall detonation to a series of single explosions separated by a minimum of 25 millisecond delay.
- Perform blasting work during non-critical or less sensitive time periods for the fish. Avoid blasting during periods of fish migration, spawning and overwintering, when fish are often concentrated in smaller, critical habitats.
- Select blasting sites to minimize the blast area and any impacts to fish habitat. Blast in shallow water as substantial blast energy dissipation occurs as the shockwave reaches the water surface. Important fish habitat such as riffles or deep pools should be avoided
- Keep fish out of the blast area. Methods include scare blasting (detonation of a length of primer cord or a blasting cap, 30 to 60 seconds before the main blast); electrofishing to

remove or scare away fish shortly before the blast; and setting block nets upstream and downstream of the blast area. The applicability of each method depends on site conditions (e.g., blocknets are only effective in small, slow moving streams). Care should be taken to avoid unplanned, dangerous detonations during pre-blast detonations and electrofishing

- Blastholes should be filled, or stemmed, with sand or gravel to grade or flush with streambed to confine the blast. Blasting mats should be placed on top of the holes to minimize the scattering of blast debris around the area.
- Ammonium nitrate-fuel oil mixtures (ANFO) should not be used in or near water due to the production of toxic by-products (ammonia).

Land-based Construction Noise Control Practices

The following best practices have been used in the U.S. (Montgomery County MD, Boston's Central Artery), suggested by FHWA for night operations in particular, and used abroad in some cases. Great Britain, Australia, and Hong Kong have been active in implementation of construction noise control measures.

- **Communicate with the surrounding community, early and often.** Put a human face on the project and the company. Let people know what is happening and, most important, when it should be over. People are more tolerant when they know what to expect. As Erich Thalheimer, Noise Control Manager at Parsons Brinckerhoff notes, excessive construction noise can motivate distressed communities to threaten a project's progress if not adequately managed; a project's "physical noise" can lead to generating more "political noise" than project managers may be able to handle.(*563*) Community outreach practices, and particularly those employed on Boston's "Big Dig," are discussed in greater detail under "Receiver Controls."
- **Require construction operations planning.** A construction noise control plan pro-actively evaluates anticipated construction noise consequences at all identified noise sensitive receptors within each contract area by: 1) identifying where and what type of construction equipment will be used during respective time periods, 2) predicting noise levels at receptor locations using accepted point-source-strength propagation algorithms, 3) comparing those predicted results against noise criteria limits, 4) if warranted, identifying proposed noise mitigation measures required to ensure compliance with the agency or project noise plan, and 5) demonstrating the expected beneficial noise reduction affects in both a qualitative and quantitative manner.(*564*) Emphasize noise control and "Work Quiet." Equal to all of the above is the awareness that noise control is an important part of the job. Everyone likes a good neighbor. Managers and supervisors should communicate that noise control is part of the job.
- **Incorporate noise control considerations in all phases of project design and planning.**
- For example, the project may specify:
  - Where practical and feasible, construction sites should be configured to minimize back-up alarm noise. For example, construction site access should be designed

such that delivery trucks move through the site in a circular manner without the need to back up.

  - Limit Equipment On-Site — Have only necessary equipment on-site.
  - Restrict the movement of equipment into and through the construction site. Long-term impacts are generated along haul routes when there are large quantities of materials to be moved.
  - Re-route truck traffic away from residential streets.
  - Impose seasonal limitations on construction noise as spring and fall are critical times in residential areas due to windows left open at night.

- **"Buy Quiet — Rent Quiet" — Require modern equipment and quiet alternatives.** Newer equipment is noticeably quieter than older models due primarily to better engine mufflers, refinements in fan design and improved hydraulic systems. Low noise equipment is also often of better quality and durability. The emission levels specified should reflect levels that can reasonably be achieved with well-maintained equipment. DOT specification of equipment noise emission limits forces the use of modern equipment having better engine insulation and mufflers. Most manufacturers can provide noise emission specs. Electric or hydraulic powered equipment is usually quieter than a diesel-powered machine. For example, electric tower cranes can be used instead of diesel power mobile cranes.
- **Employ timing restrictions**, such as those required by Montgomery County, Maryland: Between the hours of 7:00 a.m. and 5:00 p.m., Monday through Friday, noise from construction activities must not exceed 75 dBA, measured at the nearest receiving property line, but no less than 50 feet from the source. Several construction activities, such as demolition or pile driving, may inherently exceed 75 dBA, depending upon the circumstances. In those cases, the Ordinance allows up to 85 dBA, provided a Noise Suppression Plan is implemented. Essentially, these plans require the best reasonably available control technology or strategy. They may involve equipment selection, scheduling and temporary noise control devices to block or absorb the sound. At all times other than 7:00 a.m. to 5:00 p.m. weekdays, construction activities must meet the time of day receiving property line limits specified above, almost always 65 dBA daytime and 55 dBA nighttime. Construction activities are also subject to the Noise Disturbance provisions. Noise Disturbance incidents normally arise during the late night or early morning hours and involve delivering, loading and unloading equipment or materials and the associated back-up beepers. (*565*)

  City councils in Arizona, Colorado, Florida, Illinois, Maine, New Jersey, Ohio, Tennessee, and Virginia have also imposed construction timing limits, limiting night and weekend work.(*566*)
- **Schedule the more noise intense activities for less intrusive times**, such as mid-morning to mid-afternoon, whenever possible.
- **Shift work to weekend days rather than weeknights.** Because of the operating limitations placed on the contractor due to high traffic volumes during the day, some work operations on the Boston Central Artery project were necessarily scheduled for nighttime periods. At the community's urging, project schedulers evaluated the implications of performing some of this necessary work on weekend days rather than at

night during the week, where the cost for double-time work on Sundays added approximately $1 million to the project. Noise mitigation measures such as noise barriers were still used during these weekend shifts, but full compliance with Noise Spec limits could not be guaranteed during these accelerated weekend day work shifts.(*567*)

- **Employ special nighttime equipment restrictions.** Night construction is becoming increasingly common for urban widening/rehabilitation work where daylight construction closures of the routes cause unacceptable congestion problems. Heightened attention to noise control is particularly important at night. The human ear can judge sound beyond absolute terms, sensing the intensity of how many times greater one sound is to another. Because nighttime sound levels are generallylower than daytime levels and because nighttime oise can interrupt sleep, it is important to mitigate nighttime construction, including the following noise generators: (*568*)

Table 12: Critical Nighttime Construction Noise Generators

Noise Generator	Percent of DOTs identifying as Cause of Problems
Back-up Alarms	41 percent
Slamming Tailgates	27 percent
Hoe Rams	24 percent
Milling/Grinding Machines	16 percent
Earthmoving Equipment	14 percent
Crushers	6 percent

Table 13: Construction Equipment Noise Control Options

Noise Source	Control
Backup alarms	Use manually-adjustable alarms Use self adjusting alarms Use an observer Configure traffic pattern to minimize backing movement
Slamming tailgates	Establish truck cleanout staging areas Use rubber gaskets Decrease speed of closure Use bottom dump trucks
Pavement breakers (jackhammers)	Fit with manufacturer approved exhaust muffler Prohibit within 200 feet of a noise sensitive location during nighttime hours Enclose with a noise tent
Prolonged idling of equipment	Reduce idling Locate equipment away from noise sensitive areas

- **Use a noise control specification**. The [Boston Central Artery and Tunnel Project Construction Noise Control Spec 721.56] is one of the most comprehensive noise control specifications in the country. It specifies specifies a Noise Monitoring Plan be submitted prior to construction and every six months thereafter, calibration and certification of noise monitoring equipment, and Noise Measurement Reports on a weekly basis during construction including all noise level measurements taken during the previous week, construction compliance monitoring and any required complaint response investigations. Equipment Noise Compliance Certification measurements are required every six months or less if subsequent field inspection noise compliance measurements indicate that a given piece of equipment no longer meets its respective 50-foot noise emission limit. Construction noise limits are set and the spec requires the contractor to use equipment with efficient noise-suppression devices and employ other noise abatement measures such as enclosures and barriers necessary for the protection of the public. Work is required to be performed in a manner that prevents nuisance conditions such as noise that exhibits a specific audible frequency or tone (e.g., backup alarms, unmaintained equipment, brake squeal) or impact noise (e.g., jackhammers, hoe rams). The Engineer has the authority to make final interpretations on nuisance noise conditions and to stop work until nuisance noise conditions are resolved, without additional time or compensation for the Contractor. The requirements of the specification must be overseen by an approved Acoustical Engineer employed by the Contractor and the Noise Control Plan must be signed by him/her and include: contract-specific noise control commitments made previously by the Project, description of the anticipated construction activities, and an inventory of construction equipment and associated noise levels. The following example specifications have been used on the state and municipal levels:
    - **Noise reduction materials may be new or used. Used materials should be of a quality and condition to perform their designed function.**
    - Use concrete crushers or pavement saws for concrete deck removal, demolitions, or similar construction activity.
    - Pre-augur pile holes to reduce the duration of impact or vibratory pile driving.
    - Attach noise-deadening material to inside of hoppers, conveyor transfer points, or chutes.
    - Internal combustion equipment should be equipped with proper well-maintained intake and exhaust mufflers, shields, or shrouds. In particularly noise sensitive areas, use "critical" mufflers.
    - All equipment used on the construction site, including jackhammers and pavement breakers, shall have exhaust systems and mufflers that have been recommended by the manufacturer as having the lowest associated noise.
    - Maintain equipment mufflers and lubrication.
    - Maintain precast decking or plates to avoid rattling.
    - Limit 1) the number and duration of equipment idling on the site; 2) the use of annunciators or public address systems; 3) the use of air or gasoline-driven hand tools.

- The use of impact pile drivers should be prohibited during evening and nighttime hours.
- The use of pneumatic impact equipment (i.e., pavement breakers, jackhammers) should be prohibited within 200 feet of a noise-sensitive location during nighttime hours.
- The local power grid should be used wherever feasible to limit generator noise. No generators larger than 25 KVA should be used and, where a generator is necessary, it shall have a maximum noise muffling capacity. All variable message/sign boards should be solar powered or connected to the local power grid.
- Engine idling for trucks should be limited to 5 minutes maximum.

The Boston Central Artery and Tunnel Project Construction Noise Control Spec 721.56 contains both "relative" noise criteria limits at identified noise-sensitive receptor locations as well as "absolute" noise emission limits for any/all specific equipment used on site. The Noise Spec's lot-line criterion states that construction induced L10 noise levels cannot exceed baseline (pre-construction) L10 noise levels by more than 5 dBA at identified noise-sensitive receptor locations. L10 noise limits are intended to address, and have in practice been shown to correlate well with, more steady construction noise averaged over some time interval (20 minutes). To be allowed to work on a job site, each piece of construction equipment must comply with Equipment Noise Emissions Limits (Lmax, dBA, slow, at 50 ft) that are also contained in the Noise Spec for various generic types of construction equipment. Construction equipment groups were assumed for the various phases of the work. Equipment assumed to work day and night included cranes, backhoes, loaders, dump trucks, concrete pumps, mixer trucks, delivery trucks, pneumatic tools, graders, pavers, compactors, and generators. Particularly loud equipment which was only assumed to operate during the day included pile drivers, **jackhammers, how rams, and saws**. Noise emission source strength levels were taken from CA/T Noise Spec databases that provided equipment Lmax emission levels expressed in A-weighted decibels (dBA, slow) at a reference distance of 50 feet. Equipment acoustic usage factors, or the percent of time the equipment is assumed to operate at full power, were taken from CA/T databases. Then, the noise contribution from each piece of equipment was projected over the distance from the equipment to each respective receptor location.(*569*)

The City of Seattle averted a major showdown with the company building the new Seattle Seahawks stadium. The city placed noise-specific rather than time-specific restrictions on the construction project, which would initially have disallowed construction from 7 a.m. to 6 p.m.(*570*)

- **Employ measures to address and minimize back-up alarm issues**, the most common public complaint, using OSHA approved alternatives. Consider 1) use of self-adjusting ambient-sensitive backup alarms, 2) manually-adjustable alarms on low setting, 3) use of observers, 4) scheduling of activities so that alarm noise is minimized, 4) construction site access should be designed such that delivery and dump trucks move through the site in a forward manner without the need to back up. "Smart Alarms" or video systems have also been used.

Ambient-sensitive self-adjusting backup alarms increase or decrease their volume based on background noise levels. These alarms work best on smaller equipment such as backhoes and trucks. The alarm self-adjusts to produce a tone that is readily noticeable over ambient noise levels (a minimum increment of 5 decibels is typically considered readily noticeable), but not so loud as to be a constant annoyance to neighbors. The typical alarm adjustment is 82 or 107 dBA. Close attention must be give to the alarm's mounting location on the machine in order to minimize engine noise interference, which can be sensed by the alarm as the ambient noise level. These alarms should be mounted as far to the rear of the machine as possible. An alarm mounted directly behind a machine's radiator will sense the cooling fan's noise and adjust accordingly. Such a mounting will negate the purpose of the device.

Manually-adjustable alarms are effective in reducing backup alarm noise nuisance but their use requires that each alarm be set at the beginning of each day and night shift. The manual setting feature eliminates the machine mounting location problem of the ambient-sensitive self-adjusting backup alarms. The manually adjustable alarms typically have an 87 and 107 dBA setting range, with the 87 dBA setting used for nighttime operations.

Example specifications include the following:

  - All equipment with backup alarms operated by the Contractor, vendors, suppliers, and subcontractors on the construction site should be equipped with either audible self-adjusting ambient-sensitive backup alarms or manually adjustable alarms. The ambient-sensitive alarms shall automatically adjust to a maximum of 5 dBA over the surrounding background noise levels. The manually adjustable alarms should be set at the lowest setting required to be audible above the surrounding noise. Installation and use of the alarms should be consistent with the performance requirements of the current revisions of Society of Automotive Engineering (SAE) J994, J1446, and OSHA regulations, and as described in an Exhibit at the end of Division II Special Provisions.

- **Purchase an approved sound level meter for self-monitoring and documentation.**
- **Operate at minimum power.** Noise emission levels tend to increase with equipment operating power. This is a critical issue with older street sweepers, demolition work using a hoe-ram, and equipment such as vac-trucks. Require that such equipment operate at the lowest possible power levels necessary to get the job done. This saves fuel too.
- **Use noise monitoring** methods identified in Boston Central Artery and Tunnel Project Construction Noise Control Spec 721.56. Results were submitted on a standard form and plotted in 24-hour noise measurements showing L10 and Lmax noise levels vs time along with appropriate lot-line criteria limits for daytime, evening, and nighttime periods. Diagrams of the location of noise measurement equipment in relation to noise monitoring locations were required, including the location of all construction equipment operating during the monitoring period and the distance between the noise measurement location and the construction equipment. Activities occurring while performing noise measurements are noted, such as "auger banging on ground to clean soil from threads" or "heavy traffic passing near the sound level meter." Any noise level of 85 dBA or greater requires an explanation. Elements of the Boston Central Artery's noise control spec related to monitoring include the following.(*571*)

Example 9: Monitoring Related Elements of the Boston Central Artery Noise Control Specification

Noise Monitoring - General

1. The sound level meter and the acoustic calibrator should be calibrated and certified annually by the manufacturer or other independent certified acoustical laboratory. The sound level meter should be field calibrated using an acoustic calibrator, according to the manufacturer's specifications, prior to and after each measurement.

2. All measurements should be performed using the A-weighting network and the "slow" response of the sound level meter.

3. The measurement microphone should be fitted with an appropriate windscreen, should be located 5 feet above the ground, and should be at least 5 feet away from the nearest acoustically-reflective surface.

4. Noise monitoring shall not be performed during precipitation or when wind speeds are greater than 15 mph, unless the microphone is protected in such a manner as to negate the acoustic effects of rain and high winds.

Background Noise Monitoring

Background noise measurements (in dBA, slow) should be collected for at least 24 hours over two non-consecutive days Monday through Saturday and one Sunday at noise monitoring receptor locations as specified in paragraph 1.06.B.1 prior to the start of construction. Background noise measurements should be performed in the absence of any contributing construction noise for each of the noise monitoring receptor locations identified in Table 3 and Figure 1 of this Section. Background noise L10 levels should be arithmetically averaged into single L10 levels defining the background noise for daytime (7 AM - 6 PM), evening (6 PM - 10 PM), and nighttime (10 PM - 7 AM) time frames, respectively.

Construction Noise Monitoring

1. Noise level measurements should be taken at each noise-sensitive location during ongoing construction activities at least once each week during the applicable daytime, evening, and nighttime period. All other noise monitoring locations as specified in paragraph 1.06.B.1 should be measured at least once each week during the daytime period.

2. The time period for each noise measurement should be 20 minutes.

3. Construction noise measurements shall coincide with daytime, evening, and nighttime periods of maximum noise-generating construction activity, and should be performed during the construction phase or activity that has the greatest potential to exceed noise level limitations as specified in Article 1.04 of this Section. Compliance noise measurements for the noise limits in Table 1 should be performed at a point on a given lot-line which is the closest to the construction activity.

4. If, in the estimation of the person performing the measurements, outside sources contribute significantly to the measured noise level, the measurements should be repeated with the same outside source contributions when construction is inactive to determine the ambient noise level contribution.

5. All measurements should be taken at the affected lot-line. In situations where the Work site is within 50 feet of a lot-line, the measurement should be taken from a point along the lot-line such that a 50 foot distance is maintained between the sound level meter and the construction activity being monitored.

6. Up to four 24-hour noise monitors should be maintained at the lot-line of noise receptor locations and shifted among locations corresponding to construction activity as directed by the Engineer. These monitors should be capable of recording the Lmax and L10 values in 20-minute intervals over 24-hour periods. These monitors should be durable and enclosed in weather resistant cases, and located in a manner that will prevent vandalism. The data should be downloaded and submitted as specified by paragraph 1.03.E.

- **Employ on-site technician to ensure compliance with noise control requirements.** The cost to retain several staff as noise patrol and community liaisons on the Central Artery Project was estimated to amount to $1 million over the four years the contract; such positions undertook the following:(*572*)
    - Performing special noise studies and project-change impact analyses, such as evaluating noise consequences through measurements and predictive modeling and preparing noise sections for Notice of Project Change (NPC) regulatory filings.

- Overseeing contractor compliance with contract-specific noise limits by:
- Performing short-term and long-term noise compliance monitoring
- Providing a presence in the field during nighttime periods (Noise Patrol). Many noise complaints were proactively avoided and better management and control of conditions in the field were accomplished through the use of a dedicated noise technician to patrol the project at night. Should the project receive a noise complaint, the noise technician is able to immediately respond to the scene and investigate the circumstances that led to the complaint. The noise technician is empowered to intervene directly and shut down otherwise unmitigatably noisy operations that are exceeding Noise Spec limits and/or causing noise nuisances.
- Ensuring that contractors are fulfilling their noise control plans.
- Being prepared to shut down otherwise unmitigatably noisy work at night.
- Providing technical and field support to construction managers by:
- Responding to and supporting resident engineers to keep work progressing.
- Documenting contractor noise compliance for QA purposes.
- Presenting noise issues before the city and affected communities.
- Training field staff on noise issues, measurement, evaluation, and control through presentation of the CA/T Noise Control Workshop to all field staff and providing on-site mentoring and mitigation recommendations.
- Providing defendable technical advice in noise-related legal challenges, such as preparing expert witnesses for supporting courtroom testimony, defending the project's position when challenged by abutters, and documenting reasons to avoid contractor claims for noise-related work stoppages.
- Developing noise mitigation programs and strategies for policy adoption, such as developing area-specific noise mitigation measures (noise sheets), designing large-scale noise barrier/curtain systems, developing and implementing an acoustical window treatment program, developing noise-related policies (e.g. Off-Site Mitigation Policy).

- **Incorporate noise control costs in appropriate parts of the project.** CA/T primary elements as follows: 1) restricting certain noisy equipment from night work, 2) the provision of extensive noise barriers and noise curtain systems, 3) an expansion of the successful bedroom window acoustical treatment program, 4) a prohibition of backup alarms at night, and 5) an option to perform some work on Sundays (at a cost premium) that would otherwise need to be done at night due to traffic restrictions. In all, these noise mitigation measures cost the Project an estimated $2-3 million.(*573*) Noise control costs were absorbed into different parts of the project, per specification. Payment for the Noise Monitoring Plan and first Noise Control Plan were considered part of the payment for Mobilization. Payment for the 6 month Noise Control Plans, equipment certifications, and complaint response and weekly construction noise monitoring reports were considered part of the payment for related Construction. Payment for temporary noise and acoustical barriers and noise control curtains were at the Contract unit price per square foot, which included constructing, providing, placing, maintaining, moving, relocating, and disposing of temporary noise barrier walls.

Construction Noise Pathway Controls

Source noise controls are frequently inadequate at adequately minimizing noise impacts on abutting sensitive receptors because of the close proximity to residences and businesses in urban areas and because of the very nature of the construction work. When source controls are inadequate, controlling noise radiation along its transmission path should be considered a second line of defense.

Once established, only reflection, diffraction insulation, or dissipation can modify an airborne sound field. In other words, it is necessary to increase the distance from the source or to use some form of solid object to either destroy part of the sound energy by absorption, or to redirect part of the energy by wave deflection.

Noise path barriers should provide a substantial reduction in noise levels, should be cost effective, and should be implementable in a practical manner without limiting accessibility. Barriers can increase a project's visual impact and thus aesthetic effects must be considered as well, when designing barrier systems.

Path control measures include:

- **Move equipment farther away from the receiver.** Some noisy activities may be able to be moved farther away from receptors.
- **Use landscaping as a shield and dissipator;** however, research conducted by FHWA has shown that very dense trees or shrubs would be needed (100 feet deep and much taller than can normally be achieved) to get noise reductions in the 1-3 dBA range.(*574*)
- **Enclose especially noisy activities or stationary equipment with noise barriers or curtains.** Noise barriers are semi-permanent or portable wooden or concrete barriers. Noise curtains are flexible intervening curtain systems hung from supports. Enclosures encase localized and stationary noise sources. Enclosures can provide a 10 to 20 dBA sound reduction. Additionally the visual impact of roadwork activities has an affect on how construction sounds are perceived. An important noise mitigation issue, therefore, is the audio-visual sensing factor. It is common to require all jackhammers and pavement breakers used at the construction site to be enclosed with shields, acoustical barrier enclosures, or noise barriers. Example specifications include:
    - Noise reduction materials may be new or used. Used materials should be of a quality and condition to perform their designed function.
    - Noise reduction equipment and materials may include, but not be limited to:
    - Shields, shrouds, or intake and exhaust mufflers.
    - Noise-deadening material to line hoppers, conveyor transfer points, storage bins, or chutes.

  Specifications and materials descriptions are from Boston Central Artery and Tunnel Project Construction Noise Control Spec 721.56, an excerpt follows: (*575*)

Example 10: Specifications and Materials Descriptions for Barriers from the Boston Central Artery and Tunnel Construction Noise Control Spec

Temporary Noise Barriers

The Contractor shall erect temporary noise barriers to mitigate construction noise at locations specified in the Noise Control Plan or as directed by the Engineer. Temporary noise barriers should be readily moveable so that they may be re-positioned, as necessary, to provide noise abatement for non-stationary, as well as stationary, processes.

A. Temporary barriers should be constructed of 3/4-inch Medium Density Overlay (MDO) plywood sheeting, or other material of equivalent utility and appearance having a surface weight of 2 pounds per square foot or greater. The temporary noise barriers shall have a Sound Transmission Class of STC-30, or greater, based on certified sound transmission loss data taken according to ASTM Test Method E90.

B. The temporary barriers should be lined on one side with glass fiber, mineral wool, or other similar noise curtain type noise-absorbing material at least 2-inches thick and have a Noise Reduction Coefficient rating of NRC-0.85, or greater, based on certified sound absorption coefficient data taken according to ASTM Teat Method C423.

C. The materials used for temporary barriers should be sufficient to last through the duration of construction for this Contract, and should be maintained in good repair.

D. Construction Details

1. Barrier panels should be attached to support frames constructed in sections to provide a moveable barrier utilizing the standard “Temporary Precast Concrete Median Barrier” for the Project, as shown on Standard Drawing SD-H-401 and SD-H-403 for Construction Barricade, or other supports designed to withstand 80 mph wind loads plus a 30 percent gust factor.

2. When barrier units are joined together, the mating surfaces of the barrier sides should be flush with each other. Gaps between barrier units, and between the bottom edge of the barrier panels and the ground, should be closed with material that will completely fill the gaps, and be dense enough to attenuate noise.

3. The barrier height should be designed to break the line-of-sight and provide at least a 5 dBA insertion loss between the noise producing equipment and the upper-most story of the receptor(s) requiring noise mitigation. If for practicality or feasibility reasons, which are subject to the review and approval of the Engineer, a barrier can not be built to provide noise relief to all stories, then it must be built to the tallest achievable height.

E. Prefabricated acoustic barriers are available from various vendors. An equivalent barrier design can be submitted as specified in paragraph 1.03.G in lieu of the plywood barrier described above.

F. Installation, Maintenance, and Removal

1. The barriers should be installed such that the noise-absorptive surfaces face the construction noise source.

2. The Contractor shall maintain the temporary noise barriers and repair all damage that occurs, including, but not limited to, keeping barriers clean and free from graffiti and maintaining structural integrity. Gaps, holes, and weaknesses in the barriers, and openings between or under the units, should be repaired promptly or replaced by the Contractor with new material.

3. The Contractor shall remove and dispose of the temporary noise barriers at the end of the Contract or sooner at the direction of the Engineer.

Acoustical Barrier Enclosures

A. Materials

1. The acoustical barrier enclosure shall consist of durable, flexible composite material featuring a noise barrier layer bonded to sound-absorptive material on one side.

2. The noise barrier layer shall consist of rugged, impervious material with a surface weight of at least one pound per square foot. The sound absorptive material shall include a protective face and be securely attached to one side of the flexible barrier over the entire face.

3. The acoustical material used should be weather and abuse resistant, and exhibit superior hanging and tear strength during construction. The material shall have a minimum breaking strength of 120 lb/in. per FTMS 191 A-M5102 and

minimum tear strength of 30 lb/in. per ASTM D117. Based on the same test procedures, the absorptive material facing shall have a minimum breaking strength of 100 lb/in. and a minimum tear strength of 7 lb/in.

4. The acoustical material should be corrosion resistant to most acids, mild alkalies, road salts, oils, and grease.

5. The acoustical material should be fire retardant and be approved by the City of Boston Fire Department prior to procurement. It shall also be mildew resistant, vermin proof, and non-hygroscopic.

6. The acoustical material shall have a Sound Transmission Class of STC-25 or greater, based on certified sound transmission loss data taken according to ASTM Test Method E90. It shall also have a Noise Reduction Coefficient rating of NRC-0.70 or greater, based on certified sound absorption coefficient data taken according to ASTM Test Method C423.

7. The Contractor shall submit the name of the manufacturer, properties of the material to be furnished, and two one-foot square samples to the Engineer for review prior to submittal of design and detailed engineering as specified in paragraph 1.03.G.

B. Construction Details

1. The acoustical barrier enclosure should be designed similar to the example shown in Exhibit II-C, "Construction Noise Control Specification and Guidelines".

2. The acoustical material should be installed in vertical and horizontal segments with the vertical segments extending the full enclosure height. All seams and joints shall have a minimum overlap of 2 inches and be sealed using double grommets. Construction details should be performed according to the manufacturer's recommendations.

3. The Contractor should be responsible for the design, detailing, and adequacy of the framework and supports, ties, attachment methods, and other appurtenances required for the proper construction of the acoustical barrier enclosure.

4. The design and details for the acoustical noise barrier enclosure framework and supports should be prepared and stamped by a Registered Professional Engineer licensed in the Commonwealth of Massachusetts. The Contractor shall submit the design and detailed engineering drawings to the Engineer as specified in paragraph 1.03.G.

Noise Control Curtains

A. Materials

1. The noise control curtain shall consist of durable, flexible composite material featuring a noise barrier layer bonded to sound-absorptive material on one side. The noise barrier layer shall consist of a rugged, impervious material with a surface weight of at least one pound per square foot. The sound absorptive material shall include a protective face and be securely attached to one side of the flexible barrier over the entire face.

2. The noise curtain material used should be weather and abuse resistant, and exhibit superior hanging and tear strength during construction. The curtain's noise barrier layer material shall have a minimum breaking strength of 120 lb/in. per FTMS 191 A-M5102 and minimum tear strength of 30 lb/in. per ASTM D117. Based on the same test procedures, the noise curtain absorptive material facing shall have a minimum breaking strength of 100 lb/in. and a minimum tear strength of 7 lb/in.

3. The noise curtain material should be corrosion resistant to most acids, mild alkalies, road salts, oils, and grease. It also should be mildew resistant, vermin proof, and non-hygroscopic.

4. The noise curtain material should be fire retardant and be approved by the City of Boston Fire Department prior to procurement.

5. The noise control curtain shall have a Sound Transmission Class of STC-30 or greater, based on certified sound transmission loss data taken according to ASTM Test Method E90. It shall also have a Noise Reduction Coefficient rating of NRC-0.85 or greater, based on certified sound absorption coefficient data taken according to ASTM Test Method C423.

6. The Contractor shall submit the name of the manufacturer, properties of the material to be furnished, and two one-foot square samples to the Engineer for review prior to submittal of the design and detailed engineering drawings as specified in paragraph 1.03.G.

B. Construction Details

1. The noise control curtains should be designed such as described in an Exhibit at the end of Division II Special Provisions, “Construction Noise Control Specification and Guidelines.” The curtains should be secured above, at the ground, and at intermediate points by framework and supports designed to withstand 80 mph wind loads plus a 30 percent gust factor.

2. The curtains should be installed in vertical and horizontal segments with the vertical segments extending the full curtain height to the ground. All seams and joints shall have a minimum overlap of 2 inches and be sealed using Velcro or double grommets spaced 12 inches on center. Curtains should be fastened to framework and guardrails with wire cable 12 inches on center. Construction details should be performed according to the manufacturer’s recommendations.

3. The curtain height should be designed to break the line-of-sight and provide at least a 5 dBA insertion loss between the noise producing equipment and the upper-most story of the receptor(s) requiring noise mitigation. If for practicality or feasibility reasons, which are subject to the review and approval of the Engineer, a curtain system can not be built to provide noise relief to all stories, then it must be built to the tallest achievable height.

4. The Contractor should be responsible for the design, detailing, and adequacy of the framework and supports, ties, attachment methods, and other appurtenances required for the proper installation of the noise control curtains.

5. The design and details for the noise control curtains framework and supports should be prepared and stamped by a Registered Professional Engineer licensed in the Commonwealth of Massachusetts. The Contractor shall submit the design and detailed engineering drawings to the Engineer as specified in paragraph 1.03.G.

Noise Complaint Procedure

The Central Artery Project noise specification outlines a complaint procedure to ensure that public and agency complaints are addressed and resolved consistently and expeditiously. If the Contractor receives a complaint regarding construction noise, the Contractor must immediately notify the Engineer and the Interim Operations Center (IOC) or successor to the IOC. Upon receipt or notification of a noise complaint from the Engineer, the Contractor must promptly perform noise measurements at the complainant’s location during activities representative of the offending operation. The noise measurements must be performed using equipment and methods specified and reported as specified, and immediately submitted to the Engineer. In the event that the measured noise level exceeds allowable limits or result in nuisance conditions, the Contractor must immediately use noise reduction materials and methods such as, but not limited to, those described in the specification, to reduce noise levels or to alleviate the nuisance conditions.

4.10. MATERIALS STORAGE, COLLECTION, AND SPILL PREVENTION ON CONSTRUCTION SITES

Materials Management on Construction Sites

Materials management involves procedures and practices designed to reduce or eliminate pollution of stormwater from stored materials. Environmental stewardship entails use of management procedures for stockpiling:

- Contaminated and uncontaminated soil.
- Vegetative waste and paving materials.
- Materials removed from drains, ditches and culverts.
- Waste piles and any other material that could impact stormwater quality.

The following environmental stewardship practices are recommended in managing materials at construction sites:

- Minor slides/slipouts often occur during major storms. Stockpiles should be removed as soon as practicable and materials should be placed so that waterways are not impacted. See sediment control measures.
- During rain events, stockpiles of “cold mix” asphalt (i.e., pre-mixed aggregate and asphalt binder) should be covered. During rain events, soil stockpiles should be covered or protected with soil stabilization measures and a temporary perimeter sediment barrier.
- During rain events, stockpiles of Portland cement concrete rubble, asphalt concrete, asphalt concrete rubble, aggregate base or aggregate subbase should be covered or protected with a temporary perimeter sediment barrier.

Materials Storage

- Sites where chemicals, cements, solvents, paints, or other potential water pollutants are to be stored should be isolated in areas where they will not cause runoff pollution.
- Toxic chemicals and materials, such as pesticides, paints, and acids, should be stored according to manufacturers’ guidelines.
- Overuse of chemicals should be avoided and great care should be taken to prevent accidental spillage.
- Containers should never be washed in or near flowing streams or stormwater conveyance systems.
- Groundwater resources should be protected from leaching by placing a plastic mat, tar paper, or other impervious materials on any areas where toxic liquids are to be opened and stored.

Control of Sediment from Raw Materials Storage Areas

Caltrans has recommended the following stewardship practices for control of sediment from raw material storage areas.(*576*)

- Water quality, erosion and sediment control BMPs should be properly implemented and regularly maintained.
- Wind erosion control practices should be implemented as appropriate on all stockpiled material.
- In general, stockpiles should be covered or protected with a temporary perimeter sediment barrier at all times. Perimeter controls and covers should be repaired and/or replaced as needed to keep them functioning properly.
- Berms should be installed around storage areas to minimize tracking of materials out of storage areas and to contain sediment within the storage area. Permanent rolled berms or ramp berms should be made of hot asphalt or Portland Concrete Cement (PCC). Cold mix asphalt is not recommended for use as raw material containment berms. Over time,

cold mix has the potential to break up and not function as well as hot mix asphalt or PCC. Cover raw materials (especially cold mix) during the rainy season and have covers readily available outside the rainy season when rain is predicted.

- Sweep surfaces where material is tracked, blown, spilled or washed from the storage area.
- Reduce the size of stockpiles or the amount of stockpiled materials during the rainy season.
- Interim sediment controls include using temporary sediment controls to contain raw materials such as sand bags, straw bales or silt fences. Temporary sediment controls, such as sand bags and straw bales can degrade and may contribute to stormwater pollution. Temporary and permanent sediment controls should be inspected regularly and replaced or repaired as needed.
- Both permanent and temporary sediment controls require maintenance. Sediment contained by temporary or permanent controls should be removed periodically.

Collection and Disposal of Waste Materials on Construction Sites

"Good housekeeping" practices entail maintaining the site in a neat and orderly condition. Specific practices should be employed to retain runoff and to deal with toxic substances and materials.

- A plan should be formulated for the collection and disposal of waste materials on a construction site. Plan should designate locations for trash and waste receptacles and establish a specific collection schedule. Waste should not be allowed to overflow collection containers or accumulate for excessively long periods of time. Trash collection points should be located where they will least likely be affected by concentrated stormwater runoff.
- Methods for ultimate disposal of waste should be specified and carried out according to applicable local and state health and safety regulations.
- Special provisions should be made for the collection, storage, and disposal of liquid wastes and toxic or hazardous materials.
- Receptacles and other waste collection areas should be kept neat and orderly to the extent possible. Trash cans should have lids and dumpsters should have covers to prevent rainwater from entering.

Spill Prevention and Pollution Control for Hazardous Materials

Many hazardous materials are used in the construction of highway facilities. Employees must take appropriate precautions to minimize their exposure and use protective clothing and equipment. Contractors must submit material safety data sheets and obtain permission from the resident engineer before bringing any hazardous material onto the job site.

Some special permits are required for dealing with hazardous materials during construction. Demolishing a bridge, whether new, old, or temporary, requires an asbestos survey and a permit from the local air quality management district. Reusing soils contaminated with aerially deposited lead is generally prohibited.

Hazardous waste management practices are discussed in detail under Maintenance practices; however, basic construction considerations include the following:

- Develop and implement a spill prevention and pollution control program for hazardous materials.
- Identify hazardous waste training needs.
- Emphasize proper hazardous materials storage and handling procedures, including spill containment, cleanup, and reporting.
- Provide field personnel with procedures and other information so that the personnel may safely deal with known and unknown waste.
- Ensure the proper notifications if unidentified waste is found during construction.
- Prohibit refueling in sensitive areas and post signs to that effect. Limit refueling and other hazardous activities to designated upland areas.
- Inspect equipment prior to use each day to ensure that hydraulic hoses are tight and in good condition.
- If an unidentified spill is expanding and threatening adjacent sensitive areas, begin containment immediately if it can be done without personal exposure. Conventional methods for containment include interception with dikes or ditches at sufficient distance downstream to avoid contact with the material. Prevent employees, workers, or the public from being exposed to any unknown spilled material.

Minimize potential risks during project construction by having all construction personnel follow the general procedures below:

- After unknown and potentially hazardous wastes (including underground tanks) are discovered, cease construction work in that area.
- Secure the vicinity of the find by cordoning off the area with barriers or fences, and evacuate the vicinity if the resident engineer deems such an action necessary.
- Prohibit construction personnel from any exploratory or investigative work that would result in further personal exposure. Such personnel are prohibited from taking samples or testing potentially hazardous waste. This prohibition includes activities such as the following:
- Touching, smelling, or ingesting suspected materials.
- Climbing into trenches or enclosed areas where contamination is suspected.
- Reaching, looking, or placing a foreign object (such as a stick to probe or a rock to test depth or to determine the presence of a liquid) into exposed or leaking tanks or other enclosed spaces.

For any necessary exploratory, investigative, or cleanup work, use specialized consultants or safety workers who are fully trained, licensed, and qualified for hazardous waste work in accordance with state and federal regulations. Because of potentially catastrophic health effects, the Code of Federal Regulations, Title 29, Part 1910.120 (29 CFR1910.120) requires that no one enter the designated exclusion zones until the establishment of a complete and effective "hazardous waste worker protection program" or until the consultant has determined no exposure danger exists. (The designated exclusion zones are delineated in the consultant prepared hazardous waste site safety plans.) When dealing with the identification, assessment, and mitigation of hazardous material or waste, the resident engineer should obtain technical assistance. A DOT should have construction hazardous waste emergency contracts and provide procedural direction.

4.11. VEGETATION MANAGEMENT IN CONSTRUCTION

Noxious Weed Control in Construction

- **A noxious weed abatement program should be implemented**:
    - Construction equipment should be steam-cleaned and inspected to ensure that it arrives on site free of mud and seed-bearing material.
    - Seeds and straw material should be certified as weed-free.
    - Areas of noxious weeds should be identified and treated prior to construction.
- **In situations where mechanical controls are not enough, the application of fertilizers and the use of herbicides to suppress undesirable competing species may be necessary.** Herbicides can eliminate undesirable species more reliably, but they may eliminate desirable species. Their use near watercourses may also be severely curtailed by local, state, and federal permit requirements. Several herbicides are approved for near-stream use and degrade quickly, but their use should be considered a last resort and the effects of excessive spray or overspray carefully controlled. If herbicide use is both advisable and permitted, the specific choice should be based first on whether the herbicide is absorbed by the leaves or by the roots (e.g., Jacoby 1987).(*577*) The most common foliar-absorbed herbicide is 2,4-D, manufactured by numerous companies and particularly effective on broadleaf weeds and some shrubs. Other foliar herbicides have become available more recently and are commonly mixed with 2,4-D for broad-spectrum control. Root-absorbed herbicides are either sprayed (commonly mixed with dye to show the area of application) or spread in granular form. They persist longer than most foliar herbicides, and some are formulated to kill newly sprouted weeds for some time after application.
- Areas treated to remove noxious weeds should be revegetated with appropriate native species.

Revegetation and Vegetation Salvage Plan

- A revegetation plan should be developed to ensure that salvage vegetation is used where possible and that native species are used. Monitoring will occur during the revegetation period to ensure the success of the revegetation plan.
- Include at least a one-year plant establishment guarantee period from the contractor.

- Follow guidelines or specifications for protection/restoration of existing vegetation. To protect existing desirable vegetation from construction impacts: (*578*)
- Identify and delineate in contract documents all vegetation to be retained and mark in the field prior to the start of adjacent soil-disturbing activities. Mark areas to be preserved with orange polypropylene temporary fencing.
- Minimize disturbed areas by locating temporary roadways to avoid stands of trees and shrubs and to follow existing contours to reduce cutting and filling.
- When removing vegetation, consider impacts (increased exposure or wind damage) to the adjacent vegetation that will be preserved.
- Protect the root zone of vegetation out to 1.5 times the diameter of the drip line, which is the outermost reach of its branches (the drip line).
- If cuts or fills are required in the vicinity of trees to be saved, consider retaining walls, tree wells, gravel, or drainage systems to protect the root systems.
- Avoid storing, parking or driving heavy equipment around the base of a tree, which can compact the soil and deprive the tree's roots of the water and air they need to survive. Stockpiling building materials or fill can have a similar effect. Refer to the Soils and Soil Amendments section for more information on soil compaction and its minimization.
- Avoid scraping soil from roots or cutting them too deeply or too close to the tree can cause the tree to die or have a weakened hold and blow down. This damage may not be visible for years.

Mn/DOT has developed a Specification for Protection and Restoration of Vegetation. This specification promotes the protection and preservation of vegetation from damage and the use of corrective action when damage does occur.(*579*)

Example 11: Mn/DOT Specification for Protection and Restoration of Vegetation Construction Elements

A. Protecting and Preserving
The Contractor shall protect and preserve:

(1) Specimen trees.

(2) Threatened and endangered plants, as listed on the federal and state threatened and endangered species list.

(3) Vegetation designated in the Contract to be preserved.

(4) Trees, brush, and natural scenic elements within the right-of-way and outside the actual limits of clearing and grubbing.

(5) Other vegetation the Engineer identifies for protection and preservation.

The Contractor shall not place temporary structures, store material, or conduct unnecessary construction activities within a distance of 25 feet outside of the dripline of trees designated to be preserved without approval from the Engineer. The Contractor shall not place temporary structures or store material (including common borrow and topsoil) outside of the construction limits in areas designated in the Contract to be preserved.

A1 Temporary Fence
The Contractor shall place temporary fences to protect vegetation before starting construction.

The Contractor shall place temporary fence at the construction limits and at other locations adjacent to vegetation designated to be preserved when specified in the Contract, directed by the Engineer, or allowed by the Engineer. The Contractor shall not remove the fence until all work is completed or until removal is allowed by the Engineer. The fence shall prevent traffic movement and the placement of temporary facilities, equipment, stockpiles, and supplies from harming the vegetation.

A2 Clean Root Cutting

The Contractor shall cleanly cut all tree roots at the construction limits when specified in the Contract or directed by the Engineer.

The Contractor shall immediately and cleanly cut damaged and exposed roots of trees designated for protection back to sound healthy tissue and shall immediately place topsoil over the exposed roots. The Contractor shall limit cutting to a minimum depth necessary for construction and shall use a vibratory plow or other approved root cutter prior to excavation. The Contractor shall immediately cover root ends that are exposed by excavation activities to within 6 inches of topsoil as measured outward from root ends.

A8 Destroyed or Disfigured Vegetation

If the Contractor destroys or disfigures vegetation designated to be preserved, the Contractor shall, at no expense to the Department, restore the damaged vegetation to a condition equal to what existed before the damage was done. The Engineer may assess damages against the Contractor on vegetation where an equal level of restoration is not accomplished. The Engineer will assess damages to trees and landscaping at not less than the appraisal damages as determined by the International Society of Arboriculture appraisal guide. The Engineer will determine and assess damages to other vegetation.

A10 Other Vegetation Protection Measures

The Contractor shall provide other vegetation protection measures, including root system bridging, compaction reduction, aeration, and retaining walls, as specified in the Contract or as directed by the Engineer.

Table 7-1. *Tree Protection during Design and Construction* (cont'd)

Impact to Tree	Construction Activity	Methods/Treatments to Minimize Damage
	Spills, waste disposal (e.g., paint, oil, fuel)	Post notices on fences prohibiting the dumping and disposal of waste around trees. Require immediate cleanup of accidental spills.
	Concrete washout and waste dumping Soil sterilants (herbicides) applied under pavement Impervious surface over soil surface	Designate washout areas. Dig pit and remove after construction, if necessary. Use herbicides safe for use around existing vegetation and follow label directions. Utilize pervious pavement material where possible. Install aeration vents in impervious paving.
Inadequate soil moisture	Rechannelization of stream flow; redirecting runoff; lowering water table; lower grade	In some cases, it may be possible to design systems to allow low flows through normal stream alignments and provide bypass into storm drains for peak flow conditions. Provide supplemental irrigation in similar volumes and seasonal distribution as would normally occur.
Excess soil moisture	Underground flow backup; raising water table	Fills placed across drainage courses must have culverts placed at the bottom of the low flow so that water is not backed up before rising to the elevation of the culvert. Study the geotechnical report for ground water characteristics to see that walls and fills will not intercept underground flow.
	Lack of surface drainage away from tree	Where surface grades are to be modified, make sure that water will flow away from the trunk, i.e., that the trunk is not at the lowest point. If the tree is placed in a well, drainage must be provided from the bottom of the well.
	Irrigation of exotic landscapes	Some species cannot tolerate frequent irrigation required to maintain lawns, flowers, and other shallow-rooted plants. Use free-form mulch areas, avoid landscaping under those trees, or utilize plants that do not require irrigation.
Increased exposure	Thinning stands, removal	Save groups or clusters of trees when working with species that perform poorly in the open or as single trees. Maintain the natural undergrowth.
	Excessive pruning	Prune sparingly, especially in stands of shade-tolerant species. Leaves manufacture the food needed for root growth and recovery from shock.

Source: Tree City USA Bulletin No. 20, The National Arbor Day Foundation.

Site Preparation

An adequately prepared site will have these characteristics: (*580*)

- Free of construction debris.
- Relatively few large rocks or other natural objects.
- Free of ruts or gullies.
- Top two inches should be in a friable condition (non-compacted), ideally allowing a heel to make a ¼-inch impression.
- Heavily compacted sites should be scarified to a depth of 6 to 8 inches.

Availability of soil preparation equipment is often limited, but the Contractor can often use standard construction machinery. For example, ripper teeth on a grader tool bar will adequately prepare a site. Ideally, scarification will be done in two passes perpendicular to each other. However, on sloping land and in areas of high wind, use mono-directional scarification perpendicular to the direction of slope or prevailing wind. If traditional surface preparation equipment such as disks and/or chisel plows are available, the conditions required for adequate surface preparation are the same as previously noted.

4.12. SOIL MANAGEMENT IN CONSTRUCTION

Earthwork and Soil Management

General environmental stewardship practices for earthwork and soil management include the following: (*581*)(*582*)

- Minimize the extent of disturbance activities to minimize impacts to soil outside the project's construction limits.
- Mitigate construction-related soil compaction in vegetation restoration areas.
- Stockpile and reuse native soils where practical.
- Minimize erosion potential and weed species invasion by establishing a healthy plant cover.
- Note the topsoil's structure and function.
- Mitigate construction-related soil compaction in vegetation restoration areas by ripping the soil to loosen its structure.
- When stockpiling topsoil, mound soil no higher than 1.3 m (4 feet) high for less than 1 year and preferably less than 6 months. Cover to prevent soil erosion and contamination by weeds.
- Use only well composted soil amendments and incorporate them as specified.
- Avoid walking, operating equipment or driving vehicles on planting areas after soil preparation is complete.
- Minimize erosion potential by establishing a healthy plant cover.

Contouring

The erosive power of water flowing down a slope should be recognized during earthmoving. The steepest direction down a hillside is also the direction of greatest erosion by overland or channelized flow.

- The overall topography of the graded surface should be designed to minimize the uncontrolled flow of runoff.
- Channelized flow should be diverted to ditches cut into the soil that more closely follow the level contours of the land.
- Dispersed sheet flow should be broken up by terraces or benches along the slope that also follow topographic contours.
- On a fine scale, the ground surface can be roughened by the tracks of a bulldozer driven up and down the slope, or by a rake or harrow pulled perpendicularly to the slope. In either case, the result is a set of parallel ridges, spaced only a few inches apart, that follow the contours of the land surface and greatly reduce on-site erosion.

Subgrade Preparation

Proper subgrade preparation includes the clearing and grubbing of land. Subgrade preparation measures that are particularly important for restoration sites may include the following stewardship practices.

- Except for muck soils, the subgrade should be free of organic debris, demolition debris, and large stones and rocks.
- If no fill is required, the ground should then be smoothed and compacted.
- If the area requires fill, the surface should be scarified or roughened to facilitate a bond between the original soil and the fill.
- Fill should not be placed on a smooth compacted soil.

Topsoil Preservation

On a typical highway project, earthwork normally starts by scraping the ground surface, then transporting the material and placing it where fill or embankments are needed. The first layer to be excavated, usually the topsoil, is often placed at the bottom of the fill. The last layer excavated is left exposed on the final grade surface. This process results in the placement of the nutrient- and organic matter-rich topsoil at depths that are inaccessible to plant roots. The exposed geological parent material is usually a suboptimal planting medium because it is low in organic matter and often has plant nutrient imbalances.(*583*)(*584*)(*585*)

Topsoil is that uppermost layer of soil capable of growing and supporting vegetation. Topsoil contains the essential microorganisms, nutrients, organic matter and physical characteristics necessary to grow and sustain permanent vegetation. Plant life and water absorption capability require similar soil conditions: loose, friable soil with the right balance of organic matter, microorganisms, and minerals. In contrast, roadway construction requires highly compacted soils with low organic matter content for stability. DOTs typically require that soils for road foundations are compacted to 95 percent density. Plants require that soils have a density of less than 80 percent. The ideal soil for most plants is approximately 50 percent solid and 50 percent pore space. The solid component contains minerals and organic matter. Ideally, pore space contains roughly equal parts air and water. Microorganisms (such as fungi) or invertebrates (such as earthworms) are present in a healthy soil and function to process organic matter, recycle nutrients, and nurture plants. Soil organic matter holds the soil particles in an aggregated state, improving water infiltration and retention. Soil organic matter also supports a large and diverse microbial population that is critical to nutrient cycling. The organic matter also retains nutrients that weather out of the minerals and accumulate from plant growth and decay. In particular, the soil organic matter provides organic and mineral nitrogen (N), which is the most commonly deficient plant nutrient on disturbed soils.(*586*)

Any disturbance to the soil alters and influences this complex system. Disturbances include construction, fertilizer and pesticide application, soil compaction from foot traffic and equipment use, and altering hydrological patterns through irrigation, grade changes, and stormwater retention. In other words, any management activity on the roadside is a potential disturbance to the soil system. Because undisturbed soils contain large accumulations of humified soil organic matter, similar large inputs are expected to be required in order to regenerate soil function on drastically disturbed sites that have been depleted of organic matter. A second critical condition, however, is that N should be released very slowly from the organic matter in order to prevent excessive weed growth and N losses from leaching. This is especially true given the large amounts of organic amendments may be applied.

With increased focus on stormwater and new understanding of the role of soils in the mitigation of water quality and quantity, engineered soil and soil amendments have become an important stormwater stewardship practice. Much of the roadside environment is reduced to subsoil at the surface following a typical roadway construction project. Subsoil has little or no organic matter, few pore spaces, and few microorganisms. While the mineral component of soil provides structural support for roads and bridges, climax vegetation cannot grow in this environment, thus nitrogen fixing pioneer and exotic plants become necessary. The resulting community of native and exotic, invasive plants can require costly maintenance and time consuming management. The job of reconstructing a functioning soil community is difficult and costly, and might not be achievable in some areas.

Topsoil nourishes and provides structural support for plant roots and absorbs and cleans water. Stripping, stockpiling, and reusing topsoil on construction projects is essential for proper reclamation of disturbed areas. It is necessary to have healthy soil to revegetate a site. Revegetation is necessary to provide slope stabilization, erosion control, biofiltration and infiltration for water quality, screening, local climate modification, habitat, and so forth. Revegetation might also be necessary to meet permit or environmental requirements. As a result, healthy topsoil is an important component of a construction project.

- Topsoil is recommended on all disturbed sites and slopes 2H:1V or flatter that should be permanently seeded or used as a planting medium for plantings or nursery stock. Topsoil may be added to a rock mulch to enhance slope protection and provide soil for seed germination and plant growth. Topsoil can be mixed with organic material such as compost or manufactured soil amendments to improve the growing capability of seeded and planted vegetation.

- Topsoil normally should not be used on slopes steeper than 2H:1V or on sandy or silty slopes steeper than 3H:1V. Additionally, topsoil should not be placed on frozen, extremely wet, or smooth slopes.
- To the extent practicable, aboveground vegetation, including litter, should be mixed or otherwise incorporated into the topsoil prior to excavation. Topsoil should be excavated from the existing roadway shoulder to a depth of 150 mm (6 inches). For new alignments, topsoil should be excavated to the depth it exists and stockpiled.
- The topsoil should be placed into stockpiles at locations designated on the plans. Stockpiles should be treated with temporary soil stabilization and erosion control measures as per Stormwater Pollution Prevention Plan (SWPPP). Topsoil stockpile height should not exceed three meters (10 feet).
- Stockpiling topsoil will result in the disruption and loss of beneficial soil microorganisms, and if stockpiled over a length of time (six months +/-) may result in total or partial loss of soil microorganisms.
- If topsoil is stockpiled prior to placement, the top one foot of the stockpile material should be mixed with the remainder of the stockpile to ensure that living organisms are distributed throughout the topsoil material at the time of final placement.
- The use of micro-organism inoculates may be necessary to re-establish micro-organisms in topsoil material that has been stockpiled for over a nine (9) month period.
- Apply a temporary soil stabilization and erosion control treatment to the exposed topsoiled areas to protect the topsoil prior to permanent seeding.
- Soil binders may be applied to disturbed soil areas or soil stockpiles requiring short-term protection. Soil binders consist of applying and maintaining polymeric or lignin sulfonate soil stabilizers or emulsions, may be used to stabilize stockpiles. A variety of soil binders are available for use. Prior to use, the manufacturers' specifications should be reviewed and compared to the site-specific conditions. In selecting a soil binder, the following criteria should be considered: availability of product; ease of cleanup; degradability (how the product degrades and what its by-products are); length of drying time; erosion control effectiveness; longevity; mode of application and availability of application equipment; and water quality impact.(*587*)
- Apply soil binders per manufacturer's specifications.
- Soil binders should be nontoxic to plant and animal life.
- Soil binders shall not be applied to frozen soil or areas with standing water.
- Soil binders should not be applied during or immediately before rainfall.
- Avoid over-spray onto hardscaped areas.
- Check protected areas to ensure proper coverage and re-apply soil binder as needed, or implement additional BMPs.

- When stockpiling topsoil, mound soil no higher than 1.3 m (4 feet) high for less than 1 year. Cover to prevent soil erosion and contamination by weeds.

- Mitigate construction-related soil compaction in vegetation restoration areas by ripping the soil to loosen its structure. After final slope grading and prior to placement, cut slopes should be cross-ripped horizontal to the slope to assist in anchoring the topsoil. The spacing of the ripping shanks should be one meter (three feet) and penetration should not exceed 300 mm (12 inches) in depth. Where embankments are constructed, offsetting lifts of material to create an uneven surface prior to topsoil placement should be considered. Smooth slopes are not acceptable.

- Following construction, stockpiled topsoil should be uniformly redistributed (placement) to a depth of 150 mm (six-inches). Placed topsoil should be cat tracked vertically to the slope to compact the topsoil and to create horizontal pockets (safe sites) to hold seed and water.

- Leave the topsoil surface in a roughened condition to reduce erosion and facilitate establishment of permanent vegetation. The roughening establishes safe sites for seed to germinate and grow.

- Where quantities of topsoil are limited, it is recommended to cover the more critically disturbed areas to the proper depth, rather than cover all areas. If necessary, the more favorable sites may be left without topsoil.

- Approved compost and/or manufactured organic soil amendments can be added to the topsoil to increase the organic content of the soil and assist in rebuilding soil microorganism populations. Topsoil can be added to rock mulch for added slope protection, to reduce the potential of erosion, and to enhance vegetative growth.

- Do not mix organic material such as wood bark or fiber, grass hay or grain straw in topsoil unless nitrogen fertilizer is included (organic material uses nitrogen to break down and decompose the fibers).

- Compost derived from livestock or green urban waste (trees, leaves, lawn clippings) is far superior to noncomposted manure or wood fiber.

- Mix compost with surface soil to reduce drying of seeds in arid climates. A literature review by Montana DOT found that compost is rarely mixed with surface soil, which can be accomplished with a compost blower. MDT explored various equipment and methods to incorporate compost and then evaluated vegetation condition and erosion condition over three years. The research indicated that compost blowers work well, and that compost applied as a blanket is more effective at excluding weeds.(*588*)

- Periodically, and after each storm event or snow melt, inspect, repair, and reseed if necessary to control erosion and loss of topsoil.

- Procedures for periodic maintenance should apply to both temporary soil stabilization or permanent seeding application.

4.13. ESTABLISHING VEGETATION AT CONSTRUCTION SITES

When little topsoil is left in roadside environments after construction, mulches, water, lime, and/or fertilizers may be required in order to establish vegetation. A soil analysis can assist in identifying these additional requirements. A horticulturist and/or some landscape architects should be able to interpret the soil analysis. If outside the optimum planting seasons, a method of soil cover, other than vegetation, may be necessary. These include mulches and erosion control fabrics.

Some DOTs are undertaking research to identify what vegetation establishment methods work best in their states and ecoregions. Studies on compost usage are occurring in the west and mid-west, from Texas in the south to Idaho in the north. The Nebraska Department of Roads has research results due in late 2004, which will be used to develop technical guidelines for vegetation establishment on roadway shoulders. The project is examining the interaction effects of seed priming, type of mulch, and level of irrigation on soil movement and establishment of the short grass mixture on the foreslope of roadway shoulders; and the interaction effects of composted manure applications and a six to twelve inch compacted buffer strip between the paved shoulder and the seedbed on soil movement and establishment of the short grass mixture on the foreslope of the roadway. Delaware DOT will publish a vegetation management manual in 2005, in conjunction with the agency's tree preservation policy for a Livable Delaware.(*589*)

The following recommended practices to promote plant establishment during the construction stage have been culled from the best practices, manuals, bulletins, and research of lead DOTs in the field, and are summarized as follows:

- Do not deviate from plans without approval of the Landscape Architect. Plans developed by the landscape architect will include plants most appropriate for the region and landform in which construction will be occurring, and will help ensure survival of intended vegetation and minimize the spread of noxious weeds.
- Test seed for germination and to ensure that it is weed free.
- Enforce seeding contract requirements. Utilize specs that allow withholding of funds. One way to enforce the requirements of the seeding contract is to withhold funds for incomplete grading and turf establishment on a per acre level. Mn/DOT Technical Memorandum Number 85-4-RD-1 allows for $700 to $2,000 per acre to be withheld from the contract when grading and turf establishment requirements are not met.
- Use correct plant handling and planting techniques to facilitate plant establishment.
- Keep the rootball moist and bare roots covered at all times.
- When planting, the root flare should be 10 percent of the root ball depth above ground level.
- Dig the planting hole so it is a minimum of 2 times the diameter of the rootball width. Larger holes will be required in more compacted soils.
- Plants smaller than 20-gallon container size do not need to be staked.
- Mulch should cover only the edge of the rootball. When planting is completed, there should be no additional soil and little or no mulch over the root ball for container plants.
- Additional information on tree planting can be found on-line.

- Follow transplanting guidelines, if applicable. The reason for setting transplant guidelines is to increase the likelihood of plants surviving, growing to maturity, and reproducing. The chance of success is much greater if plants from the same altitude and ecosystem are used because they are adapted to that area's climate and elevation. The following guidelines are recommended by the Washington State Department of Transportation.(*590*)
  - Collect plant materials during the dormant season.
  - Collect cuttings from 30 to 50 parent plants in good condition (if available). In general, take no more than 33 percent of the parent plant's material and take no more than 50 percent of cuttings or seed from a given area.
  - For plant cuttings, use young shoots (1 to 2 years old). Older and larger stems tend to have higher mortality.
  - Keep plants protected from wind and heat.
  - Plant materials the same day as collected when possible, ideally within about 2 hours of lifting. Keep plants moist and free from wind and heat exposure.
  - In some cases soaking cuttings for up to 5 days prior to planting enhances success. Protecting stems from wind and keeping them cool and moist is essential.
  - Planting holes should be deep enough so that the downslope side of the rootball is entirely buried.
  - Plant the plant so the root collar is at the depth at which it was previously growing.
  - Spread roots out so none are kinked or circling. Protect roots, especially fine root hairs on the main root system. Add water, if available, to reduce voids and increase root and soil contact.
  - Use on-site soil to backfill the hole. Firmly tamp the soil around the plant. Be careful not to compact the soil.
- Transplanting a microsite: Depending on site conditions and project objectives, it might be preferable to salvage and transplant a small section of ground. This section usually contains several plants with roots, mycorrhizae, seed, soil, soil microorganisms, and duff materials. This technique provides great benefits to the area being revegetated. For transplanting small sections of ground, excavate an area large enough to "plant" the entire piece. Lay it in the excavated area and level with adjoining ground. Use excavated soil to secure edges of transplanted piece. Tap gently into place. Whenever possible, water the transplant.
- Apply fertilizer in a manner and at application rates that will not result in loss of chemicals to stormwater runoff. Follow manufacturer's recommendations for application rates and procedures.
- Make sure seed is covered with the correct depth of soil if broadcasting or hydroseeding. The depth will depend on the type of seed being used. Check with the HQ Horticulturist for correct planting depths for the seed mix. Composted organic amendments, in place of fertilizer, also work well. Some compost blowers are able to inject seed as the compost is blown onto the site.

- When using either cuttings or rooted stock, ensure soil and the roots make good contact. This requires compaction of the soil, either by foot or by equipment, to avoid air pockets. It also requires that the soil be at the right moisture content. Another aspect to consider is that quite frequently after planting, the resulting soil is too rough and loose to support vigorous seed growth. The roughness promotes rapid drying, and the looseness yields poor seed-to-soil contact and also erratic planting depths where mechanical seed drills are used. As a result, some means of compaction should be employed to return the soil to an acceptable state for planting. Special problems may be encountered in arid or semiarid areas (Anderson et al. 1984). The salt content of the soil in these settings is critical and should be tested before planting. Deep tillage is advisable, with holes augured for saplings extended to the water table if at all possible. First-year irrigation is mandatory; ongoing fertilization and weeding will also improve survival.
- After seeding, protect the site from additional surface water flow, specifically overland flow from roads. Direct the water flow away from the project area with gravel drains, swales, culverts, or drainpipe.
- Use weed-free straw or wood cellulose fiber mulches to minimize rain splash erosion. When using straw as a mulch, use as thin a layer as possible to cover the soil (¼ inch). Grass seed cannot sprout if the mulch is too thick. Wood mulch may be chosen over other stabilization measures to reduce germination of noxious weeds and the need for vegetation control measures. Wood mulch should not be applied to steep slopes or placed into drainage paths that could receive concentrated flow. Wood mulch is prone to displacement under these conditions. Contact the District Landscape Specialist, District Erosion Control Specialist or Landscape Architect for the appropriate application rates and use the recommended application rate. Wood mulch may be applied by hand, with blowers or with chippers. Avoid application onto hardscaped areas. Mulch will require periodic inspection.(*591*)

Establishing Native Grasses and Forbs

Although a well-chosen and established plant community should require no human assistance to maintain vigor and function, competition from other plants during establishment might be a problem. Competing plants commonly do not provide the same long-term benefits for stability, erosion control, wildlife habitat, or food supply. The restoration plan therefore must include some means to suppress or eliminate them during the first year or two after construction.

Mn/DOT has compiled a detailed set of recommendations for establishing native grasses and forbs, as summarized in this section.(*592*) Seeding native grasses and forbs (wildflowers) can be accomplished using a number of different methods; however, due to the complexity of seed sizes, textures and densities, care needs to be taken to ensure that the site is well prepared and that seed is placed properly. Older style drills may clog easily with fluffy seeds. Broadcast seeding and hydroseeding also work, natives should be seeded according to several general "rules of thumb," as recommended by Mn/DOT:

- Prepare a firm seedbed, which is preferred by native seeds.
- Large and/or fluffy seeds should be buried approximately 1/4 inch deep.
- Seed should be lightly covered with soil. Harrowing or raking works well.

- **Small and/or fine seeds (most forbs) should be scattered over the soil surface.**
- **Use diverse plantings, which are more resistant to drought, floods, and pathogens** than monotypic or low diversity plantings, though care should be taken in selecting mixes to avoid unhelpful competition between species. The inclusion of a diverse mixture of forbs is greatly beneficial to wildlife and the forbs occupy niches that would otherwise be occupied by weeds. Native legumes also fix nitrogen, which is made available to other plants in the system through fungal interactions between plants. Cool-season native grasses tend to establish quickly and will decrease over time on sites where warm-season species would normally dominate. Warm-season native grasses tend to be slower to establish, but are extremely hardy and long-lived. Warm-season grasses also tend to stay standing over the winter and provide the best snow filtering capabilities and wildlife habitat.

  Caltrans underwrote a number of experiments to study the competitive interactions between herbaceous species used in erosion control seedings and whether species that use resources differently in space and time create more stable plant communities than species with more similar resource use patterns.(*593*) The results of these experiments suggest that within an herbaceous plant community, species have the potential to partition their resources, which may allow them to co-exist without competitively excluding one another. Caltrans' researchers found that mixtures including species with different spatial and temporal resource use patterns utilized soil water more completely and produced greater and more consistent aboveground biomass than mixtures of species with more similar resource use patterns. More species rich mixtures used soil water more completely and produced more aboveground biomass with more stable species composition than less diverse mixtures. Invaders performed worst in mixtures that included species with resource use patterns similar to the invader. The researchers also reported results from a survey of erosion control plantings and relict perennial grass communities. Annual precipitation and geographic location were the environmental variables that best explained the species composition data. Relict perennial grass stands had greater mineralizable and total nitrogen levels, higher perennial grass cover, and lower legume cover than revegetation sites. Soil depth was identified as an important factor in success of revegetation seedings (*594*) but was not measured. (*595*)

- **Consider cover/nurse crops.** Cover crops provide a quick short-term vegetative cover while the permanent native species are establishing. A cover crop reduces the soils erosion potential and moderates the native seedlings microclimate during establishment. Typical cover crops in Mn/DOT's native mixes include oats/winter wheat, annual rye grass and slender wheatgrass. Winter wheat is substituted for oats during fall plantings. The annual rye grass provides good cover in early spring but does not do well in late spring and summer. It also does well dormant seeded. However, Caltrans researchers suggested that the use of non-biological means of erosion control (e.g. straw mulch, mats or wetting agents) with native perennial grasses may be preferable to including fasting growing species. Physical erosion control methods in combination with planting perennial grasses, forbs and shrubs, may optimize erosion control by shielding the soil from the impacts of rain and run-off in the short term and establishing stable plant communities with dense and deep root systems for long term soil protection.(*596*)

- **Mulching or temporary erosion control.** It is recommended to protect a new seeding by covering it with mulch or an erosion control blanket. In general, slopes that are 1:3 (vertical : horizontal) and flatter should be mulched with a clean grain straw or native grass mulch and disc anchored following seeding. Mulching should attempt to achieve 90 percent coverage of the exposed soil surface. This generally requires about 2 tons per acre of straw mulch. It is also recommended to use a high quality, certified weed free mulch. On slopes that are steeper than 1:3 it is recommended that the seeding be covered with an erosion control blanket. Generally, straw blankets containing double netting (Straw 2S) perform best with native plantings. If seeding is being done in a ditch or swale that will receive moderate water flows for periods of time, it is recommended that a straw/coconut blanket be used to cover it. Other more severe situations such as very steep slopes and/or channels exposed to high water velocities will require more specialized treatments that are not covered in this manual.

- **Fertilizer**: It is always recommended to take soil tests to determine the existing soil fertility in order to choose an appropriate fertilizer based on the soil deficiencies. It is also recommended to choose a slow release fertilizer with 80 percent Water Insoluble Nitrogen (WIN) and 0 percent chlorides. If a generic fertilizer is used, a 10-10-20 NPK analysis is recommended. A general rule of thumb is that native grasses and forbs require about 50 percent less Nitrogen and 25 percent more Potassium than turf and forage species.

- **Seeding Into Agricultural Fields**: Many fields that have been row cropped will have some amount of herbicide residue present, depending on what the crop was and what type of herbicide was used on the site to control weeds. Leaving the site fallow, or planting a temporary cover for a season before planting, will help reduce herbicide residue. Also be aware that herbicides used to control annual grasses may adversely affect native grasses being planted and broad-leaved herbicides may adversely affect forbs being planted.

- **Seed Treatments**: Be aware that seeds of many native species require specialized treatments such as cold/moist stratification, scarification, etc. Many of these species go through such treatments naturally if seeded in the fall.

- **Origin Requirements**: It is preferred that seed of all native grasses and forbs be "certified" to be of local, state, or regional origin and of wild ecotype. Some plant materials can be obtained from commercial sources, but many will need to be collected. When attempting to restore native plant communities, it is desirable to use appropriate genotypes. This requires the collection of seeds and plants from local sources. Early contact with selected sources of rooted stock and seed can ensure that appropriate species in adequate quantities will be available when needed.

- **Collecting Salvageable Plants On-Site or at a Donor Site**: The site itself might also be a good source of salvageable plants. Live cuttings can be collected from healthy native vegetation at the donor site. Sharp, clean equipment should be used to harvest the plant material. Vegetation is normally cut at a 40 to 50 degree angle using loppers, pruners, or saws. If the whole plant is being used, the cut is made about 10 inches above the ground, which encourages rapid regeneration in most species. Cuttings typically range from 0.4 to 2 inches in diameter and 2 to 7 feet long.

- **Transport and Storage of Plant Materials**: The requirements for the transport and storage of plant materials vary, depending on the type of material being used. Depending on species, seeds may require a minimum period of dormancy of several weeks or months, with specific temperature requirements during that time. Some seeds may also require scarifying or other special treatment. Nurseries that specialize in native plants are recommended because they should be cognizant of any special requirements. Although the necessary information for any chosen species should be readily available from local seed sources or agricultural extension offices, this interval should be recognized and accounted for in the overall implementation schedule. Live cuttings present rather severe limitations on holding time. In most cases, they should be installed on the day they are harvested, unless refrigerated storage areas are secured. Thus, donor sites should be close to the restoration site, and access and transportation should be orchestrated to coincide with the correct stage of construction. Live cuttings should be tied in manageable bundles, with the cut ends all lying in the same direction. Since drying is the major threat to survival at this stage, cuttings should be covered with damp burlap during transport and storage. They should always be shaded from direct sun. On days with low humidity and temperatures above 60 degrees Fahrenheit, the need for care and speed is particularly great. Where temperatures are below this level, "day-after" installation is acceptable, although not optimal. Any greater delay in installation will require refrigeration, reliably cold weather on site, or storage in water. Rooted stock is also prone to drying, particularly if pots or burlap-wrapped roots are exposed to direct sun. Submergence of the roots in water is not recommended for long periods, but 1 to 2 hours of immersion immediately prior to planting is a common practice to ensure the plant begins its in-place growth without a moisture deficit. Onsite storage areas should be chosen with ample shade for pots. Bare-rooted or burlap-wrapped stock should be heeled into damp ground or mulch while awaiting final installation.
- **Timing**. The optimum conditions for successful plant installations are broad and vary from region to region. As a general rule, temperature, moisture, and sunlight must be adequate for germination and establishment. In the eastern and Midwestern United States, these conditions are met beginning in late winter or early spring, after ground thawing, and continuing through mid-autumn. In the West, the typical summertime dryness normally limits successful seedings to late summer or early autumn. Where arid conditions persist through most of the year, plants and seedings must take advantage of whatever rainfall occurs, typically in late autumn or winter, or supplemental irrigation should be provided. Because the requirements can vary so much for different species, the local supplier or a comprehensive reference text (*597*)(*598*)(*599*)(*600*) should be consulted early in the restoration design phase. If rooted stock is to be propagated from seed before it is planted at the restoration site, 1 to 2 years (including seed-collection time) should be allowed. Plants should be installed when dormant for the highest rate of survival. Survival is further influenced by species used and how well they are matched to site conditions, available moisture, and time of installation. In mild climates, the growth of roots occurs throughout the winter, improving survival of fall plantings. Where high wintertime flows are anticipated, however, first-season cuttings might not survive unless given some physical protection from scour. Alternatively, planting can occur in the spring before dormancy ends, but supplemental irrigation might be needed even in areas

of abundant summertime rainfall. Irrigation might be necessary in some regions of the country to ensure successful establishment of vegetation.(*601*)

Interestingly, recent MoDOT research found that seed to soil contact was a critical issue in seeding, and exceeded use of native species and less than ideal timing of plantings in producing desirable germination rates. MoDOT found a 275 percent increase in the number of plants simply by rolling an area after seeding and garnered the best results by drilling the seed and rolling the area resulting in a 360 percent increase over broadcast and dragging an area. Consequently, MoDOT is revising construction requirements such that all areas of a construction project that are to be seeded and are less than or equal to 3:1 slope will have the seed placed at 1/4" depth with a drill specifically designed for native grasses, that allow for the handling of large fluffy seed and also smaller seed. The area will then be rolled prior to the application of any mulch. All other areas greater than 3:1 will have the seed placed either by broadcasting or hydraulic seeding with the area tracked with a dozer prior to the application of any mulch material to produce better seed to soil contact than seed placed loosely on the top of the soil.(*602*)

Seed Selection and Specification

- **Select species that should be on the project site.** A number of state DOTs have developed native plant mixes and selection guidelines and maps. Check with the landscape architect to see what is used in your state. As availability is a factor in seed selection, there is a natural reaction to use whatever is readily available from seed companies and native plant nurseries and try and make them work on the project. Also, there are few ways to determine what originally grew on site and what percentage of each species formed the mosaic of the original ecosystem, if the natural ecosystems are not present today. Native seeds are often not available in bulk quantities, leading project managers to the next question of where can they go for the proper genetic material.
- **Determine whether sufficient quantities of local native seeds are available**. If sufficient quantities are not available, seed samples can be collected and cultivated in bulk with a year lead time. Local seed collection of the native plant ecotypes in sufficient quantities for a project can be conducted in areas where there are still large native stands. The few pounds of seed that could be hand-collected for a project can be turned over to a grower to grow under contract bulk quantities. One pound of hand-harvested native grass seed, if put into commercial cultivation can yield 100 pounds of commercially-grown seed within 12 months. Aim to have 50-100 pounds of native seeds available for each acre that will be restored, so the exotic seedbank already in place can be overwhelmed. Calculate for 50 pounds per acre for pure-live-seed and 100 pounds per acre if it is 50-70 percent pure seed. Also be sure that the native seeds are weed, noxious weed, and "other crop" free.(*603*)(*604*)
- **Conduct many tiny test pilots to avoid tests and potential failure of large scale plantings**, each the size of a few square yards (1-2 square meters), where a broad range of sowing rates, fertilizer rates, mulches, different sowing methods, soil preparation methods, etc. are tested. Within a very short time it will be obvious which TTPs have successful results, and then those results can then be used to plant on a larger scale. Two years of test plots are ideal, with the second year of TTPs used to make the 2-10 percent

of successes to work better, and achieve close to 100 percent. This approach avoids weed control in the future. When the first acre is successfully completed, the local seed materials should then be in sufficient quantity to do a larger area, and efficient techniques developed to get the per-acre price down to a reasonable cost. Start with a smaller area to test technologies and gradually ramp them up into larger areas.(*605*)(*606*)

- **Preserve native seedbanks and ecosystems throughout the state**, to provide both models to work towards and in-situ seed resources. Caltrans, for example, has identified 20 Botanical Management Areas throughout the State and will continue to expand this list. These environmentally-significant areas exist along the state highway right-of-way and are remnants of California's native landscape. Sites are chosen for their biological integrity, species diversity, need for resource protection, and suitability for scientific evaluation, among other criteria. Caltrans and partners conduct an anaysis of the best potential local natives, ecotypes, and methods of stabilization which can control erosion and prevent slides. The sites can also be used as seedbanks. Ideally native seedbanks would exist every 10 miles.
- **Buy quality seed, which is a critical component to success.** The ideal method to assure quality is to specify "certified" seed. Certified seed must meet certain standards for germination and purity, and certification provides some assurance of genetic quality. Some native seed species are not available as certified seed; however, seed quality may be ascertained by examining percent germination and percent purity. Determine the true cost of seed by multiplying percent germination by the percent purity, which equals Pure Live Seed (PLS). Then multiply PLS by the price per pound. These calculations can increase the accuracy of bid comparisons. See must also be free of noxious weeds, which is noted on seed tags along with germination and purity.(*607*)

Seeding Methods, Considering Texture and Size

When using seeds, planting should be preceded by elimination of competing plants and by preparation of the seedbed.(*608*) The most common methods of seeding in a restoration setting are hand broadcasting and hydroseeding.

If a drill or drop seeder is used, the seed mixture ingredients should be ordered such that the seed is packaged separately based seed size and texture. Fluffy seed should be placed in the native seed box that contains picker fingers. Fine seed should be placed in the fine seed box. Cereal grains, such as oats and winter wheat, used for a cover crop should be placed in the grain seed box that contains flutes.

If a broadcast seeder is used, the seed mixture may either be ordered mixed or as separate ingredients. During installation, the operator should be aware that fluffy seed will have a tendency to bridge or "ball up" in the seeder. Fine seed has a tendency to "pour through" the seeder. Therefore, an effective agitator is required in the seed box. Mixing heavier seed such as sideoats grama, wheat and oats will also help "weigh down" the lighter fluffy seed. If a hydroseeder is used, the seed is usually ordered as a mixture. The hydroseeder has a vigorous agitator in the tank.

Drop, Drill, and Broadcast Seeding Methods

Drop Seeding Onto Tilled Sites

This is the "standard" method for seeding native species on prepared sites such as those on construction projects.

- Site Preparation - The site should be prepared by loosening topsoil to a minimum depth of 3 inches.
- Fertilizer – If not basing the fertilizer application on soil test results, the fertilizer used should be a commercial grade slow release complete fertilizer applied at a rate of 400 lbs/acre at the time of preparing the seed bed for seeding. The fertilizer should contain 10-10-20 (NPK) analysis, and should include sulfur and iron as well (not less than 1 percent and not more than 8 percent added sulfur and iron).
- Seed Installation - Seed should be installed with a drop seeder that will accurately meter the types of seed to be planted and keep all seeds uniformly mixed during planting (Trillion-type). The seeder should contain a minimum of three seed boxes; a fine seed box, a box for large/fluffy seeds, and a box for cool season or grains. It should be equipped with drop tubes and a packer assembly to compact the soil directly over the seed. All seeding should be done at a right angle to surface drainage.
- Seeding Rates - Rates are specified in the mixture tabulation for the specified mix.
- Harrowing - The site should be lightly harrowed or raked following seeding if the seeder does not contain a cultipacker.
- Packing - Cultiacking the site following harrowing is recommended to ensure a firm seed bed.
- Mulch - The site should be mulched and disc-anchored following packing.

Drill Seeding Into Temporary Cover Crops

This method involves two separate seeding operations. First, a temporary cover crop is planted on the entire site to stabilize the soil and control erosion. Second, the native seed mixture is installed the following fall or the next spring (during one of the optimum seeding dates) using either an interseeder type drill or by lightly disking down the temporary cover and seeding into it. The interseed method greatly reduces the erosion potential and reduces soil disturbance. Using this method allows for some early weed control before the native mixture is installed. This method is used for various reasons such as when a site is ready for seeding at a time of year that is not optimum for seeding a permanent seed mixture, the soils need to be stabilized rapidly for erosion control, or a field needs to be left fallow due to residual herbicide.

Establishment of Temporary Cover Crop

- Site Preparation - The new site should be prepared for the temporary seeding by loosening topsoil to a minimum depth of 3 inches.
- Fertilizer - The fertilizer used should be a commercial grade of slow release complete fertilizer applied at a rate of 200 lbs/acre at the time of preparing the seed bed for seeding. The fertilizer should contain 10-10-20 (NPK) analysis, and should include sulfur

and iron as well (not less than 1 percent and not more than 8 percent added sulfur and iron).

- Seed Installation - Temporary cover crops of oats, winter wheat, ReGreen or combinations of the above may be installed using a standard grain drill or broadcast. Planting depth should be 1/4 to 1/2 inch.
- Seeding Rates - The temporary cover crop of oats or winter wheat should be seeded at a rate of 80 lbs/acre. If ReGreen is used as a cover crop, it should be installed at a rate of 30 lbs/acre.
- Harrowing - The site should be harrowed or raked following installation of the temporary cover crop.
- Packing - Packing is not required after installing the temporary cover crop.
- Mulch - The site should be mulched and disc-anchored following packing.

Establishment of the Native Mixture

The native mixture can be established into the areas previously seeded with a temporary cover crop by one of two methods; 1) interseeding using a no-till drill, or 2) by lightly tilling the area with a disc and seeding using one of the other acceptable seeding methods.

- Site Preparation for Interseeding - No tillage is necessary for installation of the native seed mixture. The site may require mowing if the temporary cover has grown taller than 12 inches and is still actively growing (winter wheat may require this). This will stop the rapidly growing cover crop from reaching maturity and shading out the establishing native vegetation. Optimal height for existing vegetation to be drilled into is 4-6 inches. No other site preparation is necessary.
- Site Preparation with Light Tillage - The area seeded with a temporary cover crop should be prepared by lightly disking to incorporate some of the mulch and temporary cover crop into the soil surface. Approximately 50 percent of the soil surface should be visible through the mulch or plant debris. Much of the existing cover should be left in place for its mulch value.
- Fertilizer - The fertilizer used should be a commercial grade of slow release complete fertilizer applied at a rate of 200 lbs/acre at the time of preparing the seed bed for seeding. The fertilizer should contain 10-10-20 (NPK) analysis, and should include sulfur and iron as well (not less than 1 percent and not more than 8 percent added sulfur and iron). The rate is reduced by half the normal recommendation because the initial half of the fertilizer was applied with the cover crop.
- Seed Installation By Interseeding - The native seed mixture should be installed with a seed drill that will accurately meter the types of seed to be planted and keep all seeds uniformly mixed during the drilling (Truax-type). The drill should contain a minimum of two seed boxes; a fine seed box and a box for large/fluffy seeds, and it should be equipped with disc furrow openers and packer assembly to compact the soil directly over the drill rows. Maximum row spacing should be 8 inches. The inter-seeder drill should be out-fitted with trash rippers which will slice through the vegetative mat and make a furrow into the underlying soil approximately 1 inch wide by 1/2 to 1 inch deep. These furrows should be directly in line with the drill seed disc openers. Fine seed can be drop-

seeded onto the ground surface from the fine seed box, and large/fluffy seed should be placed to obtain a final planting depth of 1/4 to 1/2 inch. All drill seeding should be done at a right angle to surface drainage.

- Seed Installation by Drilling Lightly Tilled Sites - The native mixture should be installed with a seed drill that will accurately meter the types of seed to be planted and keep all seeds uniformly mixed during the drilling (Truax-type). The drill should contain a minimum of two seed boxes; a fine seed box and a box for large/fluffy seeds, and it should be equipped with disc furrow openers and packer assembly to compact the soil directly over the drill rows. Maximum row spacing should be 8 inches. Fine seed should be drop-seeded onto the ground surface from the fine seed box, and large/fluffy seed should be placed to obtain a final planting depth of 1/4 to 1/2 inch. All drill seeding should be done at a right angle to surface drainage.
- Seeding Rates - Rates are specified in the mixture tabulation for the specified mix. When using the 300 series mixtures, reduce the cover crop component from 70 lbs/acre to 35 lbs/acre.
- Harrowing - Harrowing is not necessary when seeding the native mixture.
- Packing - Packing the site is recommended to ensure a firm seed bed.
- Mulch - Mulch may not be required with installation of the native mixture, depending on existing site conditions. The site should be mulched to achieve 90 percent ground coverage (10 percent bare ground). If this condition already exists mulch is not required.

Drill Seeding Into Existing Vegetation

This method entails killing the existing vegetation with herbicide and using an interseeder drill to install the seed.

- Site Preparation - The site should be prepared by mowing existing vegetation to a height of 4-6 inches in spring or in late August/early September. The grass should be allowed to re-grow or "flush" before herbicide application with glyphosate, this may take 1-3 weeks depending on weather conditions. Addition of a surfactant and/or addition of 2,4-D to the mix often results in a more complete kill, especially with unwanted broad-leaved species. Recommended herbicide rates are 2.0 quarts/acre of glyphosate and 1.0 - 2.0 quarts/acre 2,4-D. Fall site preparation to control smooth brome grass may require higher glyphosate rates. Seeding can be performed 7-10 days after herbicide application. NOTE: Sites that contain significant weed infestations may require other types of weed control during preparation to ensure that the planting is a success.
- Fertilizer - Fertilizer is generally not required when using this seeding method.
- Seed Installation - The native seed mixture should be installed with a seed drill that will accurately meter the types of seed to be planted and keep all seeds uniformly mixed during the drilling (Truax-type). The drill should contain a minimum of two seed boxes; a fine seed box and a box for large/fluffy seeds, and it should be equipped with disc furrow openers and packer assembly to compact the soil directly over the drill rows. Maximum row spacing should be 8 inches. The inter-seeder drill should be out-fitted with trash rippers which will slice through the vegetative mat and make a furrow into the underlying soil approximately 1 inch wide by 1/2 to 1 inch deep. These furrows should be directly in

line with the drill seed disc openers. Fine seed should be drop-seeded onto the ground surface from the fine seed box, and large/fluffy seed should be placed to obtain a final planting depth of 1/4 to 1/2 inch. All drill seeding should be done at a right angle to surface drainage.

- Seeding Rates - Rates are specified in the mixture tabulation for the specified mix.
- Harrowing - Harrowing is not required when using this seeding method.
- Packing - Packing the site is recommended to ensure a firm seed bed.
- Mulch - Mulch is not required when using this seeding method.

Broadcast Seeding

Broadcast seeding is performed either with mechanical "cyclone" seeders, by hand seeding or by any other method that scatters seed over the bare soil surface. The most desirable aspect of broadcast seeding is that there is no row effect such as that which results from drill seeding. This lends a more natural appearance to the planting. However, broadcast seeding may not be desirable if the weather is hot and dry and/or the soil moisture is content is low. It is essential that steps be taken to ensure good seed to soil contact when broadcast seeding is used.

- Site Preparation - The site should be prepared by loosening topsoil to a minimum depth of 3 inches. It is critical that the seed bed be loosened to a point that there are spaces for seed to filter into cracks etc., otherwise it may end up on the surface and wash away with the first heavy rain.
- Fertilizer - If used, the fertilizer used should be a commercial grade of slow release complete fertilizer applied at a rate of 400 lbs/acre at the time of preparing the seed bed for seeding. The fertilizer should contain 10-10-20 (NPK) analysis, and should include sulfur and iron as well (not less than 1 percent and not more than 8 percent added sulfur and iron).
- Seed Installation - Seed should be installed by broadcasting it evenly over the entire site. Several types and sizes of broadcast seeders are available for use, ranging from fertilizer-type spreaders to power spreaders mounted on all terrain vehicles. Seed should be mixed thoroughly prior to seeding and should be mixed occasionally in the spreader to prevent separation and settling.
- Seeding Rates - Rates are specified in the mixture tabulation for the specified mix.
- Harrowing - The site should be harrowed or raked following seeding.
- Packing - The site should be packed using a culti-packer or equivalent following harrowing.
- Mulch - The site should be mulched and disc-anchored following packing.

Hydroseeding

Hydroseeding is an acceptable method for establishing natives when it is done correctly. However, it is imperative that the site is prepared and finished properly. Mn/DOT generally uses hydroseeding on steep slopes or other areas inaccessible to a seed drill such as wetland edges and ponds. Hydro-seeding native grasses and forbs is not recommended if the extended weather patterns are hot and dry and the soil surface is dry and dusty. The seed-water mixture should be applied within one hour after the seed is added to the hydro-seeder tank.

- Site Preparation - The site should be prepared by loosening topsoil to a minimum depth of 3 inches. It is critical that the seedbed be loosened to a point that there are a lot of spaces for seed to filter into cracks etc., otherwise it may end up on the surface and wash away with the first heavy rain.
- Fertilizer - If used, the fertilizer used should be a commercial grade of slow release complete fertilizer applied at a rate of 400 lbs/acre at the time of preparing the seed bed for seeding. The fertilizer should contain 10-10-20 (NPK) analysis, and should include sulfur and iron as well (not less than 1 percent and not more than 8 percent added sulfur and iron).
- Seed Installation - Seed should be installed by hydro-seeding it evenly over the entire site. A fan-type nozzle should be used with approximately 500 gallons of water per acre. It is recommended to add approximately 75 pounds of hydromulch per 500 gallons of water for a visual tracer to ensure uniform coverage.
- Seeding Rates - Rates are specified in the mixture tabulation for the specified mix.
- Harrowing - The site should be harrowed or raked following seeding.
- Packing - The site should be packed using a culti-packer or equivalent following harrowing.
- Mulch - The site should be mulched and disc-anchored following packing.

NOTE: When seeding in conjunction with a hydraulic soil stabilizer (bonded fiber matrixes (BFM's), hydro-mulches, etc., it is recommended that a two-step operation be used. Seed should be placed first and the hydraulic soil stabilizer be sprayed on afterwards. This is to ensure that seed comes into direct contact with the soil.

Mulches

Mulching limits surface erosion, suppresses weeds, retains soil moisture, and can add some organic material to the soil following decomposition. A variety of mulches are available with different benefits and limitations. Organic mulches, particularly those based on wood (chips or sawdust), have a high nitrogen demand because of the chemical reactions of decomposition. If nitrogen is not supplied by fertilizers, it will be extracted from the soil, which can have detrimental effects on the vegetation that is mulched. Certain species of wood, such as redwood and cedar, are toxic to certain species of seedlings and should not be used for mulch. Straw is a common mulch applied on construction and revegetation sites because it is inexpensive, available, and effective for erosion control. Appropriate application rates range from about 3,000 to 8,000 lb/acre. Straw can be spread by hand or broadcast by machine, although uniform application is difficult in windy conditions. Straw must be anchored for the same reason: it is easily transported by wind. It can be punched or crimped into the soil mechanically, which is rapid and inexpensive, but requires high application rates. It can be covered with jute or plastic netting, or it can be covered with a sprayed tackifier (usually asphalt emulsion at rates of about 400 gal/acre). Straw or hay can also be a source of un- desirable weed seed and should be inspected prior to application. Wood fibers provide the primary mechanical protection in hydraulic mulches (usually applied during hydroseeding). Rates of 1 to 1.5 tons/acre are most effective. They can also be applied as the tackifier over straw at about one-third the above rate. Hydraulic mulches are adequate, but not as effective as straw, for controlling erosion in most settings. However, they can be applied on slopes steeper than 2:1, at distances of 100 feet or more, and in the wind. On typical earthmoving and construction projects, they are favored because of the speed at which they can be applied and the appearance of the resulting slope—tidy, smooth, and faintly green. The potential drawbacks—introducing fertilizers and foreign grasses that are frequently mixed into hydraulic mulches—should be carefully evaluated. An appropriate mulch in many restoration settings is a combination of straw and organic netting, such as jute or coconut fibers. It is the most costly of the commonly used systems, but erosion control and moisture retention are highly effective, and the problems with undesirable seeds and excess fertilizers are reduced. The value of an effective mulch to the final success of an initiative is generally well in excess of its cost, even when the most expensive treatment is used.(*609*)

- **Chipped wood** Readily available; inexpensive; judged attractive by most High nitrogen demand; may inhibit seedlings; may float offsite in surface runoff
- **Rock** May be locally available and inexpensive Can inhibit plant growth; adds no nutrients; suppresses diverse plant community; high cost where locally unsuitable or unavailable
- **Straw or hay** Available and inexpensive; may add undesirable seeds; May need anchoring; may include undesirable seeds
- **Hydraulic mulches** Blankets soil rapidly and inexpensively; Provides only shallow-rooted grasses, but may out compete woody vegetation
- **Fabric mats** Relatively (organic) or very (inorganic) durable; works on steep slopes; High costs; suppresses most plant growth; inorganic materials harmful to wildlife
- **Commercial compost** Excellent soil amendment at moderate cost; Limited erosion-control effectiveness; expensive over large areas

Fertilizer

Applications of fertilizer at the time of seeding are usually necessary. Most commercial fertilizers meet minimum standards, and quality problems are seldom encountered.

- Ensure dry storage and shipment. If problems arise with fertilizers, they can usually be traced to the product becoming wet during storage or shipment.
- If possible, apply fertilizer at the same time or prior to seeding, because once the seed has been applied, no additional traffic should be allowed on the site.
- 20-20-10 fertilizer can be used unless specific site conditions require different proportions. The numbers are percentages of three elements: nitrogen, phosphorus, and potassium, respectively. Therefore, 20-20-10 fertilizer contains 20 percent nitrogen, 20 percent phosphorus, and 10 percent potassium by weight.
- Native or otherwise adapted species usually do not require the use of lime or agents to acidify the soils and fewer soil amendments (compost, etc.) may be necessary.

Irrigation

In any restoration that involves replanting, the need for irrigation should be carefully evaluated. Irrigation might not be needed in wetland and near-stream riparian sites or where rainfall is well distributed throughout the year. Irrigation may be essential to ensure success on upland sites, in riparian zones where seasonal construction periods limit installation to dry months, or where a wet-weather planting may have to endure a first-year drought. Initial costs are lowest with a simple overhead spraying system. Spray systems, however, have inefficient water delivery and have heightened potential for vandalism. Drip-irrigation systems are therefore more suitable at many sites.(*610*) There is also a greater potential for undesirable species with spray irrigation since the area between individual plants receives moisture.

Vegetation Establishment on Steep Cut Slopes

Steep cut slopes present a unique challenge to successful re-vegetation of highway corridors following disturbances. The steepness of the cut slopes prevents practical replacement of salvaged topsoil with conventional equipment. The current remedy is simply to broadcast seed and hydromulch to bare slope. Too often, these techniques result in marginal plant establishment since germination and initial seedling survival is limited by nutrient poor, rocky substrates characteristic of cut slopes. The resulting poor vegetation establishment leads to increased erosion and sedimentation, occasional slope failure, increased noxious weed growth, and low aesthetic quality, substantially increasing maintenance costs in the affected areas. The Montana DOT (MDT) is investigating methods of organic matter application and incorporation to steep slope areas and establishing experimental plots to test compost application with blowers and incorporation on steep highway cut slopes at three sites, including heavy clay soils, glacial till, and coarse textured valley fill materials.(*611*)

Performance Measures for Vegetation Establishment during Construction

DOTs and Landscape Architects frequently establish site specific performance measures for vegetation establishment. A few DOTs have established organization-wide performance measures. Missouri DOT (MDOT) evaluates contractors' performance during construction via a questionnaire, one section of which is devoted to roadside development.(*612*) Whether seed and mulch application, soil preparation, lime and fertilizer application, and/or sod installation were in compliance with the contract and the percentage of sod living at the end of the initial watering period.

CHAPTER 5: PAVEMENT, MATERIALS, AND RECYCLING

Increasingly state DOTs are employing pavement management systems to ensure that resources are targeted where they will produce the greatest effect—conservation of existing resources and infrastructure—in the most efficient or cost-effective manner. This enables transportation dollars to go further, and can lead to prolonged infrastructure life and greater periods of time between more environmentally intrusive reconstruction projects. Environmental stewardship is also practiced in the course of pavement maintenance, recycling pavement and DOT waste products, and using other recycled materials in DOT pavements and roadside structures. Recycling directly addresses energy conservation needs in construction and maintenance as well.

5.1. PREVENTATIVE MAINTENANCE AND PAVEMENT MANAGEMENT SYSTEMS

Timing is critical in preventive maintenance, as "preventive maintenance is a program strategy intended to arrest light deterioration, retard progressive failures, and reduce the need for corrective maintenance and service activities."(*613*) Preventive strategies for flexible pavements include seal coats such as chip seals, slurry seals, micro surfacing, thin overlays, and crack sealing. Rubberized asphalt concrete (RAC) usage can extend pavement life and help to address waste and landfill issues while providing a smoother ride, better resistance to cracking than other types of pavement surfaces, and less frequent maintenance. In addition, RAC has the potential to reduce noise levels to a point where a soundwall may not be needed in some locations. Preventative maintenance (PM) treatments for concrete pavements include crack and joint sealing, dowel bar retrofit, partial depth slab repairs, and diamond grinding for smoothness and improved pavement texture. All of these treatments reduce the amount of water that may infiltrate the pavement, slow the rate of deterioration, or correct surface roughness. Timely application can maintain or extend a pavements service life five to ten years or longer before significant maintenance effort is required. Surface treatments also help prevent raveling and improve surface friction properties, but can accelerate vapor action and stripping when applied to aged and open pavements.(*614*)

Caltrans determined that for every $1 spent on Preventative Maintenance or Capital Preventative Maintenance (CAPM), $3 to $20 is saved if the treatment is applied at the right time, before the pavement deteriorates into a major rehabilitation or reconstruction project. In addition, reconstruction in urban areas is more expensive. Instead of the estimated $200,000 per lane mile, the costs may exceed $1 million per lane mile. In contrast, a PM strategy will typically cost $50,000 to $100,000 per lane mile, covering many more miles for the equivalent dollar. A significant savings for PM comes from a reduction in time spent in design and construction. Prior to PM, for example, Caltrans did as much Corrective Major Maintenance as the limited budget allowed until full rehabilitation, or, in the worst-case, reconstruction was needed. Time spent waiting until the pavement can by fully rehabilitated allows time for the pavement condition to deteriorate further. Since PM projects are pavement only, they require less design time and can be delivered faster. During construction, pavement surfaces are renovated using thinner treatments, which contributes to faster production rates. Also, less construction working days reduces the disruption to the traveling public and less disturbance to roadside environments.(615)

The factors affecting pavement life include a variety of site conditions, including traffic, climate, and paving material. Condition surveys help predict the occurrence of distress (including density of cracking and the average level of crack edge deterioration), select appropriate maintenance, and program such activities before further deterioration occurs. When crack densities are low to moderate, crack sealing is effective; however, as densities progress from moderate to high, surface treatments are more effective. There are three basic techniques for surface treatment of cracked pavements: slurry, chip seals, and thin hot mix overlays. Selection of the best treatment is a function of the existing pavement condition. Results from the Strategic Highway Research Program (SHRP) suggest the following: (*616*)

- Slurry seals perform best when applied to pavements with little or no cracking.
- Chip seals perform well on cracked pavements, but add no structure and do not improve rideability.
- Thin hot mix overlays perform better than other treatments on pavements with higher roughness and/or rutting. They are also effective as a seal, and they prevent raveling.

Pavement management systems have helped DOTs prioritize improvements and document the cost-effectiveness of preventative maintenance. In a shift to a more pro-active road maintenance strategy, Nevada DOT is prioritizing projects based on how quickly roads are deteriorating or prediction models, not on the basis of their current condition. Prevention strategies are ranked by life-cycle cost, not initial cost. NDOT deployed cold-in-place recycling based on a sophisticated lifecycle cost comparison; the state optimized its projects by assigning roads to five categories based on volume and environmental conditions.(*617*)

Caltrans is among the state DOTs publishing a State of the Pavement Survey. Pavement condition is evaluated using ride score (IRI) and the pavement surface condition. The PMS provides a systematic, objective evaluation of pavement condition for identification of maintenance and rehabilitation needs and projects, and then prioritization of those projects. The tool can help a DOT track progress toward reducing total pavement needs to specified target levels as well as in improving pavement conditions overall.

5.2. FLEXIBLE PAVEMENT/ASPHALT

Flexible pavement (asphalt) maintenance activities provide public safety, protect personal property, preserve the state's capital investment, and maintain a riding quality that is satisfactory to the traveling public. Road surface maintenance typically involves the use of asphalt and other materials to create impervious surface areas or to repair existing road surfaces. Surface and inlay repair includes all repairs of road bases, surface, and shoulder irregularities, including asphalt and concrete surfaces. Asphalt plant production includes production of asphalt for patching materials, staging, moving, stockpiling and setup of asphalt plants.

The basic input materials used in asphalt preparation are hot liquid asphalt and aggregates, such as sand and gravel. Some smaller quantities of recycled asphalt pavement, sulphur, rubber, lime and foundry sands may also be incorporated into the mix. The type of process technology used is important because it also effects quantity and quality of resulting air and waterborne contaminants. Air emissions from these mixing operations are a concern primarily because of high hydrocarbon, nitrous oxides, sulphur dioxide, carbon monoxide and particulate concentrations. Waterborne contaminants originate in aggregate storage areas, air scrubbers, and vehicle wash-down areas. Airborne contaminants are typically removed using filtering baghouses, while waterborne contaminants are usually removed in large settling ponds. Stormwater collected from aggregate storage areas and wastewater from the spraying down of

HMA transport vehicles should be directed to a contaminated water treatment area. Treatment may consist of catchment basins and or settling ponds and oil-water separators. Treated water should then be discharged to local storm sewers or to a nearby river. Settled fines in the catchment basins should be removed and landfilled after being left to dry out as much as possible.(*618*)

A pollution prevention plan can encourage examination of existing process and pollution prevention technologies and consideration of upgrades or equipment improvements. Management practices play a key role in pollution prevention. Opportunities for pollution prevention through management, such as installing hot liquid asphalt storage tank high-level alarms, using soap instead of diesel for washing down trucks, and partially or completely containing raw aggregate storage areas, are suggested. Waste materials such as used baghouse socks, collected dust materials and dried sludge from settling ponds should be treated and recycled where possible. If there are no other alternatives, the materials should be disposed of in an environmentally responsible manner.

There are opportunities for changes on the most basic level in the asphalt production industry, namely changes to the input materials and products made. Because of the strict specifications and gradations required for quality HMA production, certain sands and gravels are required as the bulk of aggregate materials. However, other materials can be added to the basic aggregates without compromising the final HMA quality. Such materials are broken asphalt (taken from a road that has been ripped up), sulphur, rubber and foundry sands. Broken asphalt, known in the industry as RAP (recycled asphalt pavement), can almost always be incorporated into HMA and meet the required gradation.

Asphalt Cement Crack and Joint Grinding and Digouts/Structural Repair

Flexible pavement is susceptible to cracking, and the cracks should be repaired to prevent the entrance of moisture into the subgrade. In some instances, cracks need to be cleaned prior to filling. A stiff broom, compressed air, or a gouge-type tool or mechanical router are typically used to clean the cracks. Cracks are then filled with rubberized sealant, emulsion or liquid asphalt. Fine sand may be applied to the surface of the crack after it has been filled. The repair of slippage cracks requires the removal of the surface layer prior to patching with mixed asphaltic concrete. Other subtasks associated with this activity include vehicle operation, disposal of removed material and grindings, and post-sweeping.

Structural pavement failure (digouts), pavement grinding and paving applies to significant repairs to structural pavement that require removal of the roadway surface using graders and grinders. Subtasks associated with this activity include vehicle operation, asphalt removal, disposal of removed material and grindings, pre- and post-sweeping.

Pollutant sources associated with this work include leaks, spills, dust and grinding can result in release of fuel, asphalt release agents, hydraulic fluid, oil, sediment, aggregate material and asphalt grindings. Water may be applied during grinding or post-sweeping operations. Recommended environmental stewardship practices to control and minimize pollution include standard best management practices (BMPs) such as illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, hazardous waste management, liquid waste management, sanitary/septic waste management, safer alternative products, spill prevention and control, and sweeping and vacuuming.(*619*)

Asphalt Paving

Asphalt work involves the patching or resurfacing of the roadbed with a mixture of mineral aggregate and bituminous binder. The purpose is to repair degraded asphalt surfaces. The primary subtasks include equipment operation, pre- and post-sweeping, asphalt application, binder application (tack coating), pavement application and compaction roller operation. Pollution may occur from leaks, spills and stockpiled material from sweeping. Potential pollutants may include: fuel, asphalt release agents, hydraulic fluid, oil, sediment, asphalt and petroleum-based binders. The use of water during sweeping, asphalt application, binder application, compaction roller operation and evaporative cooling must be controlled to prevent unpermitted non-stormwater discharges. Recommended environmental stewardship practices include: illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, hazardous waste management, liquid waste management, sanitary/septic waste management, material use, safer alternative products, paving operations procedures, spill prevention and control, sweeping and vacuuming and water conservation practices.(*620*)

The asphalt plant and other facilities should be operated in such a manner so as to safeguard the air and water resources by controlling or mitigating environmental pollution in accordance with all Environmental legislation. Additional environmental stewardship practices that can minimize environmental impacts from paving operations include the following:

- Ensure that contractors and/or staff who fuel and operate asphalt plants have an adequate spill plan and materials for spill containment.
- Establish mixing plants outside of riparian corridors, site location to be approved by the Region Environmentalist/ Biologist and/or resource agencies.
- Use commercial asphalt plants for asphalt supply, where economically feasible.
- Provide areas for truck chute cleanout with proper containment of wet concrete.
- Protect inlets and catchments from fresh concrete during inclement weather.
- Where possible, perform surface work in dry weather, to minimize any runoff of potentially hazardous material.
- Do not use volatile organic compounds (VOCs) to liquefy asphalt except for asphalt used in:
- Long-life stockpile material for patching and repair.
- Low temperature applications from October 16 to May 1.
- Penetrating prime coat for preparing an untreated absorbent surface to receive asphalt.
- Pre-treat all grader blades, truck beds, tires, asphalt distributors, or other equipment and tools with vegetable oil or other approved proprietary product as a release agent for asphalt. Hand sprayers can be used to apply vegetable oil.

Emergency Pothole Repairs

Emergency pothole repairs are unscheduled, emergency repairs necessary for the protection of the traveling public. Pothole repairs involve the filling and resurfacing of potholes along flexible pavement portions of roadways and highways to eliminate holes and cuts in the pavement. Because of the unscheduled nature of the repairs, the applicability of BMPs is limited to planning measures that facilitate emergency response in an environmentally sound manner.

- The potential for spilled patch material should be managed through safer alternative products when available, and appropriate vehicle and equipment maintenance and fueling practices.(*621*)

Sealing Operations

Seal coats may be required for asphalt pavement due to erosion or oxidation of the roadway surface. Coatings may also be used to reduce the permeability of the surface or to reduce slipperiness. Seal coats include fog seal (emulsion and water), sand seal (asphalt and sand), chip seal (emulsion and rock screenings) and slurry seal (emulsion, additives, water and aggregate). Chip sealing provides a bituminous surface treatment (BST) to maintain and extend longevity for roads, and underlies many other maintenance and operations activities, such as shoulder rehabilitation, vegetation and shoulder projects. Crack sealing and surface treatments can extend the useful life of a pavement and delay the need for more costly or environmentally intrusive repairs. When crack densities are low to moderate, crack sealing is effective; however, as densities progress from moderate to high, surface treatments such as chip sealing are more effective.

Primary subtasks include pre- and post-cleaning, seal application, sand or aggregate application and compaction roller application. Associated subtasks include equipment operation. Potential pollutant sources include leaks, spills, dust, material tracking and excess release agent. These pollutants can release fuel, asphalt release agents, hydraulic fluid, oil, sediment, aggregate material and asphalt emulsion. Water may be applied during post-sweeping operations and needs to be managed to prevent polluted discharge.

Much research has been performed in the United States and abroad on the materials, design, construction techniques, and effectiveness of chip seals in practice. Louisiana Department of Transportation and Development chip seal practice research was completed in 1998, South Dakota completed research on chip seal best practices in 2000; and Oregon DOT chip seal research; however, environmental stewardship recommendations particular to this paving practice have not been explicitly addressed. Research is being summarized through a survey of BMPs and a research synthesis, started in fall 2003 with anticipated publication in 2005. According to the Project Investigator, the only environmental practice found was wetting the aggregate to reduce dust; however, this practice may not be included in the synthesis as wetting the aggregate can degrade adhesion.(*622*)

DOTs have employed the following environmental stewardship practices primarily to control water related discharges: illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, hazardous waste management, liquid waste management, sanitary/septic waste management, material use, paving operations procedures, safer alternative products, spill prevention and control, sweeping and vacuuming and water conservation practices.(*623*)

Asphalt Equipment Cleaning

Diesel fuel used to be the product of choice to clean and pretreat equipment when working with bituminous pavement; however, environmental regulations prohibit dumping or spilling diesel or asphalt. The following policy is the best known management practice when asphalt cleaning is necessary.(*624*)

- Eliminate diesel as a releasing or cleaning agent and use environmentally sensitive cleaning and releasing agents.
- Spray the beds down with vegetable oil after each load using just a thin stream at the top of the bed, it will run down and coat the entire side, then put one coat on the floor. Spray once as needed. At the end of the day there may be some mix on the tailgate, spray a thin bead around the top; the next day the mix should remain soft and come off with the first load.
- Spray vegetable oil on the grader blades once a day or as needed.
- Spray it down with the vegetable oil during the day, then clean it with a citrus based cleaner in the evening only as needed.
- The asphalt distributor bar may need to be coated with vegetable oil after every spray.
- Using vegetable oil on tools such as rakes and shovels works well, the mix does not build up on them, and what does remain can be easily tapped off.
- Carry adequate erosion control supplies (diapers, kitty litter, shovels, etc.) to keep materials out of water bodies.
- Use heat sources to heat and clean tack nozzles during operations.
- Contain all products (including the cleaning product and the contaminated asphalt residue cleaned from the equipment) during cleaning using tarps, sand pads, pails or other collection methods to avoid spillage or accidental release of cleaning products.
- When cleaning the distributor bar, always catch any diesel or asphalt. Use a tray and recycle the diesel or asphalt into the tank, then reverse the pump to clean out the piping and snivies or reverse the pump to suck all the asphalt and diesel back into the tank. Consult the asphalt distributor's operations manual for the correct method to reverse suction.
- Do not clean equipment or tools near streams, ponds, or drainage structures.
- Remove pieces of asphalt by scraping or other mechanical means, if possible, prior to application of a cleaning agent. Asphalt removed solely by mechanical methods is disposed of as construction and demolition debris.
- Use a minimal amount when a petroleum product is used for cleaning and recover all of the cleaning product.
- Use hand sprayers or other similar devices to minimize the amount of petroleum product applied.
- Report releases of petroleum products.

Pavement Disposal

- Pavement should be recycled whenever possible.
- Contaminated sand, soil, asphalt pavement residue, and other debris containing petroleum products resulting from activities such as paver cleaning with petroleum products should be handled as petroleum contaminated soil/debris and should be disposed at an authorized disposal site.
- Recognizable uncontaminated broken concrete and asphalt from demolition activities or excess material from a project should be taken to an off-site disposal facility or to a construction and demolition waste processing facility and/or not disposed of within 30 meters (100 feet) of wetlands, archeological sites or other sensitive environmental areas.

5.3. CONCRETE INSTALLATION AND REPAIR

Rigid pavement maintenance activities are designed to provide safety, preserve the state's capital investment and maintain a riding quality that is satisfactory to the traveling public. Road surface maintenance typically involves the use of concrete and other materials to create impervious surface areas or to repair existing road surfaces. Pollution control activities focus on ensuring that removed materials and Portland cement concrete wastes remain controlled and are not released to the environment.

Environmental stewardship practices for ready mix concrete operations include, and were initially developed for the Frasier Basin, in British Columbia: (*625*)

- Reduction of use of toxic substances, raw materials and nonrenewables.
- Reuse of recovered raw material, products and hazardous substances.
- Elimination or minimization of environmental releases.
- Recycling of recovered materials off-site.
- Treatment of non-recoverable waste with a focus on recovery and minimization of residues.
- Safe disposal of wastes.
- Safe handling of chemicals and products to ascertain that no site contamination or sudden releases occur.

The questions below may be used as performance measures in evaluating sustainability. The checklist items also describe recommended environmental stewardship measures: (*626*)

Reduction of Use of Toxic Substances, Raw Materials and Non-renewables

- Are preventive measures in place to avoid "off-spec" concrete, (e.g., periodic testing of scales, batch gate operation, etc.)?
- Is an operator's manual available?
- Is regular operator training provided?
- Is water conservation practiced by restriction of freshwater uses to purposes such as, truck exterior washoff, hot water production, and batch waters for high quality concrete?
- Are flow controls installed on freshwater sources?

Reuse of Recovered Raw Material, Products and Hazardous Substances

- Are volumes of returned concrete minimized (i.e., less than 2.5% of total production volume)?
- Is all returned concrete either reused (precast products, road base, etc.) or recycled (reclaimed)?
- Are all air pollution control residues reused?
- Are all drum washout solids reused or recycled?
- Are settling basin sludges reused or recycled?
- Is 100 percent of the process water (drum washout, truck wash) reused?
- Is collected yard stormwater used for washdown, etc.?

Elimination or Minimization of Environmental Releases

- Are spills of cement and concrete cleaned up immediately?
- Is the process area paved and curbed to collect processing water for treatment and/or recycling?
- Is the pavement and curbing in good condition (i.e., no cracks)?
- Is the size of the processing area minimized and/or roofed to reduce exposure to rainfall?
- Is yard stormwater diverted from the process area?
- Are oil separators installed in truck wash areas and other areas where oil releases may occur?
- Are measures taken to ensure proper dust control during transfer of cement and fly ash?
- Are aggregate piles designed to minimize fugitive dust control (e.g., minimal surface area, storage bins, covers)?
- Are high vehicle traffic areas paved?
- Is the traffic system controlled (e.g., low speed limits, one-way traffic to separate dirty from clean vehicles)?
- Are paved portions swept to remove accumulated dust?

Recycling of Recovered Materials Off-site

- If all concrete and sludges are not recovered on-site, are the materials used off-site (e.g., road base)?

Treatment of Non-recoverable Waste with a Focus on Recovery and Minimization of Residues

- Is there a system (e.g., settling basin) for treatment of excess water?
- Does the treatment system enable pH control?
- Is the process area minimized (i.e., <10% of total yard area)?
- Does routine monitoring of effluent quality occur?

- Is the wastewater holding basin of sufficient volume to manage all effluent in high precipitation events?
- Can concrete fines and aggregates be removed from the basins?
- Is unusable sludge disposed of in approved facilities?
- Are admixture and other chemical containers returnable to the supplier?
- Are all chemicals no longer in use removed from the site?

Safe Disposal of Wastes

- Are lead batteries, solvents, waste oils, etc., stored in secure locations?
- Are lead batteries, solvents, waste oils, etc., recycled?
- Are operating procedures for waste disposal adequately defined?
- Has management confirmed that approved facilities are used for waste disposal?
- Is all documentation at hand for transport manifests, certification of destruction, etc.?

Safe Handling of Chemicals and Products to Ascertain That No Site Contamination or Sudden Releases Occur

- Are aboveground piping and valves visible and labelled?
- Are tank materials and designs as per all applicable codes and manufacturers' recommendations?
- Are spill response equipment, absorbents and personnel protection equipment provided?
- Is worker training for spill response provided?
- Are signs in place to identify contents of bulk tanks and drums?

Portland Cement Crack, Patch, and Sealing

Cracks and joints in Portland cement concrete pavement should be filled to prevent the entrance of moisture into the subgrade. A stiff broom or compressed air are sometimes used to clean cracks prior to sealing. Aphaltic and rubberized sealants are used to fill the cracks; then sand may be applied. Other subtasks associated with this activity may include vehicle operation and post-sweeping. Leaks, spills, excess emulsion and dust can release pollutants such as fuel, asphalt release agents, hydraulic fluid, oil, sediment, asphalt and rubberized sealant. Recommended environmental stewardship practices to control such discharges include illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, hazardous waste management, liquid waste management, sanitary/septic waste management, material use, safer alternative products, spill prevention and control, and sweeping and vacuuming.(*627*)

The following general practices should be employed for patching, resurfacing, and sealing:

- Schedule patching, resurfacing and surface sealing for dry weather.
- Stockpile materials away from streets, gutter areas, storm drain inlets or watercourses.

- During wet weather, cover stockpiles with plastic tarps or berm around them if necessary to prevent transport of materials in runoff.
- Pre-heat, transfer or load hot bituminous material away from drainage systems or watercourses.
- Where applicable, cover and seal nearby storm drain inlets (with waterproof material or mesh) and maintenance holes before applying seal coat, slurry seal, etc. Leave covers in place until job is complete and until all water from emulsified oil sealants has drained or evaporated. Clean any debris from covered maintenance holes and storm drain inlets when the job is complete.
- Prevent excess material from exposed aggregate concrete or similar treatments from entering streets or storm drain inlets. Designate an area for clean up and proper disposal of excess materials.
- Use only as much water as necessary for dust control, to avoid runoff.
- Sweep, never hose down streets to clean up tracked dirt.
- Use a street sweeper or vacuum truck.
- Do not dump vacuumed liquid in storm drains.
- Catch drips from paving equipment that is not in use with pans or absorbent material placed under the machines. Dispose of collected material and absorbents properly.

Mudjacking and Drilling

Mudjacking is necessary for the maintenance and repair of rigid type surfacing, its associated base and any Portland concrete cement shoulders less than two feet in width. A Portland cement and pozzolan grout mixture is pumped below the slab (i.e., mudjacking) to replace lost or settled base material. Subtasks include vehicle and equipment operation, drilling, mixing, and pumping. Potential pollutant sources such as leaks, spills and concrete washout may result in the release of pollutants such as fuel, hydraulic fluid, oil, sediment and concrete. Water applied during drilling and pumping operations must be controlled to prevent unpermitted nonstormwater discharges. Recommended environmental stewardship practices to control discharges include: illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, liquid waste management, sanitary/septic waste management, concrete waste management, material use, safer alternative products, spill prevention and control, sweeping and vacuuming and water conservation practices.(*628*)

Concrete Installation and Slab and Spall Repair

Spalling (i.e., chipping of Portland cement concrete surfaces), slab cracking and settlement are common problems associated with Portland cement concrete pavement that require repairs. Subtasks include vehicle operation, repair and cleaning (may include use of a compressor, jackhammer or sawcutting), curing and the disposal of removed materials. Leaks, spills and concrete washout may cause pollution from fuel, hydraulic fluid, oil, sediment and concrete. Water applied during curing operations should be controlled to prevent unpermitted non-stormwater discharges. Recommended environmental stewardship practices include: illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, hazardous waste management, liquid waste management, sanitary/septic waste management, concrete waste management, material use, safer alternative products, spill prevention and control, sweeping and vacuuming and water conservation practices.(*629*)

For concrete installation and repair also:

- Schedule asphalt and concrete activities for dry weather.
- Take measures to protect any nearby storm drain inlets and adjacent watercourses, prior to breaking up asphalt or concrete (e.g. place san bags around inlets or work areas).
- Limit the amount of fresh concrete or cement mortar mixed, mix only what is needed for the job.
- Store concrete materials under cover, away from drainage areas. Secure bags of cement after they are open. Be sure to keep wind-blown cement powder away from streets, gutters, storm drains, rainfall, and runoff.
- Return leftover materials to the transit mixer. Dispose of small amounts of hardened excess concrete, grout, and mortar in the trash.
- Do not wash sweepings from exposed aggregate concrete into the street or storm drain.
- Collect and return sweepings to aggregate base stockpile, or dispose in the trash.
- When making saw cuts in pavement, use as little water as possible and perform during dry weather.
- Cover each storm drain inlet completely with filter fabric or plastic during the sawing operation and contain the slurry by placing straw bales, sandbags, or gravel dams around the inlets.
- After the liquid drains or evaporates, shovel or vacuum the slurry residue from the pavement or gutter and remove from site. Alternatively, a small onsite vacuum may be used to pick up the slurry as this will prohibit slurry from reaching storm drain inlets.
- Wash concrete trucks off site or in designated areas on site designed to preclude discharge of wash water to drainage system.

Further Practices for Preventing Contamination from Concrete Washout

Using Portland cement-containing products requires prevention of the discharge of high pH liquids to creeks, streams, and other water bodies, or in places where it might eventually reach creeks and streams.(*630*)

- Be aware of local environmental sensitivities around the job site. Know where streams and street drains are in order to avoid discharging harmful materials.
- Install continuous pH monitoring devices on effluent outflow. If the pH goes outside of the range of 6.5-9.0, have a means of treating the effluent prior to discharge.
- Grade the site to prevent storm runoff from leaving yard.
- Have an adequately-sized effluent pond.

- Have reliable means of testing pH on site and personnel trained in the measurement of pH (see How Can I Measure pH?).
- Wash chutes off in an area with permeable ground, and away from any subsurface drains (tile fields, perimeter drains, etc.), streams or storm drains.
- Have some means of containing the wash-water for disposal back at the plant if there is no appropriate place to wash the chute at the job site.
- Use equipment with wash water containment systems.

In the event that conditions at the work site change, a back-up plan is needed as the user should know ahead of time what to do if this happens. The following are practices to lessen the damage a spill of alkaline material might do to a fish-bearing waterway: (*631*)

- Have on hand the names and telephone numbers of vacuum pumper truck companies that can come and clean out the catchbasins of street drains, or clean up material spilled on the ground (look in the Yellow Pages under "septic tanks - cleaning and removal"). Many DOTs and municipalities also have vacuum trucks.
- Have on hand some means of blocking storm drains or other potential routes to any water bodies.
- Have on hand some means of checking the pH of spilled material.

5.4. Pavement Marking

Work to replace and maintain roadway delineation typically includes refurbishing, delineation and replacement of missing markers. Environmental stewardship practices ensure that paints, debris and excess maintenance and repair materials remain controlled and are not released to the environment.

In September 1999, EPA redefined traffic paint into two categories, traffic marking coatings and zone marking coatings. Zone marking coatings are defined as those used on sidewalks, driveways, parking lots, curbs and airport runways and packaged in containers of five gallons or less, with Volatile Organic Compounds (VOCs) limited to 450 grams/liter or less; i.e. traditional oil-based traffic paint. Traffic marking coatings are now defined as those used for streets, highways and traffic areas as well as the purposes outlined for zone markings, with a VOC limit of 150 grams/liter. This means that traffic marking contractors must use low-VOC traffic paint when marking roadways, which in most cases will mean using latex traffic paint. In transitioning to latex traffic paint, DOTs have had to make sure that equipment is waterbase compatible, in order to avoid application and maintenance problems. Modifications have included use of stainless steel on critical wetted parts, with plated components being adequate in very few areas. New application techniques have also applied, especially for low-VOC alkyd paints which contain acetone, a product with a low flash point.

Practices for Specific Types of Pavement Marking

Paint Striping and Marking

Pavement striping is used for lane stripes and other pavement markings to guide motorists. Surfaces may be swept prior to painting. Water-based paints are applied using striper paint systems. Other pavement markings may be applied using striper paint systems or stencils. Potential pollutant sources such as overspray, dust, spills and leaks may create pollutants, including paint, sediment, fuel, hydraulic fluid and oil. Water used during presweeping operations should be controlled to prevent unpermitted non-stormwater discharges. Other recommended environmental stewardship practices include illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, spill prevention and control, safer alternative products, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, liquid waste management, material use, sweeping and vacuuming and water conservation practices.(*632*)

Raised/Recessed Pavement Marker Application and Removal

Pavement markers supplement traffic signs. Markers may either be surface mounted (raised) or placed in recessed slots in the pavement. Markers are applied using bitumen/epoxy adhesives. Damaged markers are removed using hand tools or graders and loaders. Potential pollutant sources such as excess application, spills and leaks may result in the release of potential pollutants of epoxy, fuel, hydraulic fluid and oil. Recommended environmental stewardship practices include illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, spill prevention and control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, and material use.(*633*)

General Environmental Stewardship Practices for Pavement Marking

General environmental stewardship practices for pavement marking include the following: (*634*)

- Schedule pavement marking activities for dry weather. Do not conduct painting or traffic marking activities during rain events.
- Replace solvent-based alkyd traffic paints with waterborne paints that contain 80 percent less organic solvents and with epoxy paints that release no solvent vapors.
- Develop paint handling procedures for proper use, storage, and disposal of paints.
- Transfer and load paint and hot thermoplastic away from storm drain inlets.
- Provide drop cloths and drip pans in paint mixing areas.
- Properly maintain application equipment.
- Street sweep thermoplastic grindings. Yellow thermoplastic grindings may require special handling as they may contain lead.
- Properly dispose of paints containing lead or tributyltin, which are considered a hazardous waste.
- Use water based paints whenever possible. If using water based paints, clean the application equipment in a sink that is connected to the sanitary sewer.
- Properly store leftover paints, if they are to be kept for the next job, or dispose of properly.

Removing Traffic Stripe and Pavement Marking

Waste from removal of yellow thermoplastic and yellow painted traffic stripe and pavement marking contains lead chromate in average concentrations greater than or equal to 350 mg/kg and less than 1000 mg/kg Total Lead. Residue produced when yellow thermoplastic and yellow paint are removed may contain heavy metals in concentrations that exceed established thresholds and may produce toxic fumes when heated. Waste from removal of yellow thermoplastic and yellow painted traffic stripe and pavement marking contains lead chromate in average concentrations greater than or equal to 5 mg/L Soluble Lead or 1000 mg/kg Total Lead. Caltrans has specified the following environmental stewardship practices for removing traffic stripe and pavement marking: (*635*)

- Removed yellow thermoplastic and yellow paint should be disposed of at a Class 1 disposal facility or a Class 2 disposal facility. Testing of residue is likely to require EPA's Total Lead and Chromium Method 7000 series. If the yellow thermoplastic and yellow painted traffic stripe and pavement marking residue is transported to a Class 1 disposal facility, a manifest should be used, and the transporter should be registered with the California Department of Toxic Substance Control. The Engineer will obtain the United States Environmental Protection Agency Identification Number and sign all manifests as the generator within 2 working days of receiving sample test results and approving the test methods.
- The contractor should prepare a project specific Lead Compliance Plan to prevent or minimize worker exposure to lead while handling removed yellow thermoplastic and yellow paint residue. Personal protective equipment, training, and washing facilities required by the Contractor's Lead Compliance Plan should be supplied by the Contractor.
- Prior to removing yellow thermoplastic and yellow painted traffic stripe and pavement marking, personnel who have no prior training, including State personnel, should complete a safety training program provided by the Contractor that meets state requirements.
- Where grinding or other methods approved by the Engineer are used to remove yellow thermoplastic and yellow painted traffic stripe and pavement marking, the removed residue, including dust, should be contained and collected immediately. Sweeping equipment should not be used. Collection should be by a high efficiency particulate air (HEPA) filter equipped vacuum attachment operated concurrently with the removal operations or other equally effective methods approved by the Engineer.
- The Contractor should submit a written work plan for the removal, storage, and disposal of yellow thermoplastic and yellow painted traffic stripe and pavement marking to the Engineer for approval.
- The removed yellow thermoplastic and yellow painted traffic stripe and pavement marking residue should be stored and labeled in covered containers, conforming to state provisions. The containers should be a type approved by the United States Department of Transportation for the transportation and temporary storage of the removed residue. The containers should be handled so that no spillage will occur. The containers should be stored in a secured enclosure at a location within the project limits until disposal, as approved by the Engineer.

5.5. Curb and Sidewalk Repair

Curb and sidewalk repair may include use of a compressor, jackhammer or sawcutting, curing, and the disposal of removed materials. Leaks, spills and concrete washout can create result in release of pollutants such as fuel, hydraulic fluid, oil, sediment and concrete.

- Water applied during curing operations should be controlled to prevent unpermitted non-stormwater discharges.
- Other recommended environmental stewardship practices include illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, hazardous waste management, liquid waste management, sanitary/septic waste management, concrete waste management, material use, safer alternative products, spill prevention and control, sweeping and vacuuming and water conservation practices. (*636*)

5.6. Recycling in Pavement and Roadside Appurtenances

Recycling in the Aggregate Industry and Pavement Construction

Recycled aggregate is usually defined as aggregates resulting from the reprocessing of mineral construction materials, mainly crushed concrete and asphalt. Recycling is a major area of growth in the aggregate industry. A number of European countries already have legal requirements, and in the United Kingdom (U.K.) the government has indicated that as much as 25 percent of construction aggregate demand should in the future be met from secondary and recycled sources.(*637*) Recycling in the aggregate industry and pavement construction is on the rise in the U.S. as well, as detailed in the individual sections below.

FHWA's Recycled Materials Policy stresses recycling in pavement construction, stating that "[r]ecycling and reuse can offer engineering, economic and environmental benefits. Recycled materials should get first consideration in materials selection. Determination of the use of recycled materials should include an initial review of engineering and environmental suitability. An assessment of economic benefits should follow in the selection process. Restrictions that prohibit the use of recycled materials without technical basis should be removed from specifications."(*638*) FHWA developed User Guidelines for Waste and Byproduct Materials in Pavement Construction, with guidelines are available for the following materials: (*639*)

- Baghouse Fines
- Blast Furnace Slag
- Coal Bottom Ash/Boiler Slag
- Coal Fly Ash
- FGD Scrubber Material
- Foundry Sand
- Kiln Dusts
- Mineral Processing Wastes
- MSW Combustor Ash

- Nonferrous Slags
- Quarry Byproducts
- Reclaimed Asphalt Pavement
- Reclaimed Concrete Material
- Roofing Shingle Scrap
- Scrap Tires
- Sewage Sludge Ash
- Steel Slag
- Waste Glass

Furthermore, FHWA developed descriptions of the following applications: (*640*)

- Asphalt Concrete Pavement
- Portland Cement Concrete Pavement
- Granular BaseEmbankment or Fill
- Stabilized Base
- Flowable Fill

Table 14: Recycled Materials Applications – FHWA

Application/Use	Material
Asphalt Concrete – Aggregate (Hot Mix Asphalt)	Blast Furnace Slag Coal Bottom Ash Coal Boiler Slag Foundry Sand Mineral Processing Wastes Municipal Solid Waste Combustor Ash Nonferrous Slags Reclaimed Asphalt Pavement Roofing Shingle Scrap Scrap Tires Steel Slag Waste Glass
Asphalt Concrete – Aggregate (Cold Mix Asphalt)	Coal Bottom Ash Reclaimed Asphalt Pavement
Asphalt Concrete – Aggregate (Seal Coat or Surface Treatment)	Blast Furnace Slag Coal Boiler Slag Steel Slag
Asphalt Concrete – Mineral Filler	Baghouse Dust Sludge Ash Cement Kiln Dust Lime Kiln Dust Coal Fly Ash
Asphalt Concrete – Asphalt Cement Modifier	Roofing Shingle Scrap Scrap Tires

Portland Cement Concrete – Aggregate	Reclaimed Concrete
Portland Cement Concrete – Supplementary Cementitious Materials	Coal Fly Ash Blast Furnace Slag
Granular Base	Blast Furnace Slag Coal Boiler Slag Mineral Processing Wastes Municipal Solid Waste Combustor Ash Nonferrous Slags Reclaimed Asphalt Pavement Reclaimed Concrete Steel Slag Waste Glass
Embankment or Fill	Coal Fly Ash Mineral Processing Wastes Nonferrous Slags Reclaimed Asphalt Pavement Reclaimed Concrete Scrap Tires
Stabilized Base – Aggregate	Coal Bottom Ash Coal Boiler Slag
Stabilized Base – Cementitious Materials (Pozzolan, Pozzolan Activator, or Self-Cementing Material)	Coal Fly Ash Cement Kiln Dust Lime Kiln Dust Sulfate Wastes
Flowable Fill – Aggregate	Coal Fly Ash Foundry Sand Quarry Fines
Flowable Fill – Cementitious Material (Pozzolan, Pozzolan Activator, or Self-Cementing Material)	Coal Fly Ash Cement Kiln Dust Lime Kiln Dust

Federal Highway Administration, "User Guidelines for Waste and Byproduct Materials in Pavement Construction." www.tfhrc.gov/hnr20/recycle/waste/index.htm.

The University of Texas Center for Transportation Research has also produced overviews of how recycled products can be used in several applications, including: (*641*)

- Recycling In Concrete
- Recycling in Embankments
- Recycling in Roadbase
- Roadway Safety Devices

FHWA has developed two NHI Courses on recycling as it pertains to pavement., Portland Cement Concrete Pavement Evaluation and Rehabilitation (131062A) (*642*) and Hot Mix Asphalt Pavement Evaluation and Rehabilitation (131063A).(*643*)

***Reclaimed Asphalt Pavement* (*RAP*)**

Asphalt pavement is the nation's most widely recycled product; twice as much asphalt pavement is recycled as paper, glass, plastic and aluminum combined.(*644*) The Federal Highway Administration reports that 73 million metric tons of the 91 million metric tons (or 80.3 million of the 100.1 million tons) of asphalt pavement that is removed each year during resurfacing and widening projects is reused as part of new roads, roadbeds, shoulders and embankments, for a recycling rate of 80 percent. When a road is widened or resurfaced, the top layer of asphalt pavement is removed and later re-mixed with fresh materials. Hot Mix Asphalt provides a way not only to reuse old asphalt pavement but also to put other waste products to good use. Specifications for asphalt pavement now include such ingredients as rubber from old tires, slag from the steel-making process, sand from metal-casting foundries, and waste from the production of roofing shingles.(*645*)

Although some form of pavement recycling was practiced as early as 1915, the first sustained efforts to recover and reuse old asphalt paving materials were conducted in the mid 1970s. With financial support of FHWA and technical assistance from trade associations such as the National Asphalt Pavement Association and the Asphalt Institute, more than 40 states placed demonstration reclaimed asphalt pavement (RAP) projects by 1982. RAP, is now routinely used in nearly all 50 states. FHWA estimates that nearly 30 million tons are recycled into hot-mix asphalt (HMA) pavements each year, saving taxpayers more than $300 million annually by reducing material and disposal costs.(*646*)

Asphalt and aggregate are non-renewable resources. Mining quality aggregate and opening new quarries has its problems. Often the roadway that needs to be rehabilitated may possess the best available aggregate. In addition to its environmental benefits, recycling provides a cheaper, faster and less disruptive alternative to conventional methods of reconstruction. It saves time during construction and time to the traveling public.(*647*)

Reclaimed asphalt pavement (RAP) is defined as salvaged, milled, pulverized, broken, or crushed asphalt pavement. It is removed or reprocessed from pavements undergoing reconstruction or resurfacing. Reclaiming the bituminous concrete may involve either cold milling a portion of the existing bituminous concrete pavement or full depth removal and crushing.(*648*) RAP is produced by crushing and screening the material to a ¼ to ½ -inch in size. It is tested to ensure that the proper applicable gradation and quality is satisfied, and if so, the RAP is mixed with virgin aggregate and asphalt as needed, then placed. When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement. Since millings from different projects will have different characteristics, contractors must maintain separate stockpiles of milled material, and the properties of particular stockpiles will change as it used and reused. (*649*) Although the majority of old asphalt pavements are recycled at central processing plants, asphalt pavements may be pulverized in place and incorporated into granular or stabilized base courses using a self-propelled pulverizing machine. Hot in-place and cold in-place recycling processes have evolved into continuous train operations that include partial depth removal of the pavement surface, mixing the reclaimed material with beneficiating additives (such as virgin aggregate, binder, and/or softening or rejuvenating agents to improve binder properties), and placing and compacting the resultant mix in a single pass.(*650*)

RAP properties largely depend on its existing in-place components. There can be significant variability among existing in-place mixes depending on type of mix, and in turn, aggregate quality and size, mix consistency, and asphalt content. Due to traffic loading and method of processing, RAP is finer than its original aggregate constituents are; it is finest when milled.(*651*)

Reflection cracking induced by environmental or traffic loads, and/or a combination of the two is a principal form of distress in hot mix asphalt (HMA) overlays of resurfaced flexible and rigid pavements. When these cracks propagate through the AC overlay, infiltration of water and de-icing salts can cause rapid deterioration of the underlying pavement structure and foundation. The basic mechanisms leading to the development of reflection cracking are horizontal and differential vertical movements between the original pavement and HMA overlay.

Recent work performed under NCHRP Project 1-37A, *Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II*, found that the severity of reflection cracks (transverse and longitudinal) significantly affects ride quality as measured by the International Roughness Index (IRI). In 2005, NCHRP will oversee research to identify the most appropriate mechanistic-based model for reflective cracking in AC overlays and calibrate, validate, and incorporate that model into the framework and procedure (software) being developed under NCHRP Project 1-37A. Traffic levels, overlay thickness, environments and "foundation" types (e.g., old PCC, stabilized base, and old AC) will be examined.(*652*)

FHWA's Turner Fairbanks Research Center makes the following recommendations for use of milled or crushed RAP in a number of highway construction applications, including as an aggregate substitute and asphalt cement supplement in recycled asphalt paving (hot mix or cold mix), as a granular base or subbase, stabilized base aggregate, or as an embankment or fill material: (*653*)

Example 12: Uses of Recycled Asphalt Pavement

Asphalt Concrete Aggregate and Asphalt Cement Supplement

Recycled asphalt pavement can be used as an aggregate substitute material, but in this application it also provides additional asphalt cement binder, thereby reducing the demand for asphalt cement in new or recycled asphalt mixes containing RAP. When used in asphalt paving applications (hot mix or cold mix), RAP can be processed at either a central processing facility or on the job site (in-place processing). Introduction of RAP into asphalt paving mixtures is accomplished by either hot or cold recycling.

Hot Mix Asphalt (Central Processing Facility)

Recycled hot mix is normally produced at a central RAP processing facility, which usually contains crushers, screening units, conveyors, and stackers designed to produce and stockpile a finished granular RAP product processed to the desired gradation. This product is subsequently incorporated into hot mix asphalt paving mixtures as an aggregate substitute. Both batch plants and drum-mix plants can incorporate RAP into hot mix asphalt.

Hot Mix Asphalt (In-Place Recycling)

Hot in-place recycling is a process of repaving that is performed as either a single or multiple pass operation using specialized heating, scarifying, rejuvenating, laydown, and compaction equipment. There is no processing required prior to the actual recycling operation.

Cold Mix Asphalt (Central Processing Facility)

The RAP processing requirements for cold mix recycling are similar to those for recycled hot mix, except that the graded RAP product is incorporated into cold mix asphalt paving mixtures as an aggregate substitute.

Cold Mix Asphalt (In-Place Recycling)

The cold in-place recycling process involves specialized plants or processing trains, whereby the existing pavement surface is milled to a depth of up to 150 mm (6 in), processed, mixed with asphalt emulsion (or foamed asphalt), and placed and compacted in a single pass. CIR is suitable for roadways with moderate to severe distresses where reflection cracking is a concern. CIR involves milling the existing pavement, screening for oversize, addition of asphalt emulsion, and mixing; then this cold renewed material is spread, reprofiled, and compacted on the roadway in one continuous operation.There is no processing required prior to the actual recycling operation.

Granular Base Aggregate

To produce a granular base or subbase aggregate, RAP must be crushed, screened, and blended with conventional granular aggregate, or sometimes reclaimed concrete material. Blending granular RAP with suitable materials is necessary to attain the bearing strengths needed for most load-bearing unbound granular applications. RAP by itself may exhibit a somewhat lower bearing capacity than conventional granular aggregate bases.

Stabilized Base Aggregate

To produce a stabilized base or subbase aggregate, RAP must also be crushed and screened, then blended with one or more stabilization reagents so that the blended material, when compacted, will gain strength.

Embankment or Fill

Stockpiled RAP material may also be used as a granular fill or base for embankment or backfill construction, although such an application is not widely used and does not represent the highest or most suitable use for the RAP. The use of RAP as an embankment base may be a practical alternative for material that has been stockpiled for a considerable time period, or may be commingled from several different project sources. Use as an embankment base or fill material within the same right-of-way may also be a suitable alternative to the disposal of excess asphalt concrete that is generated on a particular highway project.

Practices in Use of RAP

The University of Texas at Austin's Center for Transportation Research (CTR) conducted study 7-2918, Production Variability Analysis of Hot-Mixed Asphalt Concrete (HMAC) Containing RAP, evaluated the production and construction variability of HMAC containing high quantities of RAP material and recommended the following practices to effectively use this recycled resource: (*654*)

- When the RAP material is used, the gradation of the RAP should be determined using a procedure that results in an aggregate gradation similar to what is obtained during the milling operation. RAP aggregate gradation from road cores can differ significantly from RAP aggregate gradation obtained from milling, the latter being finer owing to the crushing action of the milling machine. The mix design gradation based on road cores may not be representative of the actual gradation during construction.
- The use of a high percentage of RAP should be restricted until means are available to reduce the mix variability when a high quantity of RAP is used, or until sufficient evidence exists that further deviations from the target values can be allowed without adversely influencing the pavement performance.

Florida DOT studies to develop specifications for using RAP as base, subbase or general fill materials found that an 80 percent RAP-20 percent soil mix produced the most desirable engineering behavior and that RAP poses no environmental concerns when used as a highway material. The concentrations of heavy metals were well below the EPA standards after samples were taken over a 12-month period and subjected to four different environmental testing procedures.(*655*)

The Joint Task Force #38 on CIR (AASHTO/AGC/ARTBA) voted and approved specifications for Cold In-place Recycling (CIR), for which the University of New Hampshire (UNH) in conjunction with University of Rhode Island (URI) was commissioned to develop a performance based mix design. Joint Task Force #40 on Hot In-place Recycling (HIR) is underway, and a proposed Joint Task Force for Full Depth Reclamation was submitted by Asphalt Recycling and Reclaiming Association (ARRA) for consideration. NCHRP Project 1-37A, due in 2004, is developing a new *Guide for Design of New and Rehabilitated Pavement Structures*, accompanied by the necessary computational software, for adoption and distribution by AASHTO. The new guide will contain procedures for the design and analysis of all types of new and rehabilitated pavement systems (e.g., flexible, rigid, and semi-rigid pavements) and is expected to provide many improvements over current pavement design procedures. The Guide will emphasize rehabilitation design, since approximately 73 percent of the Nation's pavement design dollars are spent on rehabilitation. The Guide will include procedures for evaluating existing pavements; recommendations on rehabilitation treatments; procedures for life cycle cost analysis and reliability; procedures for calibrating for local conditions; and ways to reduce life cycle costs and make better use of available materials.

Use of RAP in Superpave

Originally the Strategic Highway Research Program, Superpave (SUperior PERforming Asphalt PAVEments) did not provide guidelines for the inclusion of RAP. However, agency and industry personnel, as well as researchers, seem to agree that as long as RAP is treated as an engineered construction material and the unique properties of the RAP are known. Recently completed research, conducted under the auspices of the National Cooperative Highway Research Program (NCHRP), the North Central Superpave Center, and the Asphalt Institute confirms that Superpave can easily and effectively accommodate the use of RAP. The overall Superpave mix design process with RAP is is very similar to that described in AASHTO MP2. Although RAP is treated like any other stockpile for blending and weighing, the following practices are required:

- The RAP must be heated gently to avoid changing the RAP binder properties.
- The RAP aggregate specific gravity must be estimated.
- The weight of the binder in the RAP must be accounted for when batching aggregates, and the total asphalt content reduced to compensate for the RAP binder.
- The virgin binder grade may need to be changed depending upon the RAP percentage and binder grade and the desired blend. Though not Superpave-specific, other factors to consider when using RAP are those related to production and quality control testing.
- Higher plant temperatures are necessary if the ambient temperature is low or the moisture content of the materials is high. Greater energy consumption may affect plant production.
- Stricter stockpile management and more frequent sampling and testing of the RAP may be necessary to ensure consistency and quality.

As described in NCHRP Research Results Digest 253, the findings of the NCHRP Project 9-12 research effort largely confirmed current practice and supported the use of blending charts. The report, "Incorporation of Reclaimed Asphalt Pavement in the Superpave System", promotes a tiered approach to the use of RAP. Low amounts of RAP, typically 10-20 percent, can be used without testing the recovered binder. With higher RAP contents, Superpave binder tests can be used to determine how much RAP may be added or which virgin PG binder is needed. Conventional Superpave binder tests can be used to determine how much RAP can be added or which virgin binder to use when higher RAP contents are desired.(*656*)

- The properties of the aggregate in the RAP may limit the amount of RAP that can be used and should be considered as the RAP comprises another aggregate stockpile. It may be presumed that the mixtures being recycled met specifications and certain minimum aggregate properties and mixture properties when constructed; however, such specs differ from those of Superpave.

- RAP aggregates should be blended with virgin aggregates, so the blend meets the consensus properties.
- In the mix design, the RAP binder should be taken into account, and the amount of virgin binder added should be reduced accordingly. DSR and bending beam rheometer (BBR) tests may replace the viscosity tests that were previously used, but the concepts are still the same.

The authors concluded that such practices are already widely utilized, the research effort should give agencies confidence in extending the use of RAP to Superpave mixtures.(*657*)

Illinois DOT is among the state DOTs that allow incorporation of RAP into Superpave mixes. As of 2000, the amount of RAP allowed for low volume roads increased from 25 percent to 30 percent. For some non-critical mixes, such as the shoulder, base, and subbase, up to 50 percent RAP is allowed. For high-type binder courses, up to 25 percent is allowed. For surface courses, the amount allowed ranges from 10 percent to 15 percent for all but the highest volume highways. RAP is not allowed in the Department's highest-class bituminous concrete surface or polymer-modified mixes to maintain acceptable friction requirements. The Department also allows RAP to be used in place of aggregate or earth in some non-structural backfill situations. Recently, RAP has been used in 40 to 60 percent of the Department's most common surface and base course mixes, and over 60 percent of total shoulder mix tonnage; 623,000 tons were used in 2001. (*658*)(*659*) The Illinois DOT used about 623,000 tons of RAP in 2001 as a viable aggregate substitute for scarce bituminous resources.(*660*)

A regional pooled fund project was recently conducted to investigate the performance of Superpave asphalt mixtures incorporating RAP to determine if findings of NCHRP 9-12 (Incorporation of Reclaimed Asphalt Pavement in the Superpave System) were valid for Midwestern materials and to expand the NCHRP findings to include higher RAP contents. Mixtures were designed and tested in the laboratory with RAP materials from Indiana, Michigan and Missouri, virgin binder and virgin aggregate at RAP contents up to 50 percent.

- The results showed that mixtures with up to 50 percent RAP can be designed under Superpave, provided the RAP gradation and aggregate quality were sufficient. In some cases, the RAP aggregates limited the amount of RAP that could be included in a new mix design to meet the Superpave volumetric and compaction requirements. Linear binder blending charts were found to be appropriate in most cases.
- In general, increasing the RAP content of a mixture increased its stiffness and decreased its shear strain, indicating increased resistance to rutting.
- Best practices require consideration of the RAP aggregate gradation and quality in the mix design, since a poor aggregate structure could reduce mixture stiffness and ultimately performance.

The study showed that provided the RAP properties are properly accounted for in the material selection and mix design process, Superpave mixtures with RAP can perform very well.(*661*)

The Asphalt Recycling & Reclaiming Association (ARRA) recently spent two years producing the Basic Asphalt Recycling Manual (BARM) endorsed by FHWA. The BARM introduces road managers to the recycling technologies that are available today; six different disciplines that can effectively recycle and rejuvenate those deteriorated asphalt pavements. Dry planning, hot plant, hot in-place recycling, cold in-place recycling, full-depth reclaiming and soil stabilization can address a range of problems associated with asphalt pavements and base soils. The BARM covers each discipline from historic information, pavement assessment, structural capacity, material properties, geometric, traffic, economic and environmental assessments. It also provides mix design, blending charts, method specifications, end results specifications, inspection, quality control and quality assurance.

In-Situ Hot Mixes: Cold In-Place Recycling and Hot In-Place Recycling

Hot in-place recycling (HIR) is a process of repaving that is performed as either a single or multiple pass operation using specialized heating, scarifying, rejuvenating, laydown, and compaction equipment. Cold in-place recycling (CIR) process involves specialized plants or processing trains, whereby the existing pavement surface is milled to a depth of up to 150 mm (6 in), processed, mixed with asphalt emulsion (or foamed asphalt), and placed and compacted in a single pass. Neither process requires processing prior to the actual recycling operation.

Joint Task Force #38 on CIR (AASHTO/AGC/ARTBA) voted and approved specifications for Cold In-place Recycling (CIR), for which the University of New Hampshire (UNH) in conjunction with University of Rhode Island (URI) was commissioned to develop a performance based mix design. Joint Task Force #40 on Hot In-place Recycling (HIR) is underway, and a proposed Joint Task Force for Full Depth Reclamation was submitted by Asphalt Recycling and Reclaiming Association (ARRA) for consideration.

Cold In-Place Recycling

Cold in-place recycling, which is essentially total reconstruction of a road, encounters few cost-prohibitive problems. Material costs are less because the existing material is recycled and reused. Though many times aggregate or asphalt must be added to create a proper base, this is much more cost-effective than removing the road bed. Additionally, the material is recycled "in-place," meaning there is little need for excavation or hauling. In the end, cold in-place recycling costs anywhere from one-third to one-half of the total cost incurred for conventional reconstruction. Furthermore, when done properly, cold in-place recycling can offer better results than conventional reconstruction. Reasons that CIR is not more common include the perception that it only involves the road's top layer of asphalt; however, cold in-place recycling is total reconstruction of a road because the process goes down to the subgrade. Additives have also been a point of debate, though the recycling process itself should not be jeopardized by choices of wrong additives or dilution.(*662*)

In-place recycling has played a large role in pavement maintenance strategies in some states. In a shift to a more pro-active road maintenance strategy, Nevada DOT is prioritizing projects based on how quickly roads are deteriorating or prediction models, not on the basis of their current condition. Prevention strategies are ranked by life-cycle cost, not initial cost. The program required initial larger expenditures on pavement preservation, to reduce its backlog. NDOT deployed cold-in-place recycling based on a sophisticated lifecycle cost comparison; the state optimized its projects by assigning roads to five categories based on volume and environmental conditions. Cold-in-place recycling provided a pavement performance life comparable to that of overlays. Cold in-place recycling was adapted for harsher winter conditions in Nevada by adjusting the lime added to the mix. (*663*)

The Montana Department of Transportation (MDT) turned to CIR to deal with has dealt with road maintenance needs, insufficient maintenance funds, challenges in siting new quarries and asphalt plants, diminishing supplies of virgin aggregates, expensive freight costs for paving remote locations, and environmental concerns. MDT found that CIR produces less thermal and reflective cracking than HIR in Montana, and that CIR can be used to remove thermal and reflective cracks, maintain clearances, improve poor aggregate gradations, reuse existing materials and minimize the need for new materials, as well as strengthen the pavement. MDT's process combines a defined sampling protocol, an engineered design protocol with performance-related testing of laboratory prepared samples, quicker field compaction and construction specifications and a new chemistry (ReFlex) emulsion. The new chemistry allows a better coating and higher asphalt content than conventional CIR. The performance-related specifications include tests for low-temperature cracking, raveling, strength and stripping resistance. The specifications also include requirements for the construction equipment and practices, as well as quality control and quality assurance.

Hot In-Place Recycling

HIR is considered a maintenance technique because HIR is a shallow-depth treatment used to rehabilitate road surfaces with minor deficiencies in the upper 1 to 2 inches of existing asphalt pavement before major distresses appear. There are three different types of HIR processes, each with its own benefits and best applications, but generally hot-in-place recycling is used by agencies as an alternative to milling 2 inches of pavement and laying down 2 inches of new hot-mix asphalt. The HIR processes have the advantages of being inexpensive, relatively fast, and adding substantial life to the original pavement. Advances in technology and techniques in the 90s made hot-in-place recycling an increasingly popular and cost-effective pavement maintenance technique. Contractors now heat the pavement more gradually, using multiple pre-heaters operating at lower temperatures to gently bring the pavement up to scarifying temperatures. A much higher quality recycled mix results, with minimal vapors produced by the process. Better emissions systems incinerate fumes, reducing them to carbon dioxide and water.

The following overview of the three main HIR processes is from K. Lander's "Recycling as a Life-Extending Maintenance Tactic," in *Better Roads*, July 2002.

Surface Recycling

Surface recycling is the most basic type of hot-in-place recycling. It is used for scarifying depths of 0.75 to 1.5 inches, with a depth of one inch being most common. The treatment can be used to rejuvenate the asphalt binder in the existing pavement, to eliminate surface irregularities, and to create a uniform grade line and cross section to the pavement surface.

In surface recycling, two or three pre-heating units are followed by a heating/scarifying unit which provides final heating and loosens the asphalt. Augers mix the scarified asphalt with the recycling agent, which is metered into the mix by means of a computer controlled injection system. The mix is leveled and spread by a free-floating screed or a modified asphalt paver; heated, vibrating screeds are usually used to provide initial compaction. Traditional hot-mix asphalt compaction follows: breakdown rolling, usually with a pneumatic compactor, then a double-drum vibratory steel wheel roller. Static steel-wheel rollers are sometimes used for finish rolling. Because the existing asphalt pavement below the recycled mix is warm, a thermal bond develops between the two layers and there is ample time for compaction rolling. When the recycled mix cools, the road can be opened to traffic.

Surface recycling is usually followed with a surface treatment or a thin hot-mix asphalt lift. Without a surface treatment, the pavement's service life probably ranges between two and four years; with a surface treatment, service life expectancies range from five or six years with a chip seal to ten years with a two-inch asphalt overlay.

Surface recycling is especially well suited to preparing pavements in rural areas, far removed from established HMA plant locations, for overlays. In such applications, the recycling crew creates a leveling course for the overlay, opening lanes for traffic as they go. This flexibility makes it possible to hold off bringing in the paving crew and its portable HMA plant until the entire leveling course has been completed. Thus, when the final lift is put down, both the paving crew and the hot-mix plant can work at maximum production rates — rather than having to adjust production to the pace of an HIR train or milling machine — saving time and money.

According to the Asphalt Recycling and Reclaiming Association's Basic Asphalt Recycling Manual, surface recycling is most effective in addressing pavement raveling and improving ride quality. It can also be effective in treating pavements suffering from minor degrees of potholes, bleeding, rutting, corrugations, shoving, cracking, and other surface imperfections. It is not an effective solution for problems with skid resistance, shoulder drop off, fatigue cracking, edge cracking, discontinuity cracking or pavement strength.

Remixing

Remixing is the hot-in-place recycling technique that provides the most options for pavement remediation. It is considered a very cost effective solution to rutting, raveling, oxidation, and other flaws in the upper two inches of a pavement.

Recycled asphalt modifications that are possible with remixing include aggregate gradation, abrasion/friction number enhancement, asphalt binder content, asphalt binder rheology, mix stability, and mix void properties.

In this process, preheaters and a heater/scarifying machine heat the pavement to depths of 1.5 to 2 inches, scarify it into windrows, then convey it to an on-board mixer. In the mixing chamber, the recycled mix is combined with any combination of modifiers, including recycling agents, admix, or virgin HMA. The modified mix is then placed with a full-floating screed or modified asphalt paver. The screeds are usually heated, with vibratory or tamping bar designs for initial compaction and with automatic grade and slope control.

As with the other HIR processes, remixing produces a heating bond between layers of asphalt. The underlying pavement is usually between 120-180 degrees F and the recycled mix is between 230-265 F when the mix is placed. In addition, the heating units usually warm the pavement 4 to 6 inches beyond the scarification width, providing a thermally integrated bond between the recycled mix and the adjacent material. Proponents of HIR say this creates a seamless longitudinal joint that resists environmental and traffic degradation. Compaction is the same as for surface recycling.

Single-stage remixing — where the full depth of pavement is scarified in one operation — usually treats depths of 1 to 2 inches of pavement, with 1.5 inches the most common depth. This process was developed in Europe and Japan in the late 1970s and is widely used throughout the world.

Multiple stage remixing was developed in North America in the late 1980s and early 1990s as a way to achieve greater treatment depths with HIR. In this variation, the pavement is sequentially heated, softened, and scarified in layers, usually two to four layers. This process is used for remixing depths of 1.5 to 3.0 inches, with 2 inches being the most common.

Remixing can produce a wear-course-quality pavement with a service life of 7 to 14 years, depending on the quality of the original pavement and the admix and binder modifiers used. That makes remixing an effective option for road repairs that cannot add elevation to the original roadway whether it's because of clearance problems or because repairs are needed on just one lane of a 2-lane road.

Remixing can also produce a leveling-course-quality pavement designed for a hot-mix asphalt overlay. The life expectancy for these applications is usually the life expectancy of the wear course — between 7 and 15 years, as a rule.

According to the Asphalt Recycling and Reclaiming Association's Basic Asphalt Recycling Manual, remixing is most effective for treating pavements with potholes, bleeding, corrugations, shoving, or ride quality problems, as well as the fore-mentioned rutting, raveling, and oxidation, when these conditions are confined to the top two inches or so of the pavement. It can also be effective in treating a variety of cracks, surface irregularities, and skid-resistance deficiencies. It is not considered an effective treatment for shoulder drop-off problems, discontinuity cracking, or inadequate pavement strength, nor is it recommended for pavements with distresses that are more than two inches deep.

Repaving

Repaving combines the remixing process with the placement of an integral hot-mix asphalt overlay, with both layers compacted simultaneously.

Repaving is used when surface recycling or remixing alone cannot restore the pavement profile or surface requirements such as friction number. Because it makes possible the use of a very thin HMA wear course layer, it is also used when a conventional HMA overlay isn't practical. And repaving is used when pavement strengthening is needed; remixing can add up to 0.75 inches of pavement strengthening, while repaving can add up to 2 inches of strengthening.

In single-pass repaving, the last unit in the HIR train uses one screed to place the recycled mix and a second to place the HMA mix; both layers are then compacted as one. In the multiple-pass method, the last unit in the train has a single screed that places the recycled mix while a conventional HMA paver follows immediately behind to place and screed the virgin hot-mix asphalt layer on the recycled mix; both layers are compacted as one.

Repaving treatments usually involve a recycled depth of 1 to 2 inches and an overlay of 1 to 2 inches; the typical combined thickness is three inches or less. Combined thickness of 4 inches or more can present difficulties in placement, compaction, and smoothness.

Because of the thermal bonding between layers, very thin HMA overlays are possible with this technique — as thin as 0.5 inches if the appropriate HMA mix is specified. With conventional overlays using two to three times as much hot-mix asphalt, thin-layer repaving is often less expensive than other hot-in-place recycling options that involve an overlay.

More typically, repaving specialists are recycling one inch of old pavement and adding a one-inch overlay in competition with a conventional two-inch mill-and-fill. Repaving has also proven to be well suited to municipal applications. Though the repaving train is slower than a milling machine and a paver in a mill and fill operation, it only interrupts traffic once and may displace traffic for less total time than a mill and fill solution. On an even more practical level, advocates point out that the repaving train only blocks access to any given parking lot or driveway for 10 or 15 minutes, and it leaves behind a road ready to use.

Re- paving does not require a tack coat between the leveling course and the wearing course. This is a plus because it eliminates the spread of the tar-like substance to parking lots, car panels, and shoes. Because of the relatively small volumes of HMA placed daily in repaving, the process is most practical for projects that are located within efficient hauling distances of established HMA plants.

According to the Asphalt Recycling and Reclaiming Association's Basic Asphalt Recycling Manual, repaving is most effective in treating raveling, potholes, many types of cracking, or deficiencies in skid resistance or ride quality. It can be effective in treating bleeding, rutting, corrugations, shoving, and other surface imperfections. It can also be used to increase pavement strength.

Hot-in-place recycling is widely used in its various forms throughout the United States and Canada, though there are major concentrations of usage in areas where specialty contractors are based. Colorado's Department of Transportation is one of the most prolific and experienced users of the remixing form of HIR; CDOT Region 5 reports crack elimination, excellent smoothness, and five to 10 years of service from this process in a tough mountain region when it is capped with a 2-inch overlay. Smoothness is also a benefit the Texas Department of Transportation touts for its use of the HIR repaving process in metropolitan areas. In 2000, the department's Houston District awarded three major HIR repaving projects totaling nearly 600,000 square yards. The largest of those projects, a heavily traveled, seven-lane arterial highway reported in the September 2001 issue of Better Roads, qualified for 85 percent of the contract's smoothness bonus. Repaving also eliminated complaints about tack coat used in conventional overlays being tracked into businesses and cars. Driveways and intersections were blocked for no more than 15 minutes.(*664*)

Recycling with Foamed Asphalt

In situ hot-mix recycling, including hot in-place recycling (HIR) and cold in-place recycling (CIR) has proved to be an economical rehabilitation technique that conserves granular materials and energy and results in zero waste.(*665*) An increasingly popular version of in-place recycling uses foamed asphalt. "Foamed" or "expanded" asphalt is a road base recycling process in which pulverized pavement is mixed with an asphalt froth to create a stabilized road base. The expanded asphalt forms a mortar or glue that bonds particles. The technology sidesteps several aspects of conventional asphalt such as the use of solvents and the time waiting for the break for emulsions.

Reclaimed asphalt pavement is often unusable as a new asphalt concrete mix or cold in-place recycled mixture because it is not uniform or the underlying pavement does not provide adequate structural support. Construction of a base with full depth reclamation (FDR) materials stabilized with foamed asphalt can solve the support problem. Result of studies by the Iowa and Kansas DOTs indicated that the foamed asphalt stabilized FDR material is a uniform material that can be placed and compacted easily, and that it can be efficiently used as base material in flexible pavements.(*666*)

Foamed asphalt is formed by carefully injecting a predetermined amount of cold water into hot penetration-grade asphalt in the mixing chamber of a pavement remixing unit. There, air bubbles in the expanded liquid asphalt froth act as the carriers of liquid asphalt to fines in a reclaimed asphalt pavement aggregate mix. While expanded asphalt doesn't completely coat all aggregate surfaces, it does form a mortar or glue which bonds the particles together. In less than 15 seconds, the froth subsides and the dispersion of asphalt is achieved, eliminating time waiting for the "break" required when expensive asphalt emulsions are used. The technology also sidesteps use of costly cutback solvents. The liquid asphalt cement is pure, with nothing added to it to change its properties. That makes it more economical and environmentally viable than emulsions comprised of processed oil.

Louisiana is among the transportation agencies that have investigated and found great potential in the use of FA-treated RAP as a base course material in lieu of a crushed-limestone base beneath a concrete pavement layer.(*667*) Caltrans has experimented with foamed or expanded asphalt used along with in-place base recycling, largely because conventional reconstruction adds limited life but cold foaming gives another 10 years of operability. Closure times have also factored into the calculus; the cost of conventional reconstruction—months-long closure, excavation, trucks out with old pavement and base, trucks in with new base and pavement materials, and a parade of construction equipment—made reconstruction prohibitively expensive on a number of highways given their remote location, the few vehicles per day they served, and water-logged environments. Foamed asphalt stabilization requires a mix design using actual materials from the job site to be developed prior to construction, which can be accomplished in a portable lab. With Caltrans, the cold-foamed asphalt process took about four working days to rebuild from bottom-up at a depth of 6 inches. A chip seal seal coating was added, so the road was effectively rebuilt in six days whereas conventional treatments would have taken 30-60 days. Caltrans is currently evaluating the cold foam under various extreme climatic conditions.(*668*)

Ulster County in New York's Catskills has also begun to utilize the process to avoid weeks-long truck traffic, demolition material and virgin aggregate hauling, noise, dust and commotion, and to create a virtually new, high-performance road base at a fraction of the cost of new base materials and deep lifts of asphalt pavements. In-place recycling with foamed asphalt allows the County to reconstruct more roads each season in addition to the documented benefits of greater pavement resistance to penetration of water and rapid strength gain allowing traffic to resume as soon as compaction is complete. Additional water is not added to the recycled material, as is necessary when emulsion is used. The surface also accommodates excessive heaving caused by major expansion of clay road bases.(*669*)

The Recycled Materials Resource Center produced a study on the use of foamed asphalt as a stabilizing agent, outlining the steps involved to design a foamed asphalt mix, construction of the foamed asphalt sections, and a preliminary evaluation of the application in Maine. The authors found that during the mix design process, the use of the foamed asphalt laboratory equipment is important to optimizing the design as proper asphalt-water ratios are determined to maximize performance. Preliminary evaluation using Falling Weight Deflectometer data revealed the structural capacity of foamed asphalt sections are greater than pical full depth reclamation sections. Long term evaluation of performance is planned.(*670*)

Recycled Concrete Material/Aggregate (*RCM/RCA*)

Recycling is a major part of the concrete industry, which is exploring environmental practices such as recycling of wastes as raw material and fuel for cement manufacturing; development of environmentally compatible cement (Ecocement) using wastes; environmental load-reducing cement emitting less carbon dioxide and NOx during manufacturing; up-grading of the performance of concrete aiming at energy-, resources-, and manpower-savings; utilization of wastes for concrete raw materials; and recycling of concrete wastes from obsolete concrete structures.(*671*)

Recycled Concrete Material (RCM) or Recycled Concrete Aggregate (RCA), also known as crushed concrete, is reclaimed PCC pavement material. Primary sources of RCM are demolition of existing concrete pavement, bridge structures, curb and gutter, and from central recyclers, who obtain raw feed from commercial/private facilities. This material is crushed by mechanical means into manageable fragments and stockpiled. RCM may include small percentages of subbase soil and related debris. The excavated concrete that will be recycled is typically hauled to a central facility for stockpiling and processing or, in some cases (such as large reconstruction projects), processed on site using a mobile plant. At the central processing facility, crushing, screening, and ferrous metal recovery operations occur. Present crushing systems, with magnetic separators, are capable of removing reinforcing steel without much difficulty. Welded wire mesh reinforcement, however, may be difficult or impossible to remove effectively. To avoid inadvertent segregation of particle sizes, coarse and fine RCM aggregates are typically stockpiled separately. RCM is rougher and more absorbent than its virgin constituents. Furthermore, differences among concrete mixes and uses result in varying aggregate qualities and sizes; for example, pre-cast concrete is less variable than cast-in-place. (*672*)

The use of RCM as an aggregate substitute in pavement construction is well established, and includes use in granular and stabilized base, engineered fill, and Portland cement concrete pavement applications. Other potential applications include its use as an aggregate in flowable fill, hot mix asphalt concrete, and surface treatments. To be used as an aggregate, RCM must be processed to remove as much foreign debris and reinforcing steel as possible.

Concrete pavements can be inexpensively repaired and restored with proper equipment, materials and procedures, and when concrete pavement restoration methods are no longer viable concrete overlays can add structural capacity and returning pavements to a smoother, safer condition. Concrete overlays include bonded, unbonded, whitetopping and ultra-thin whitetopping. AASHTO published a guide in 2001 on the use of fiber reinforcement in concrete transportation infrastructure and overlays. The resource includes general information on fibers, as well as guidance on proportioning, mixing and placing fiber-reinforced concrete. Typical applications of fiber-reinforced concrete also are discussed. The report can be obtained from AASHTO at www.transportation.org, publication code TF36-1.(*673*)

State DOT Experiences with RCA

FHWA has research in progress on state DOT experiences with RCA, which are summarized in this section.(*674*) In response to a survey by FHWA, 11 state DOTs said they used RCA in PCC.(*675*) A much higher number, 38 DOTs, said they used RCA in aggregate base. Seventeen states use RCA in miscellaneous areas and applications. A graphic display of these states and uses is available at FHWA's RCA website.(*676*) Minnesota, Utah, Virginia, Texas, and Michigan were chosen for an in-depth review of their recycled concrete aggregate program because of their experience with recycling concrete aggregate.

FHWA's study also identified the following research needs where DOTs and industry suppliers are still looking to gain additional experience or information:

- Development of performance curves for concrete made with recycled aggregate.

- Development of database for RCA final product performance.
- Development of appropriate test procedures for specifying final products made with RCA.
- Development of a performance based specification for RCA.
- Research related to:
    - Minimize reflective cracking in pavements built over thick RCA base due to increased base stiffness.
    - Understand of recycled aggregate products; how they are affected in terms of strength, constructability, and long-term performance.
    - Incorporate RCA affected by D-cracking and ASR and in what proportions.
    - Effect on product made with recycled aggregate affected by alkali silica reaction.
    - Shrinkage effect on product made with recycled aggregate.

Texas DOT (*TxDOT*)

TxDOT is a large user of RCA materials, though private industry and municipalities consume over 60 percent of the RCA currently produced in Texas.(*677*) Initially, there was a general perception that RCA is a waste product and thus substandard material. TxDOT has used RCA where the risk is minimal and with a high potential for performance. The use of RCA in new concrete also initially created problems with mix workability due to problems with the absorbency of the aggregate and the difficulty maintaining a consistent and uniform saturated surface dry condition of RCA aggregate. This hurdle was overcome by the contractor through their process control program, which heightened awareness of the need to water stockpiles and to conduct more frequent testing of aggregate for moisture content. Due to compressive strength and workability issues, TxDOT determined that 20 percent was the maximum amount of RCA fines that would be allowed in the concrete.

TxDOT has also performed training and continually present information to their Districts concerning the performance of the projects they have completed around the state. Through research, implementation, and competition, TxDOT has found that using RCA, like many other recycled materials, provides engineering, economic, and environmental benefits. (*678*)

- RCA in new concrete decreases the resilient modulus and increases the creep, changes which are benefits in specific applications. TxDOT does not currently use RCA in structural concrete because of the possible issues with creep and shrinkage. However, TxDOT has used RCA in some structural applications and is monitoring them.
- RCA that originated as concrete with rounded aggregate yields a new product with particles having fractured angular shapes for increased paste bond.
- RCA eliminates the development of waste piles of concrete.
- Haul distances are decreased with RCA because the waste stream of RCA usually originates and is consumed within the same urban area. This decreases energy consumption and helps improve air quality through reduced mobile source emissions.
- Over 10 years experience TxDOT believes RCA provides a cost benefit in specific applications. The RCA is bid as an option, so the economics of the low bid system drives the use of RCA.

TxDOT has also established mechanisms, such as waste stream documentation, to identify the source of the materials.

Michigan DOT (*MDOT*)

Michigan DOT shared the following experiences and practices with FHWA's research team: (*679*)

- RCA used in the base and sub-base material can have performance comparable to virgin aggregate where recycled material is allowed.
- Damage to the highway infrastructure can be reduced due to proximity of aggregate crushing plants.
- Cracking performance problems in RCA pavements can be reduced when the old pavement is crushed to a smaller aggregate size.
- Using RCA in the Detroit metropolitan region is more advantageous than in rural areas of the state, since sources of old concrete are readily available and virgin aggregate sources are not as plentiful. The proximity to metro areas of the RCA production plants also makes this aggregate economically attractive for commercial uses in base and parking lots.
- A recent value-engineering proposal for RCA in the pavement structure on US-41 resulted in savings of $114,000 on a 3 million dollar project. This savings was shared in equal parts by the contractor and the state.
- Normally commercial sources of concrete are not allowed for recycling in the crushing plants. Most recycled material comes from the MDOT's reconstruction projects. This assures a consistent source of original aggregate. MDOT has also used certification of recycling aggregate producers and the approval of stockpiles.
- Changes in the design on the permeable base allow RCA to be used when the density of material is increased and the design of the drainage system is modified.

Minnesota DOT (*Mn/DOT*)

Minnesota DOT's (Mn/DOT) experience with the use of RCA are as follows: (*680*)

- Statewide use of RCA is permitted in the Mn/DOT Standard Specifications for Construction. The specifications establish that RCA can be used as coarse aggregate in Portland cement concrete (PCC) in section 3137.2 B, as aggregate for surface and base courses in section 3138.2 A, and as granular material in section 3149.2.
- Minnesota currently uses almost 100 percent of the concrete removed from its pavements as dense graded aggregate base. This material must meet the 3138.2 section of Mn/DOT specification and can include a maximum of 3 percent by mass of asphalt binder from recycled asphalt pavement.
- From the late 1970s through the 1990s, RCA was used as coarse aggregate for PCC pavements on over 20 projects. Today, Mn/DOT uses a 60-year pavement design life on its high-volume freeways and a 35-year design life on all others. The associated requirements have limited the economic use of RCA in concrete pavements. Currently, Mn/DOT is incorporating RCA primarily as aggregate base in highways projects.

- Observations suggest that RCA used in the base and sub-base material performs similarly to new aggregate where recycled material is allowed. Research is underway to establish laboratory performance parameters for RCA used in aggregate base and sub-base.
- Rubblization, crack & seat, and unbonded concrete overlay have been used as reconstruction strategies. All of these processes have shown to be provide good performance. Unbonded concrete overlay is the most used technique of pavement rehabilitation in the state.
- It is a common practice in Minnesota to crush the material on site. This lowers the transportation costs and has less effect on traffic.
- Preservation of natural aggregate resources is a priority for Mn/DOT as a 10-year aggregate availability study identified these materials as potentially in short supply.
- RCA is being included in a permanent rule relating to Beneficial Use of Solid Waste, where RCA will be considered a standing beneficial use and not subject to review or permitting by Pollution Control Agency.
- Beneficial Use of Solid Waste rule will be instrumental in establishing a database of information on other non-RCA recycled source materials, conditional uses, evaluation process, and stockpiling requirements.
- Lack of data and base line information on effluent leachate and particulate quality was considered a potential barrier in light of new NPDES and TMDL rule or other local regulations.
- Experiences shared by industry in Minnesota included:
    - There is no need to remove fines when RCA is used in absence of drainage layers and/or perforated drainage pipes, making the use of RCA more efficient.
    - Recycled material coming typically from Mn/DOT's reconstruction projects may assure a consistent source of aggregate.
    - Steel removal has become easier through years, generating a cleaner recycled aggregate.

Recommendations provided by Mn/DOT for using RCA in state highways include the following: (*681*)

- Washing of RCA is required if used in PCC pavements in order to eliminate excess fines.
- Quality requirements for new aggregate do not specifically apply to RCA when the pavement comes from a known source.
- In presence of drainage layers and/or perforated drainage pipes:
    - A blend of RCA with new aggregate may be used as subgrade when at least 95 percent of the RCA is retained on the 4.75 mm sieve.
    - RCA may be used up to 100 percent in construction of the filter/separation layer under a permeable aggregate base drainage layer in accordance with the applicable drainage specifications.
- Mn/DOT Research Record of March 1995, "Uses of Crushed Concrete Products in Minnesota Pavement Foundations," provides methods for mitigating precipitate and drainage problems.

Caltrans

Caltrans initially limited the amount of RCA to 50 percent by weight of the total aggregate. Today, a 100 percent of recycled concrete aggregate is allowed by a special provision. Caltrans is working with the concrete and aggregate industries to develop further applications/uses of RCA. Recently, the City of San Francisco approved the use of RCA as aggregate concrete in curbs, gutter, sidewalk, and street base.

Ready Mix Industry suggested that plastic Portland cement concrete (PPCC) can be reclaimed and separated in coarse aggregate, fines, and slurry. The reclaimed aggregate is used as aggregate for concrete or base material. Furthermore, the reclaimed slurry may also potentially be reused Ready Mix Industry suggested that the concrete plant could become a zero-waste facility through the reclaim of PPCC and hardened concrete. As a result of a joint committee among City of Los Angeles, Concrete and recycled aggregate producers ("Greenbook"), reclaimed PPCC is allowed to be used in concrete mixtures in a maximum of 15 percent by volume of concrete; RCA is allowed to be used in concrete in a maximum of 30 percent by weight of total aggregate. The City of San Francisco recently approved the use of RCA non-structural concrete. Orange County and Industry are working together to develop specifications for successful use of RCA.

Virginia DOT (*VDOT*)

Virginia DOT has found that even though the initial production cost of RCA may be higher than that of new aggregate, the location of RCA plants near project areas lowers the final cost of using RCA primarily due to reduced hauling and overhead costs. VDOT uses RCA in base, sub-base, synthetic reefs, and embankments. One example of VDOT's use of RCA in sub-base aggregate is the I-66 project, which won the National Concrete Paving Award after completion. This project was a part of a $140 million reconstruction program on a section of Interstate 66 in Fairfax and Prince William Counties.

Illinois DOT (*IDOT*)

Illinois DOT is among agencies allowing the use of RCM as a coarse aggregate in aggregate surface courses, granular embankments, stabilized bases, and subbase courses provided the project materials' specifications are not compromised.(*682*) Illinois DOT used 321,000 tons in 2001, reducing landfill space needs.(*683*)

Indiana DOT (*INDOT*)

At the Indiana Department of Transportation, most concrete structures that meet the requirements of INDOT Specifications and are proportioned according to American Concrete Institute Specification 211.1 may utilize as much as 77 percent recycled materials by weight, and concrete bridge decks may consist of as much as 50 percent recycled materials by weight.(*684*)

Use of Recycled Concrete as Aggregate in PCC Pavements

AASHTO has a Specification for Recycled Concrete as Aggregate in PCC Pavements.(*685*) The specification covers coarse aggregate derived from reclaimed concrete for use in Portland cement concrete. The specification is not intended for use when lightweight, high density, or other specialty Portland cement concrete applications are required. When aggregate materials are properly processed and manufactured to the requirements of this specification, combined and mixed in accordance with the appropriate requirements, and placed, consolidated, and cured properly, a Portland cement concrete structure of acceptable strength and durability can be produced. The following practices are recommended: (*686*)

- The engineer should ensure that reclaimed concrete source materials are not contaminated with extraneous solid waste or hazardous materials. Methods and criteria for examining and approving reclaimed concrete materials prior to use should be established by the specifying jurisdiction. The presence of deleterious materials in aggregates used in the production of Portland cement concrete could adversely affect concrete setting time and/or strength, and could also induce expansive reactions that could result in premature deterioration of the concrete structure. Strict quality control and quality assurance procedures (outlined in AASHTO Standard Practice R 18-97) should be implemented to ensure that reclaimed concrete aggregate material used as coarse aggregate in the production of Portland cement concrete will not adversely affect the quality of the concrete product.
- Reclaimed concrete aggregate should not contain: clay lumps and friable particles, chert, and coal and lignite or other deleterious substances that exceed the maximum allowable amounts listed in the AASHTO specification.
- Reclaimed concrete aggregate should not contain more than 1.0 percent by mass of material finer than the 75-Fm (No. 200) sieve. This maximum quantity may be increased to 1.5 percent by mass if the fines are derived from the aggregate crushing process.
- Reclaimed concrete aggregate when sampled and tested according to AASHTO Standard T260 should not contain chloride ion in excess of 0.6 lbs of chloride ion per cubic yard of Portland cement concrete.
- The engineer should be aware that coarse reclaimed concrete aggregate may contain air entrained concrete mortar and, therefore, may be highly absorptive and can exhibit low and highly variable specific gravity values. Utilizing highly absorptive aggregates (coarse and fine) that do not exhibit consistent specific gravity values in Portland cement concrete can adversely affect the weighing and batching process in the concrete production operation.
- Some reclaimed concrete aggregate materials may yield higher than expected soundness loss values when subjected to conventional sulfate soundness testing methods. Such testing methods may not be reliable for reclaimed concrete aggregate soundness testing.
- Coarse reclaimed concrete aggregate should either conform to the coarse aggregate gradation requirements prescribed in AASHTO M 43 for the size number specified in the contract documents, or should conform to the coarse aggregate gradation requirements of the specifying jurisdiction. Where coarse aggregate size numbers like 357 or 467 of AASHTO M 43 or other size numbers that exhibit a range of particle size distributions that can result in aggregate segregation are used, the aggregate should be furnished in at least two separate sizes. If the contractor/supplier wishes to use combinations of reclaimed concrete aggregate or reclaimed concrete aggregate and other approved aggregate materials, a request should be made to the engineer for approval. The percentage of combined materials should be established as part of a presubmitted blended aggregate combination. At the engineer's discretion, revised Portland cement concrete mix designs should be required when percentages of materials change.

- If reclaimed concrete aggregate is blended with other approved aggregates, this should be accomplished by mechanical interlock blending or belt blending to ensure uniform proportioning. Other methods of blending should be permissible if it can be demonstrated to the engineer that the alternate blending method will prevent segregation.
- Reclaimed concrete aggregate should comply with the Los Angeles abrasion or Micro Deval test requirements for the various class designations shown in the AASHTO specification.
- Reclaimed concrete aggregate soundness testing should be required at the discretion of the engineer. Alternative soundness test methods and acceptance criteria are included in the AASHTO specification.
- Reclaimed concrete aggregate for use in concrete that will be subject to in-service wetting, extended exposure to humid atmosphere, or contact with moist ground should not contain any materials that are reactive with alkali components in the cement in an amount sufficient to cause excessive expansion of mortar or concrete, except that if such materials are present in injurious amounts, the coarse aggregate may be used with a Portland cement containing less than 0.6 percent alkalies calculated as sodium oxide equivalent or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. Alkali reactivity should be testing in accordance with AASHTO T 303 when alkali silica reaction is suspected, in accordance with ASTM C 586 when alkali carbonate reaction is suspected, or in accordance with other equivalent test methods approved by the specifying jurisdiction. A listing of alternative test methods are in AASHTO's specification.
- Reclaimed concrete aggregate for use in concrete that will be subjected to freeze-thaw action should not contain aggregate components that expand and result in D-cracking of the concrete. When potential D-cracking is suspected by the specifying jurisdiction, the reclaimed concrete aggregate should be tested in accordance with ASTM C 666 or other equivalent method and should meet the acceptance requirements of that jurisdiction.
- Reclaimed concrete aggregate should meet the flat and elongated particle requirements of the specifying jurisdiction.
- Reclaimed concrete aggregate should be saturated with water for a time period that is sufficient to saturate all particles, prior to introducing the reclaimed concrete aggregate into a Portland cement mix, by means of a water sprinkling system or another approved method. At the time of batching, the reclaimed concrete aggregate should contain water in excess of the saturated surface dry condition. Provision should also be made for the free drainage of excess water.

Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course

AASHTO developed a Specification for Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course: AASHTO Designation: M 319-02.(*687*) When properly processed, hauled, spread, and compacted on a prepared grade to appropriate density standards, reclaimed concrete aggregate used alone or blended with natural or crushed aggregate can be expected to provide adequate stability and load support for use as road or highway base courses, the uppermost unbound granular layer of the pavement structure. The following practices are recommended: (*688*)

- The purchaser or specifier should reference the AASHTO specification, grading to be furnished for the granular base, soundness testing requirements, and any additions to or exceptions from the AASHTO specification. The percentage of materials should be established as part of a pre-submitted blended aggregate combination.
- Reclaimed concrete aggregate should consist of crushed concrete material and natural aggregate particles derived from the crushing of Portland cement concrete that are hard, durable fragments of stone, gravel, slag, crushed concrete, or sand.
- Reclaimed concrete aggregate should contain not more than five percent bituminous concrete materials by mass. Reclaimed concrete aggregate should contain not more than five percent brick by mass.
- Reclaimed concrete aggregate material should be free of all materials that fall under the category of solid waste or hazardous materials as defined by the state or local jurisdiction.
- Reclaimed concrete aggregate should be substantially free of wood, metal, plaster, and gypsum board, when these materials are not classified as solid waste. Substantially free, in the context of this specification, should mean percentages of undesirable materials that are less than the following: wood—0.1 percent maximum; metals— 0.1 percent maximum; plaster and gypsum board—0.1 percent maximum. At the engineer's discretion these respective quantities may be adjusted if, in the engineer's opinion, such adjustment will not impact the performance of the base course.
- The engineer should provide appropriate construction specifications to ensure compaction to an extent that further densification of the compacted pavement from traffic loadings will be insignificant. At the time of placement, the reclaimed concrete aggregate material should contain moisture approximately equal to the optimum moisture content necessary to make certain that the design density requirements are obtained when the material is compacted. Reclaimed concrete aggregate can be expected to exhibit higher absorption than natural aggregate materials. Accordingly, the engineer should expect to experience moderately higher optimum moisture content values than would be expected with natural aggregate materials. The reclaimed concrete aggregate should be compacted using vibratory or other proven effective rollers or tampers to achieve the required density results.
- When the engineer permits the contractor/supplier to combine reclaimed concrete aggregate with other approved aggregates, this should be accomplished by mechanical interlock blending or belt blending to ensure uniform mixing. The contractor/supplier may use other methods of blending if it can be demonstrated to the engineer that the alternate blending method will prevent segregation.
- The engineer should be aware of the highly alkaline nature of reclaimed concrete aggregate, the relatively high degree of solubility of these alkaline materials, and the potential increase in pH that could occur in waters percolating through a reclaimed concrete aggregate base. Depending on the sensitivity of local soils, surface waters, and groundwater to the presence of alkaline material, the engineer should set appropriate limits on the proximity of placement of reclaimed concrete aggregate relative to groundwater and surface waters. Additionally, the presence of water percolating through reclaimed concrete aggregate will induce a corrosive solution with a pH of approximately

11 to 12. Therefore, reclaimed concrete aggregate should not be used in the vicinity of metal culverts such as aluminum culverts that are sensitive to highly alkaline environments.

- The engineer is cautioned to prevent, or minimize when possible, the use of reclaimed concrete aggregate over a geotextile drainage layer, gravel drain fields, drain field piping, or open soil-lined stormwater retention or detention facilities. Soluble minerals rich in calcium salts and calcium hydroxide can be hydraulically transported from the reclaimed concrete aggregate material. When this occurs and the reclaimed concrete aggregate is located above such porous drainage systems, there is a tendency for the referenced minerals to precipitate out of solution and bind the drainage structure. The mineral deposits formed are sometimes referred to as tufa-like or Portlandite deposits. Over time the permeability of the drainage system can be reduced.
- The engineer should be aware that reclaimed concrete aggregate used as base course could, with time, gain strength and exhibit a corresponding loss of permeability in the base course layer. This is due to residual cementitious reactions in the concrete material. If the base course is intended for use as a drainage layer, then the fine portion of the reclaimed concrete aggregate should be removed or modified to reduce the potential for this occurrence.
- The engineer is cautioned that some reclaimed concrete aggregate materials will yield high soundness loss values when subjected to conventional sulfate soundness testing methods, and such testing methods may not be suitable for reclaimed concrete aggregate soundness testing.
- The engineer is cautioned to ensure that reclaimed concrete source materials are not contaminated with extraneous solid waste or hazardous materials. Methods and criteria for examining and approving reclaimed concrete materials prior to use should be established by the specifying jurisdiction.
- Reclaimed concrete aggregate should be limited in plastic soils such that the minus 0.425-mm (No. 40) sieve material when tested for liquid limit (T 89) should not be greater than 30 and the plasticity index (T 90) should not be greater than four, and/or at the discretion of the engineer, the sand equivalent value (T 176) of the minus 0.425-mm (No. 40) sieve material should be a minimum of 25 percent.
- Reclaimed concrete aggregate should have a percentage of wear by the Los Angeles abrasion test (T 96) of not more than 50 percent.
- Reclaimed concrete aggregate should have a percentage of wear by the Los Angeles abrasion test (T 96) of not more than 50 percent.
- Reclaimed concrete aggregate soundness testing should be required at the discretion of the engineer.

Recycled Roofing Shingles

Waste roofing shingles are generated during the demolition of existing roofs, and from scraps of trimmed asphalt shingles. Consumer aged waste shingles are referred to as tear-off shingles (90-95 percent of the available material), whereas manufacturer waste is known as roofing shingle tabs or punch-outs, which includes “out-of-spec” and mis-colored or damaged shingles. Both materials are shredded in two to three stages to achieve the desired size.

Roofing shingle tabs are used as an asphalt cement modifier often resulting in a stiffer mix with improved temperature susceptibility and rut resistance. Tear-off shingles may be used in the same way, but are difficult to process due to the presence of foreign materials, and may also be in an irreversible age-hardened state. In general, both types may function as fine aggregate or mineral filler depending on the size of the shredded material. Roofing shingles may be susceptible to moisture-related damage thus mix designs should include an anti-strip or retained stability test.(*689*)(*690*)

FHWA’s recommends asphalt shingles for use as asphalt cement modifier when contaminants and debris can be removed, and as a binder, aggregate substitute, or mineral filler, guidance which is available at their recycled waste materials website.

AASHTO and RMRC have developed a Draft White Paper for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt,(*691*) which reviews state specifications and other sources regarding addition rates of recycled asphalt shingles, found addition rates of 3 to 10 percent. The spec is likely to recommend an approach limiting the addition rate to direct performance criteria that include gradation requirements of the new hot mix asphalt, the performance grade of the virgin asphalt binder, and the volumetric properties of the new hot mix asphalt. The white paper authors believe that the principles in AASHTO MP-2, “Superpave Volumetric Mix Design” Appendix X1, which establishes various approaches to the use of RAP in Superpave mixtures depending on the percentage of RAP intended for use, are applicable, with modification, to the use of recycled asphalt shingles in hot mix asphalt applications.

State DOT Experiences with Use of Recycled Roofing Shingles

PennDOT, Mn/DOT, Illinois DOT and Iowa DOT are among the many states that have investigated waste roofing shingles in combination with bituminous concrete mixes. Pennsylvania has determined that a bituminous concrete modified with properly shredded fiberglass shingle tabs performs as well as a conventional bituminous pavement. Minnesota has had similar results with both felt and fiberglass shingle tabs. Both states were able to reduce the amount of virgin asphalt cement required a potential for cost savings. Both states have issued provisional specifications allowing limited amounts of processed shingle tabs in bituminous concrete mixes.(*692*)(*693*) Iowa DOT inspected efforts in utilizing bitumen tear-off shingles. One year after construction, the roadway remained workable and virtually dust free. NCDOT added usage of post-industrial scrap shingles to its 2002 Standard Specification Books as an alternate for all construction contracts.(*694*)

Mn/DOT has conducted several projects on the use of roofing shingles in HMA pavements. Findings from a study on their use in dense-graded mixes indicated that the addition of roofing shingle waste can result in a reduction in optimum neat binder content, enhance the ability to densify under compaction, and increase the plastic strain component in permanent deformation measurements. Cold tensile strengths were also reduced, but the impact on the corresponding strains was dependent on the type of shingle waste and the grade of asphalt cement. This finding could indicate that HMA’s potential for thermal cracking could be reduced by adding roofing shingle wastes.(*695*)

Mn/DOT also studied the use of roofing shingle waste in stone matrix asphalt mixes. The research showed that adding 10 percent of manufactured roofing shingle waste to the mix resulted in a 25- to 40-percent reduction in the required neat binder content. Mn/DOT completed a project in 1991 that used from 5 to 7 percent asphalt shingles by weight of mix. The shingles were ground to a uniform consistency resembling coffee grounds and were added to a drum mix plant as if they were recycled asphalt pavement. No construction problems were noted; further, no problems have been reported regarding pavement performance.(*696*)

NJDOT experimented with an asphalt cold-patch material made from old roofing material. The resulting patch material showed only minor signs of distress after 22 months of service. In comparison, conventional cold-patch material generally lasts only three to six months.

Illinois DOT has expressed concerns regarding the presence of any asbestos in tear offs, glass felt tabs, and/or from storage cross-contamination, along with the presence of any foreign debris from nails, wood, and insulation, and the environmental impact of polynuclear aromatic hydrocarbons present in roofing tars on plant and paving site air emissions.(*697*)

Fly Ash

Fly ash is the finely divided residue that results from the combustion of pulverized coal. This airborne residue exits a coal combustion chamber with the flue gas and is removed from the flue gas by electrostatic precipitation, baghouses, or other particulate control devices prior to the introduction of scrubber reagents. Use of recycled fly ash reduces the solid-waste disposal problems associated with fly ash, reduces the cost of concrete production, and improves the physical and mechanical properties of concrete.(*698*) Almost a quarter of the fly ash produced is recycled, most of it in Portland cement concrete, where it has been successfully used for 60 years.(*699*) Currently, over 20 million metric tons (22 million tons) of fly ash are used annually in a variety of engineering applications. Typical highway engineering applications include: Portland cement concrete (PCC), soil and road base stabilization, flowable fills, grouts, structural fill and asphalt filler (FHWA's Fly Ash Facts for Highway Engineers-online.

Fly ash may be categorized as two types. One is self-hardening and the other is non-self-hardening. Both types contain siliceous or siliceous and aluminous materials, which in the presence of lime or Portland cement and water react to form a cementitious material. The self-hardening type will form cementitious material in the presence of water alone.

AASHTO M 295 delineates the physical, chemical, and mechanical properties requirements for fly ash to comply with the Class F or Class C specifications. Generally speaking, Class F fly ash is pozzolanic, with little or no cementing value alone, and Class C has both self-cementing properties as well as pozzolanic properties.

The following uses and benefits are taken from FHWA's Fly Ash Fact Sheet for Engineers.(*700*)

Fly Ash in PCC

Fly ash is most commonly used as a pozzolan in PCC applications. Pozzolans are siliceous or siliceous and aluminous materials, which in a finely divided form and in the presence of water react with calcium hydroxide at ordinary temperatures to produce cementitious compounds. The unique spherical shape and particle size distribution of fly ash make it a good mineral filler in hot mix asphalt (HMA) applications and improves the fluidity of flowable fill and grout. The consistency and abundance of fly ash in many areas presents unique opportunities for use in structural fills and other highway applications. Fly ash utilization, especially in concrete, has significant environmental benefits including: 1) increasing the life of concrete roads and structures by improving concrete durability, 2) net reduction in energy use and greenhouse gas and other adverse air emissions when fly ash is used to replace or displace manufactured cement, 3) reduction in amount of coal combustion products that must be disposed in landfills, and 4) conservation of other natural resources and materials.

Benefits to concrete vary depending on the type of fly ash, proportion used, other mix ingredients, mixing procedure, field conditions and placement. Some of the benefits of fly ash in concrete higher ultimate strength, improved workability, reduced bleeding, reduced heat of hydration, reduced permeability, increased resistance to sulfate attack, increased resistance to alkali-silica reactivity (ASR), lowered costs, reduced shrinkage, and increased durability. Proper design and construction practices should address the potential for decreased air entraining ability with high carbon fly ash, and potential for reduced durability, reduced early strength, and reduced heat of hydration in colder climates, as indicated in FHWA's Chapter 3 (Fly Ash in Portland cement concrete) on the topic. Mass Highway also has a spec for fly ash use to mitigate Alkali-Silica Reactivity (ASR) in Portland cement concrete that says fly ash should constitute 15-30 percent of the cementitious material (15 percent by weight of the design cement content, any additional fly ash will be considered as fine aggregate); see Spec M4.02.00.(*701*)

Fly Ash in Stabilized Base Course or Pozzolanic-Stabilized Mixtures (PSMs)

Fly ash and lime can be combined with aggregate to produce a quality stabilized base course. These road bases are referred to as pozzolanic-stabilized mixtures (PSMs). Typical fly ash contents may vary from 12 to 14 percent with corresponding lime contents of three to five percent. Portland cement may also be used in lieu of lime to increase early age strengths. The resulting material is produced, placed, and looks like cement-stabilized aggregate base, but has the following advantages over other base materials: use of locally available materials, strength and durability, lower costs, autogenous healing, increased energy efficiency. This mixture also can be placed with conventional equipment. PSM bases require attention to seasonal limitations and traffic loading before complete curing.

Proper sealing and protection with asphalt or other surface treatment are required to improve skid resistance. FHWA's Chapter 4 (Fly Ash in Stabilized Base Course) provides more information on use of fly ash in stabilized base courses.

Research has demonstrated a correlation between compressive strength gain and increase in resilient modulus as a function of curing time with the addition of fly ash to stabilized recycled concrete base.(*702*) Also, a study on mechanical stabilization of cemented soil-fly ash mixtures with recycled plastic strips found ranges in strength values suitable for a high-quality stabilized base course for a highway pavement; the use of fiber reinforcement significantly increased the postpeak load carrying capacity of the mix and thus the fracture energy, leading the researchers to conclude that the lean cementitious mix containing recycled materials offer a lot of promise as an alternative material for civil engineering construction.(*703*)

Fly Ash as a Flexible Base

Several TxDOT districts have been experimenting with the use of fly ash treated (or cured) with water (hydrated fly ash) as a flexible base. They found that hydrated fly ash very easily meets strength criteria for flexible base materials and that the material can satisfactorily function as a road base for an extended period. While the Texas Transportation Institute (TTI) noted that hydrated fly ash appears to have great potential for use as a flexible base material, appropriate methods must be adopted in its production or else durability problems may arise. The researchers made the following observations and recommendations for practice on the use of fly ash as a flexible base: (*704*)

- Strict adherence to the gradation specification may not be needed; it was observed in the field that the material undergoes further hydration after placement, thus forming a stiff, nearly homogeneous layer.
- Laboratory compaction tests using hydrated fly ash with two different gradations (gap-graded and well-graded) revealed that both gradations gave nearly the same maximum dry density values, though at different moisture contents. Powdered fly ash hydrated at lower moisture contents provides much higher strengths, resulting in better resistance of the aggregate to degradation. Also, thorough mixing with the water should be emphasized. Aggregates produced using higher hydrating moisture contents possess lower unit weight and lower strength.
- Care must be taken during the curing process to ensure that the material attains to the required level of strength before it is milled. Otherwise, the material may not meet specifications for degradation and durability.
- Care must be taken during the curing process and during construction to ensure that the material is not allowed to dry excessively. If allowed to dry, it will form compounds that may impair the durability of the material.
- Sufficient allowance should be made for subsequent wetting during curing and construction, as hydrated fly ash has a high water demand. Shrinkage cracks may appear if the fly ash has not reached an advanced stage of hydration in the curing ponds.

Fly Ash in Flowable Fill

Flowable fill is a mixture of coal fly ash, water, and Portland cement that flows like a liquid, sets up like a solid, is self-leveling, and requires no compaction or vibration to achieve maximum density. In addition to these benefits, a properly designed flowable fill may be excavated later. For some mixes, an optional filler material such as sand, bottom ash, or quarry fines is added. Flowable fill is also referred to as controlled low-strength material, flowable mortar, or controlled density fill. It is designed to function in place of conventional backfill materials such as soil, sand, or gravel and to alleviate problems and restrictions generally associated with the placement of these materials. Using flowable fill allows placement in any weather, even under freezing conditions; achieves 100 percent density with no compactive effort; fills around/under structures inaccessible to conventional fill placement techniques; increases soil-bearing capacities; prevents post-fill settlement problems; increases the speed and ease of backfilling operations; decreases the variability in the density of the backfilled materials; improves safety at the job site and reduces labor costs; decreases excavation costs, and allows easy excavation later when properly designed. FHWA provides guidance for fly ash use in flowable applications in Chapter 5 (Fly Ash in Flowable Fill). Mass Highway has a spec for use of fly ash as an ingredient in very flowable *Controlled Density Fill*, available as Spec M4.08.00.(*705*)

Fly Ash in Soil Improvement

Fly ash is an effective agent for chemical and/or mechanical stabilization of soils. Typical applications include: soil stabilization, soil drying, and control of shrink-swell. Fly ash eliminates need for expensive borrow materials, expedites construction by improving excessively wet or unstable subgrade, promotes cost savings through reduction in the required pavement thickness by improving subgrade conditions, and can reduce or eliminate the need for more expensive natural aggregates in the pavement cross-section. Use of fly ash as an admixture in the stabilization of a soft marine clay has resulted in stabilized samples with an improved strength more than 75 times that of the untreated clay. Incorporation of fly ash also improved drainage property by at least one order of magnitude and reduced both the plasticity and compression indices by about 69 and 23 percent, respectively. Leachate investigation carried out on fly ash-stabilized soils indicated that chromium was well-below the World Health Organization drinking water limit, while nickel and lead were in excess of the limits. Nickel and lead leachate concentrations diminished to below the acceptable drinking water limits over about 130 and 110 days, respectively.(*706*)

Important considerations for soil improvement projects using fly ash are:

- The rate of the hydration reaction upon exposure to water.
- Soil moisture content at the time of compaction.
- Fly ash with a sulfate content greater than 10 percent may cause soils to expand more than desired.
- In many cases, leaching tests may be required by local and state agencies.

FHWA's guidelines for use of fly ash in soil improvements are discussed in their Chapter 7 (Fly Ash in Soil Improvement).

Fly Ash in Asphalt Pavements and in Pavement Subsealing

Fly ash can be used as mineral filler in HMA paving applications. Mineral fillers increase the stiffness of the asphalt mortar matrix, improving the rutting resistance of pavements, and the durability of the mix. Fly ash will typically meet mineral filler specifications for gradation, organic impurities, and plasticity. Benefits include reduced potential for asphalt stripping due to hydrophobic properties of fly ash. Lime in some fly ashes may also reduce stripping and may afford a lower cost than other mineral fillers. FHWA's guidelines for use of fly ash are in Chapter 8 (Fly Ash in Asphalt Pavement).

Grouts are proportioned mixtures of fly ash, water, and other materials used to fill voids under a pavement system without raising the slabs (subsealing), or to raise and support concrete pavements at specified grade tolerances by drilling and injecting the grout under specified areas of the pavement. Fly ash grouts can be used to correct undermining without removing overlying pavement and can be accomplished quickly with minimum disturbance to traffic. Fly ash grouts also develop high ultimate strength; however, they require curing period before extremely heavy loading because of low early strength and require confinement of the grout mixture under pavement.

Fly Ash in Structural Fills/Embankments

Fly ash can be used as a borrow material to construct fills and embankments. When fly ash is compacted in lifts, a structural fill is constructed that is capable of supporting highway buildings or other structures. Fly ash has been used in the construction of structural fills/embankments that range from small fills for road shoulders to large fills for interstate highway embankments. When used in structural fills and embankments, fly ash offers several advantages over soil and rock. It is cost-effective where available in bulk quantities and eliminates the need to purchase, permit, and operate a borrow pit. Fly ash can be placed over low bearing strength soils and ease of handling and compaction reduces construction time and equipment costs. Further practice recommendations are detailed in FHWA's Chapter 6 (Fly Ash in Structural Fills/Embankments) and AASHTO's specification.(*707*)

AASHTO's draft specification for use of fly ash in embankments and structural fills identifies a number of recommended practices: (*708*)

- Fly ash must be conditioned at the source prior to use. If self-hardening fly ash is used, this conditioning will result in rapid curing and hardening, making the cured product unsuitable for use without reprocessing (by recrushing) of the material prior to placement.
- The purchaser or specifier should include in the purchase order or contract documents references to the spec and to state and/or local environmental protection agency requirements, as well as grading and blending requirements, type or types of fly ash specified, and exceptions or additions to the spec.
- Due to the fact that local agencies have widely differing policies and/or regulations regarding where and how fly ash can be used as a structural fill or embankment material, out of concerns relative to leachate that might contain elevated levels of contaminants, local requirements must be investigated when considering the use of fly ash as a structural fill or embankment material.
- The engineer should be aware that the engineering properties of fly ash are similar to those of non-cohesive silt materials. The silt-like nature of fly ash is sufficiently different from traditional embankment materials that specialized practices are required for the successful construction of fly ash embankments.
- Proper compaction is critical to the performance of a conventional soil embankment or structural fill and may even be more so when recycled materials, such as fly ash, are used in such construction. Fly ash can be expected to exhibit high water absorption and, because of the fineness (size) of the material, a propensity to retain inter-granular water. As a result, fly ash, in most instances, will exhibit a higher optimum moisture content and a lower maximum dry density value than conventional embankment materials. Maximum dry density values may also vary somewhat from day to day or even from truck load to truck load. The engineer is cautioned to provide appropriate construction specifications to ensure compaction of the embankment to the extent that further densification of the compacted embankment from traffic loadings will be insignificant. At the time of placement, the fly ash material should contain the necessary moisture content to ensure that the design density requirements are obtained when the material is compacted.
- If necessary for proper compaction, water should be added to the fly ash by the use of a water distribution tank trucks. The water and fly ash should be mixed using a rototilling mixer or other approved method. At the time of compaction, the fly ash should have a moisture content that will result in an after compaction dry density greater than that specified.
- The first pass in the compaction process should be accomplished by the method known as tracking. This involves the use of a bulldozer track to accomplish initial compaction. The

bulldozer is moved progressively across the fly ash structural fill or embankment until the entire area is tracked.

- The fly ash structural fill or embankment should subsequently be compacted using pneumatic tired, vibratory or other approved types of compaction equipment. The equipment should work from the edge of the structural fill or embankment toward the center.
- At the completion of each days work, the surface of the fly ash structural fill or embankment should be sealed. This means that it should be graded after compaction so that rain would tend to flow off the embankment rather than penetrate into the material.
- Fly ash should be compacted using vibratory, pneumatic tired or other proven effective rollers or tampers, until the density no longer increases. Compaction techniques may vary among jurisdictions. However, as a matter of practicality lift thicknesses for fly ash of 20 or 25 centimeters (8 or 10 inches) are generally specified. A defined and effective rolling pattern should be developed. Acceptance of each lift should be based on in-place density as a percentage of maximum dry density as determined by AASHTO T 310.
- Delivery of fly ash should be in closed or covered trucks. To avoid the dispersement of fly ash, deliveries of fly ash should not be placed in temporary stockpiles on the project site and should be discharged directly to the embankment site where placement and compaction will take place. The delivery, placement, spreading, and compaction of fly ash should be carefully planned so that the work can proceed from one step to the next without delay.
- Before construction of the fly ash embankments begins, containment berms should be constructed to a thickness of at least six feet at the top of each containment berm segment and located on the outside limits of the embankment foot print. The containment berm segments should have a trapezoidal cross section and side slopes of 2:1 or less. As the structural fill or embankment is constructed upward, containment berms should be placed on the outside of each new tier before placing fly ash. For narrow embankments, like ramps, the engineer may consider narrower containment berms.
- The natural soil materials should be placed in 20 centimeter (8-inch) loose lifts. Containment berms should be compacted as required by the specifying agency. Fly ash material should also be spread into loose lifts of approximately 20 centimeter (8-inch) thickness. The engineer may consider thicker lift dimensions if it can be satisfactorily demonstrated with a test section that adequate compaction can be achieved over the full depth of the thicker lift.
- Fly ash should be conditioned for dust control and to prevent erosion by the addition of from 10 to 15 percent water by mass at the source site prior to delivery. This conditioning may include subsequent storage (stockpiling) of the fly ash after it has had water mixed with it for a period of 24 hours or more until the water is evenly dispersed. If the supplier can demonstrate that water is evenly distributed throughout the fly ash, then stockpiling may not be required.
- As fly ash that is not protected from the elements may become saturated with rainwater and erode or release soluble components, there should be no large-scale storage of fly ash at the project construction site. Small amounts of fly ash may be stored for short periods

of time to facilitate construction specifications when done in accordance with the project sediment and erosion control plan.

- The contractor should make available and use water, if necessary, to control the generation of dust due to drying of the fly ash.
- The final grade of the fly ash structural fill or embankment should be accomplished by the placement of at least 60 centimeters (24 inches) of compacted natural soil material at the top of the embankment, placed in four 20-centimeter (8-inch) loose lifts. The entire structural fill or embankment structure, with the exception of the roadway pavement structure, should be covered with at least 20 centimeters (8 inches) of topsoil.
- In the event impermeable containment below the fly ash structural fill or embankment is required by the specifying agency, then such containment should be accomplished in accordance with the permeability requirements of the specifying jurisdiction.
- If chemically stabilized fly ash is specified, the contractor should submit a mix design for approval by the engineer. The materials should be mixed in a pugmill or other approved method. The use of certain stabilizing agents may elevate pH values of aqueous solutions that may contact metal structures or conduits within the stabilized fly ash embankment. (*33*)

In FHWA's Fly Ash Fact Sheet for Engineers, FHWA points out potential frost susceptibility problems with fly ash and recommends that a layer of coarse-grained material be placed below the embankment to break the capillary structure and prevent the vertical migration of water to freeze zones.(*709*) Most states are concerned with the potential for capillary water migration and the resulting loss of stability, and frost susceptibility in fly ash structural fills and embankments. As a result, many states require the placement of special materials to prevent ground water migration. In some cases a highly granular layer of soil material at the bottom of the fly ash embankment is specified. This acts as an openly porous structure, providing a discontinuity to the vertical capillary movement of water. In other cases a cover of two or three feet of traditional soil material over the top of the fly ash that prevents the penetration of frost into the fly ash layer from above (thus preventing a site within that layer where ice lens and ultimately frost heating may occur) is specified.(*710*)

- The vertical migration of water may be minimized or prevented by the placement of an open-pored granular material at the base of the fly ash structural fill or embankment. This underlayer effectively stops vertical water migration because the soil pore structure is so large the surface tension of water is not sufficient to move the water upward. This granular layer at the base of the embankment will prevent the possibility of saturation and loss of shear strength.
- The onset of freezing in the upper portion of the embankment may be prevented from occurring within the fly ash layer by the placement of sufficient cover material. Generally, frost will penetrate into the soil as a function of the prevailing winter temperatures for a given geographic area. In order to prevent the penetration of frost in most areas, at least 90 centimeters (36 inches) of cover, consisting of a natural soil material, should be placed over the fly ash structural fill or embankment. This will act as a kind of thermal insulation. In extreme northern locations, additional cover may be required, but as a general rule 90 centimeters (36 inches) should be sufficient.

- A granular base layer at least 60 centimeters (24 inches) thick may be placed below the fly ash and a minimum cover of three feet of soil aggregate above the fly ash should be required.
- Some states have indicated success with reducing frost susceptibility by blending fly ash with bottom ash or other coarse materials to alter the capillary structure.
- The potential for frost susceptibility may be evaluated in the laboratory by the use of ASTM Standard D 5918-96. This test method involves the compaction of a soil specimen and then freezing it at one end while free liquid water is in contact with the other end of the specimen. The specimen is subjected to a conditioning cycle and then two freeze-thaw cycles. The specimen is measured for heave and then it is tested for California Bearing Ratio after freeze-thaw cycling. The California Bearing Ratio value is compared with a control test where the specimen is not subjected to freeze-thaw.

DOT Experiences with and Requirements for Use of Fly Ash in Embankments

DelDOT requires that a fly ash embankment be built on a foundation that consists of 30 centimeters (12 inches) of washed sand and a minimum of 60 centimeters (24 inches) of traditional borrow material. This layered structure serves the purpose of breaking the capillary system as well as being a drainage foundation for the embankment.

The Illinois Department of Transportation (IDOT), in its special provisions for the use of coal combustion by-products as embankment in an on-going airport project, requires that a protective clay liner 90 centimeters (36 inches) thick be placed below the fly ash layer, and above this layer place a 1.5 millimeter (60-mil) polyvinyl chloride geomembrane. Progressing upward, a 30 centimeter (12 inch) thick sand blanket is placed. IDOT also requires that the fly ash embankment be covered with a 60 centimeter (2 foot) layer of clay. The IDOT system prevents frost from penetrating into the fly ash, it prevents capillary movement of water upward through the fly ash, and it prevents the percolation of water into or out of the fly ash. IDOT's specifications are primarily intended to prevent leachate generation and migration. When IDOT anticipates that frost heaving may be a problem on a project where coal combustion by-products or other materials are used, it requires that 60 centimeters (2 feet) of cover be placed. This cover should have a plasticity index of not less than 12, a liquid limit of less than 50, and a total of silt and fine sand content not more than 65 percent.

The Ohio Department of Transportation specifies the containment of the fly ash embankment core with a 2.5 meter (8 foot) thick layer of natural soil above the fly ash core. A drainage system is also required at the base of the embankment. The lateral containment and overburden layer are intended to prevent frost penetration into the fly ash embankment.

MDSHA requires that a one meter (three foot) thick filter layer be placed below the fly ash embankment. A one meter (three foot) thick cover layer of soil aggregate is then placed over the fly ash embankment. This overlayment may include all pavement components.

NCDOT prevents frost penetration into the embankment by requiring a 30 centimeter (12 inch) cover be placed over the fly ash with an additional 15 centimeters (6 inches) of topsoil on the slopes. This totals 45 centimeters (18 inches) of frost protection. These layers also provide erosion control and a medium for plant growth.

The Virginia Department of Transportation (VDOT) requires that a 30 centimeter (12 inch) thick layer of free-draining material be placed in the footprint of the fly ash embankment. VDOT requires that this material contain no more than ten percent by mass passing the 75 Fm (No. 200) sieve. This layer acts as an open-graded layer that breaks the capillary flow of water upward into the fly ash embankment. VDOT also requires that a soil material be the final 30 centimeters (12 inches) of material placed on slopes.

Two states (Maryland and North Carolina) have established specifications for the use of fly ash in structural fill or embankment applications. Neither of these states establishes any requirement for gradation. Most localities specify a maximum size limit for embankment material, e.g., ten centimeters (four inches). Due to its fine nature, fly ash can always be expected to comply with such a top size specification. There are several jurisdictions that permit the blending of fly ash with other materials (e.g., coal combustion bottom ash) prior to use and other jurisdictions that restrict blending. DelDOT does not permit the mixing of fly ash and bottom ash for structural fill and embankment applications. MDSHA and NCDOT do not permit the mixing of fly ash and bottom ash for structural fill and embankment applications. Fly ash alone is the only material permitted to be used.

The loss on ignition (LOI) test is a measure of the amount of unburned carbon that is present in the fly ash. While there are rigid limitations when fly ash is used as an admixture in Portland cement concrete, such limitations need not be as demanding when fly ash is used as a structural fill or embankment material. One state (Illinois) was found to limit the LOI content of fly ash used in embankments. The AASHTO spec limits LOI content to ten percent.

Due to the chemistry of some fly ash materials, the pH of aqueous solutions that pass through a fly ash structural fill or embankment could induce corrosive conditions**.** Drainage and utility structures in the vicinity of such a structural fill or embankment are of particular concern. Reinforced concrete and metal culvert pipe may be reactive in low or high pH environments. The Virginia Department of Transportation places some limits on corrosive potential of fly ash and defines such limitations in terms of pH. VDOT limits the pH of fly ash to a range of from 5 to 9.

Foundry Sand

Recycled foundry sand (RFS) or Waste Foundry Sand (WFS) is high quality silica sand with uniform physical characteristics. It is a byproduct of the ferrous and nonferrous metal casting industry, where sand has been used for centuries as a molding material because of its thermal conductivity. In modern foundry practice, sand is typically recycled and reused through many production cycles. The automotive industry and its suppliers are the primary generators of this material. The presence of heavy metals is of greater concern in nonferrous foundry sands. WFS generated from brass or bronze foundries may contain high concentrations of cadmium, lead, copper, nickel, and zinc.

RFS grain size distribution is more uniform and somewhat finer than conventional concrete sand. The fineness of this substance contributes to good suspension limiting segregation in flowable fills, which are manmade self-leveling, self-compacting backfills. The material displays favorable durability characteristics with resistance to weathering in bituminous concrete paving applications; however, the high amount of silica found in this material may result in stripping of the asphalt cement coating aggregate, which contributes to pavement deterioration.(*711*) Foundry sand can replace as much as 15 percent of fine aggregates in asphalt concrete and as much as 45 of the fine aggregate in concrete (though green sand can replace only 9 to 15 percent of the fine aggregate), a percentage which industry says can be increased if the foundry sand is processed and fines are removed.(*712*) Purdue University conducted a study with bituminous concrete samples containing up to 30 percent WFS; this study concluded that including more than 15 percent WFS lowered the unit weight, increased air voids, decreased the flow and stability of the mixes, and reduced the indirect tensile strength.(*713*)

Foundry sands have also been used as structural fills in highway embankments and sub-grade projects. The specifications for using foundry sands as fill materials generally have been the same as the specifications for typical backfills. These specifications are universal and vary depending on the use of the material, i.e. embankment, structural fill, roadway sub-base, and foundation sub-base, and consist of compacting the material in layers to a minimum percentage of the maximum dry unit weight. The material should also be compacted to a minimum unit weight of 14.9 kN/m3 (95 pcf) and at a water content around optimum water content. Most specifications require a maximum liquid limit of 65 percent, and a plasticity index less than the liquid limit minus 30. Most foundry sands satisfy these requirements and therefore are eligible to be considered as construction fill materials. Foundry sand has also been studied for use in flowable fills.

Glass Aggregate/Cullet

Glass makes up approximately 7 percent (approximately 12 million tons) of the total weight of U.S. municipal solid waste discarded annually; approximately 20 percent of this glass is being recycled, primarily for cullet in glass manufacturing.(*714*) Recycling efforts around the country have led to large quantities of broken glass aggregate, or cullet, in many areas that finds few uses due to mixing of colors and high transport costs. The material's density and color is not an obstacle for use in the transportation industry though. The ability to use glass in highway construction depends on the types of collection methods used, costs, and public factors. In general, the large quantities of waste glass needed for such application are found only in major metropolitan areas.(*715*)

When glass is properly crushed, glass cullet exhibits coefficient of permeability similar to coarse sand. Also, the high angularity of this material, compared to rounded sand, may enhance the stability of asphalt mixes. In general, glass is known for its heat retention properties, which can help decrease the depth of frost penetration. Recycled waste glass can increase the strength, durability and aesthetic appearance of concrete products. Harmful expansion can occur when alkali in the cement paste reacts with the silica in the glass, but technical research has led to ways to suppress the detrimental effects of alkali-silica reaction. While use of glass may not be cheaper unless a ready supply is available nearby, glass is durable, abrasion resistant, improves the flow properties of fresh concrete so that very high strengths can be obtained and can serve both as partial cement replacement and filler.(*716*)

AASHTO's Final Glass Cullet specification - Designation: M 318-01 recommends the following practices in use of glass cullet for soil aggregate base course. (30)

- The engineer should provide appropriate construction specifications to ensure that sufficient compaction is achieved so that further densification of the completed pavement from traffic loadings will be insignificant. The method requires compaction of the material at a suitable moisture content on a firm foundation of a short control strip by means of vibratory or other proven effective rollers or tampers, until no further increase in density results. Compaction requirements should ensure that the average density of the final base course is an appropriate percentage of the maximum density obtained for the control strip; for base courses, achieving on average 98 percent of the maximum control strip density is suggested.

- The DOT should reference the AASHTO specification, grading to be furnished for the granular base, percentage of glass cullet by mass in the granular base, the optimum moisture content and maximum density of the granular base, and exceptions or additions to the specification.
- The glass cullet should consist of broken food and beverage containers. China dishes, ceramics, or plate glass should be limited to a maximum of 5 percent by mass of glass cullet. Container tops, paper, labels, food residue, foil, wood and other deleterious materials should be limited to a maximum of 1 percent by mass of the glass cullet of which no more than 0.05 percent by mass of paper should be permitted. Extraneous soil-like materials should be limited to a maximum of 2 percent by mass of the glass cullet. Methods to determine these are discussed in the AASHTO spec. Glass cullet should be free of TV or other cathode ray tubes, fluorescent light bulbs, and any toxic or hazardous materials as defined by the state or local jurisdiction.
- Glass cullet should be crushed and screened if necessary so that 100 percent of the glass cullet material passes the 9.5 mm (3/8 in.) sieve. Glass cullet should be free of odor.
- Glass cullet material should be processed so as to limit the quantity of shard-like particles to less than 1 percent by mass as measured by ASTM Standard D 4791, Flat and Elongated Particles in Coarse Aggregate.
- Glass cullet should be combined with soil-aggregate material to form a blended material conforming to the requirements of AASHTO Standard M 147, ASTM D 2940, or the requirements of the specifying jurisdiction.
- The supplier should be permitted to use up to 20 percent by mass of glass cullet in composite glass cullet/soil-aggregate mixtures. If the engineer wishes to use a combination of materials that exceeds the glass percentage limit indicated above, then reference should be made to the evaluation methods described in the AASHTO spec.
- The supplier should ensure that composite material is uniformly blended.
- Glass cullet soil-aggregate composite should be sampled and tested in accordance with standard methods of the American Association of State Highway and Transportation Officials.

DOT Experiences with Glasphalt and Glass Aggregate

In bituminous pavements, glass bonds poorly to the asphalt, which can result in stripping and raveling problems.(*717*) Glasphalt is a new road building material that consists of 30 percent recycled waste glass that has been used in several road maintenance projects in the United Kingdom. Glasphalt is a base-course material that forms part of the structure of the road beneath the surface or wearing course. Trials have shown that glasphalt matches the properties of other sub-base systems when mixed with crushed limestone. Glasphalt can be produced using standard asphalt methods and laid using conventional equipment, and has the advantage of remaining workable longer than traditional asphalt.(*718*)

Glass aggregate has been investigated by a number of state DOTs including New York, Washington, Pennsylvania, and Texas. Since the 1960s, Washington DOT (WSDOT) has used a portion of glass aggregate in bituminous concrete pavements. This aggregate material is also used in backfill for foundations, pipe bedding, and other applications not subject to heavy repeated loading. WSDOT has not utilized this material on any recent projects. NYSDOT uses a limited amount of this material in embankments and bituminous concrete base and binder courses. This is a non-surface mix material because of concerns that it could result in injury claim liability. NYSDOT has experienced problems with stripping asphalt binder not adhering to aggregate that may be controlled by adding an anti-stripping agent, which in turn adds costs. Pennsylvania DOT also allows a portion of this material in nonstructural fills and drainage applications, while experimentation with this material in bituminous concrete has yielded results similar to New York's.

New Jersey Department of Transportation (NJDOT) specifications has allowed the substitution of up to ten percent glass (by weight) for aggregate in asphalt base courses. In 1992, the department placed two sections of asphalt surface courses of about 0.5 kilometers (0.3 miles) each containing ten percent glass. One of the sections contained an anti-strip additive; the other did not. Results to date indicate that both of these sections are performing as well as conventional pavement. The Clean Washington Center of Seattle, Wash., has conducted laboratory tests on glass cullet for compaction, durability, gradation, permeability, shear strength, specific gravity, thermal conductivity, and workability as a construction aggregate. The center has subsequently developed recommendations for the approximate percentages of glass to be used for different applications.(*719*)

Several agencies are routinely using recycled glass in the manufacture of glass beads for traffic control devices, and now the material is being used in filtration as well. NYSDOT has used crushed glass (3/8" to 5/8" – See NYSDOT Spec 17605.13 M - Crushed Glass Water and Stormwater Pollution Control Filter) as a Pre-filter to fabric in a filtration system to remove hydro-demolition waste material.(*720*) At a cost of approximately $4.00/ton for glass, compared to approximately $20/ton for sand, glass has provided a lighter and easier medium for the contractor to handle, a higher porosity (ten seconds per inch) than common sand, and the ability to backfill post-filtration material as "Exempt C&D" waste.(*721*) Most importantly for the environment, the filtration method reduced Total Suspended Solids (TSS) from 2800 mg/L to 150 mg/L, a removal rate of 96 percent, while reducing pH from 12.0 to 11.8 Std units.(*722*) Finally, crushed glass material is readily available in the vicinity of recycling facilities.

Mass Highway's specifications for processed glass aggregate require the material to consist of recycled glass food or beverage containers free of debris and manufactured from an approved supplier of crushed cullet, (*723*) (M2.01.8), and stipulate that glass cullet:

- May be homogeneously blended with *Ordinary Borrow* material up to an addition rate of ten percent by mass in unexposed areas. (*724*) (M1.01.0)
- May be homogeneously blended with *Special Borrow* material up to an addition rate of ten percent by mass in unexposed areas. (*725*) (M1.02.0)
- May be homogeneously blended with *Gravel Borrow* material up to an addition rate of ten percent by mass in unexposed areas. (*726*)(M1.03.0)
- May be homogeneously blended with *Processed Gravel* material for *Subbase* up to an addition rate of ten percent by mass in unexposed areas. (*727*) (M1.03.1)

- May be homogeneously blended with *Sand Borrow* material up to an addition rate of ten percent by mass in unexposed areas. (*728*) (M1.04.0)
- May be homogeneously blended with *Sand Borrow* material for *Subdrains* up to an addition rate of ten percent by mass in unexposed areas. (*729*) (M1.04.1)
- May be homogeneously blended with *Dense Graded Crushed Stone* material for *Subbase* up to an addition rate of ten percent by mass in unexposed areas. (*730*) (M2.01.7)
- May be used as *Mineral Aggregate in Class I Bituminous Concrete* at a maximum addition rate of ten percent by mass (in place of RAP). (*731*) (M3.11.00)

TTI's Study 0-1331, *Use of Glass Cullet in Roadway Construction*, identifies sound engineering and environmental uses of glass cullet in roadway construction and maintenance projects and develops specifications. After conducting literature reviews and identifying uses, disadvantages or obstacles, and costs, TTI performed lab testing to provide information not available from the literature search or to ensure the accuracy of the information found. The TTI research team found glass cullet to be appropriate in the following non-pavement applications, according to the specifications below: (*732*)

Table 15: Non-Pavement Applications for Glass Cullet - TxDOT/TTI

TxDOT Item No.	Application	Percentage of Glass Cullet
132	Embankments	Shall not exceed 20% by weight of the total mix
247	Flexible Base (Type D)	Shall not exceed 20% by weight of the total mix
301	Asphalt Antistripping Agents	When cullet is used as an aggregate in asphalt-stabilized bases, lime and some liquid antistripping agents may not perform adequately.
345	Asphalt Stabilized Base	Shall not exceed 5% of the total weight of the aggregate
400	Excavation and backfill for structures	a.) Utility bedding material may comprise up to 100% b.) Backfill that will support any portion of roadbed or embankment shall include less than 20% c.) Backfill that does not support any portion of the roadbed or embankment may include up to 100%
423	Retaining Wall	Structural backfill limited to maximum of 20% Non-structural backfill up to 100%
556	Pipe Underdrains	Up to 100%
Other	Open-graded Base Courses	The use of cullet in this application shall be governed by Item 345, "Asphalt Stabilized Base." Not to exceed 5%.

FHWA's guide for waste glass recycling discusses Asphalt Concrete Aggregate and Granular Base or Fill applications and is available at the Turner Fairbanks Highway Research Center recycling site.(*733*)

Steel Slag

Steel slag, a by-product of steel making, is produced during the separation of the molten steel from impurities in steel-making furnaces. The slag occurs as a molten liquid melt and is a complex solution of silicates and oxides that solidifies upon cooling. Virtually all steel is now made in integrated steel plants using a version of the basic oxygen process or in specialty steel plants (mini-mills) using an electric arc furnace process. Steel slag has sufficient material properties including favorable frictional properties, high stability, and resistance to stripping and rutting. In general, processed (i.e. crushed) steel slag is more angular, more dense and harder than comparable natural aggregates.(*734*) Consequently, steel slag has been considered as an aggregate for use in granular base, embankments, engineered fill, highway shoulders, and hot mix asphalt pavement.

FHWA advises that prior to its use as a construction aggregate material, steel slag must be crushed and screened to meet the specified gradation requirements for the particular application. It is primarily used as a coarse aggregate for use in high-type bituminous concrete mixes and seal coats. The slag processor may also be required to satisfy moisture content criteria (e.g., limit the amount of moisture in the steel slag aggregate prior to shipment to a hot mix asphalt plant) and to adopt material handling (processing and stockpiling) practices similar to those used in the conventional aggregates industry to avoid potential segregation. In addition, expansion due to hydration reactions should be addressed prior to use.(*735*)

Scrap Iron Use for Steel Reinforcement

Scrap iron for steel reinforcement comes from salvaged automobiles, appliances, and steel-reinforced structures which include reinforced concrete pavements, bridges, and buildings. Tons of steel and aluminum scrap recovered from guardrails, sign posts and signs from DOT construction projects is auctioned off to metal scrap dealers each year. The steel industry currently utilizes steel scrap to make structural shapes and plates at the rate of 95 percent and to make steel reinforcing bars at the rate of 47.5 percent.(*736*)

Two common forms of steel production are the basic oxygen and electric arc processes. In the electric arc process, "cold" ferrous material, which is generally 100 percent scrap steel, is the major component melted with alloys in an electric furnace. In the basic oxygen process, molten iron is removed from the blast furnace, combined with alloys, and up to 30 percent steel scrap-used as an additive to lower the temperature of the molten composition. In both processes, high-pressure oxygen is blown into the furnace causing a chemical reaction that separates the molten steel and impurities, which can be recycled as slag (*737*)(*738*)

Steel reinforcement plays an important role in concrete structures; for example, reinforcing in PCC pavements holds cracks together ensuring high aggregate interlock exists across the pavement. Steel reinforcement is used to strengthen concrete structures, such as reinforced PCC pavements and bridge decks. Two types of commonly used reinforced concrete pavements are jointed reinforced concrete (JRC) and continuously reinforced concrete (CRC). JRC pavements utilize welded wire fabric, while CRC consists of overlapping longitudinal and transverse reinforced steel bars.(*739*)

While steel scrap iron is usually recycled, finding alternatives to minimize use also saves on resource consumption and disposal costs, and in the case of guardrail repair times and costs as well. Colorado DOT is replacing some sections of guardrail with wire rope safety fence (WRSF), which has the lowest life cycle costs of any barrier examined and notably improves safety, here measured as driver ability to walk or drive away from accidents. When the WRSF is impacted, usually only a few posts are damaged and must be replaced. In the case of guardrail, posts and long sections of guardrail have to be replaced. While steel can be recycled the fact that much less needs to be replaced with WRSF is a real benefit. Repairs required for vehicles that impact the WRSF are significantly less than other types of safety barriers. Furthermore, during repair, guardrail usually requires heavy equipment and a lane closure greatly slowing traffic (fuel and emissions). WRSF can be repaired with one man in a pickup without a lane closure in normally less than 30 minutes. The design allows small animals to pass through, and has been credited with saving many koala bear lives in Australia. Snow plowing is minimized because snow passes through the design instead of drifting up against it. The same benefits apply in desert conditions with blowing sand. WRSF also offers the visual attributes of blending into the surroundings. WRSF can also help minimize the approach slope needed; concrete barrier and guardrail require ten to one approach slopes while WRSF can have six to one slopes, adding a land consumption benefit in some cases.(*740*)

Wet Bottom Ash and Boiler Slag

Wet-Bottom Boiler Slag (WBBS or "black beauty") is a by-product of coal burning in wet-bottom boilers. Slag tap boilers burn pulverized coal and retain up to 50 percent of the accumulated ash as slag-the rest being fly ash. Cyclone boilers burn crushed coal, and retain as much as 80 percent as boiler slag. In both cases, the bottom ash is held at the bottom of the furnace in a molten liquid state, hence the name "wet-bottom." The product is generally a durable material of uniform size that can be blended with other fine aggregates to meet gradation requirements. WBBS has been used most extensively by local governments on lower volume roads as a seal coat aggregate on very low volume highways or as an abrasive mixed with deicing salt. It can also be used as an aggregate in top surface dressing of bituminous surfaces, embankments, trench backfills, sand backfills for underdrains, bedding, porous granular backfills, membrane water proofing, snow and ice control. It has been used in roadway base and subbase applications as well.

Bottom ash is a coarse, angular material of porous surface texture and size ranging from fine gravel to fine sand, predominantly sand-sized, composed of silica, alumina, and iron with small amounts of calcium, magnesium, and sulfate. Bottom ash has been used for snow and ice control, as aggregate in lightweight concrete masonry units, and as raw feed material for Portland cement. This material has also been utilized as an aggregate in cold mix emulsified asphalt mixes, base or subbase courses, or in shoulder construction, where the gradation and durability requirements are not as critical. West Virginia and Texas researchers conducted a study in which some of the observations made concluded that performance depends on the amount of pyrites and sulfates present. Also, the quality of the material depends upon how the material was stockpiled before use.(*741*)

FHWA's recommended uses for wet bottom ash and boiler slag include the following: (*742*)

Example 13: Uses of Recycled Bottom Ash and Boiler Slag

Both bottom ash and boiler slag have been used as fine aggregate substitute in hot mix asphalt wearing surfaces and base courses, and emulsified asphalt cold mix wearing surfaces and base courses. Because of the "popcorn," clinkerlike low durability nature of some bottom ash particles, bottom ash has been used more frequently in base courses than wearing surfaces. Boiler slag has been used in wearing surfaces, base courses and asphalt surface treatment or seal coat applications. There are no known uses of bottom ash in asphalt surface treatment or seal coat applications.

Screening of oversized particles and blending with other aggregates will typically be required to use bottom ash and boiler slag in paving applications. Pyrites that may be present in the bottom ash should also be removed (with electromagnets) prior to use. Pyrites (iron sulfide) are volumetrically unstable, expansive, and produce a reddish stain when exposed to water over an extended time period.

Granular Base (Bottom Ash and Boiler Slag)

Both bottom ash and boiler slag have occasionally been used as unbound aggregate or granular base material for pavement construction. Bottom ash and boiler slag are considered fine aggregates in this use. To meet required specifications, the bottom ash or slag may need to be blended with other natural aggregates prior to its use as a base or subbase material. Screening or grinding may also be necessary prior to use, particularly for the bottom ash, where large particle sizes, typically greater than 19 mm (3/4 in), are present in the ash.

Stabilized Base Aggregate (Bottom Ash and Boiler Slag)

Bottom ash and boiler slag have been used in stabilized base applications. Stabilized base or subbase mixtures contain a blend of an aggregate and cementitious materials that bind the aggregates, providing the mixture with greater bearing strength. Types of cementitious materials typically used include Portland cement, cement kiln dust, or pozzolans with activators, such as lime, cement kiln dusts, and lime kiln dusts. When constructing a stabilized base using either bottom ash or boiler slag, both moisture control and proper sizing are required. Deleterious materials such as pyrites should also be removed.

Embankment or Backfill Material (Mainly Bottom Ash)

Bottom ash and ponded ash have been used as structural fill materials for the construction of highway embankments and/or the backfilling of abutments, retaining walls, or trenches. These materials may also be used as pipe bedding in lieu of sand or pea gravel. To be suitable for these applications, the bottom ash or ponded ash must be at or reasonably close to its optimum moisture content, free of pyrites and/or "popcorn" like particles, and must be non-corrosive. Reclaimed ponded ash must be stockpiled and adequately dewatered prior to use. Bottom ash may require screening or grinding to remove or reduce oversize materials (greater than 19 mm (3/4 in) in size.

Flowable Fill Aggregate (Mainly Bottom Ash)

Bottom ash has been used as an aggregate material in flowable fill mixes. Ponded ash also has the potential for being reclaimed and used in flowable fill. Since most flowable fill mixes involve the development of comparatively low compressive strength (in order to be able to be excavated at a later time, if necessary), no advance processing of bottom ash or ponded ash is needed. Neither bottom ash nor ponded ash needs to be at any particular moisture content to be used in flowable fill mixes because the amount of water in the mix can be adjusted in order to provide the desired flowability.

Flue Gas Desulfurization (FGD) Waste

Research on the use of Flue Gas Desulfurization (FGD) waste has focused on its use in stabilized road bases and as an embankment material. Research by the Texas Transportation Institute addressed the use of cement-stabilized FGD waste in roadbase construction.(*743*) The research consisted of placing two 91.4 m (300 ft) experimental sections containing FGD waste stabilized with 7 percent by dry weight of high early strength, high sulfate-resistant Portland cement. To date, no distress related to the FGD waste in either pavement section has been identified. It was also found that the strength of the cement-stabilized FGD increased when mixed with coal bottom ash. Additionally, surface water and soil leachate were analyzed for both sections; the material constituents were compared with EPA drinking water standards and TCLP concentrations. The results showed that none of the EPA heavy metal concentrations were exceeded. However, the drinking water standards were exceeded for sulfates; TCLP standards do not contain values for sulfate levels.

Tire/Rubber Scraps

Approximately 280 million tires are discarded each year in the U.S., approximately one per person, only 15 million of which are converted to crumb rubber.(*744*) Around 30 million of these tires are retreaded or reused, leaving roughly 250 million scrap tires to be managed annually.(*745*) In addition, it has been estimated that there may be as many as 2 to 3 billion tires that have accumulated over the years and are contained in numerous stockpiles.(*746*)

In addition to tires produced by the general public, tires are a significant waste stream produced by DOTs in the operation and maintenance of hundreds of vehicles. Beside resource depletion (tropical forests) and tire disposal concerns, waste tires have the potential to create a variety of health and safety hazards: tire fires are very difficult to extinguish and stockpiles of waste tires are prime breeding habitats for certain rodents and insects.

A number of DOTs have been contributing to tire recycling efforts. As one example, Indiana DOT (INDOT) is collecting tires at facilities for pickup by a private company that grinds them into small pieces and incorporates them in playground cover, walking trails, running tracks and horse arena covering. In the two years that the program has been in operation, INDOT has diverted well over 20,000 tires of varying sizes from Indiana landfills. Scrap tires, tire pieces that are collected off of the state roads and highways by INDOT maintenance crews are stored in roll-off containers and are taken to landfills where they are utilized in the construction of leachate collection systems and daily cover to aid in drainage. In the past two years, INDOT has recovered and diverted approximately 650 tons of scrap tires from Indiana highways and State Roads.

Asphalt Rubber/Rubber Pavements

The benefits of asphalt rubber use include reduced reflective cracking, traffic noise, design thickness, life cycle costs, increased fatigue life, and resistance to rutting. Asphalt Rubber Hot Mix Gap Graded Specification, is the most popular mix used by agencies in the U.S.(*747*) Asphalt-Rubber is a mixture of 80 percent hot paving grade asphalt and 20 percent ground tire rubber.

FHWA notes the following applications for ground rubber as an aggregate substitute and as an asphalt modifier: (*748*)

- Aggregate Substitute - Ground Rubber has been used as a fine aggregate substitute in asphalt pavements. In this process, ground rubber particles are added into the hot mix as a fine aggregate in a gap-graded friction course type of mixture. This process, commonly referred to as the dry process, typically uses ground rubber particles ranging from approximately 6.4 mm (1/4 in) down to 0.85 mm (No. 20 sieve). Asphalt mixes in which ground rubber particles are added as a portion of the fine aggregate are referred to as rubberized asphalt.
- Asphalt Modifier - Crumb Rubber can be used to modify the asphalt binder (e.g., increase its viscosity) in a process in which the rubber is blended with asphalt binder (usually in the range of 18 to 25 percent rubber). This process, commonly referred to as the wet process, blends and partially reacts crumb rubber with asphalt cement at high temperatures to produce a rubberized asphalt binder. Most of the wet processes require crumb rubber particles between 0.6 mm (No. 30 sieve) and 0.15 mm (No. 100 sieve) in size. The modified binder is commonly referred to as asphalt-rubber.
- Asphalt-rubber binders are used primarily in hot mix asphalt paving, but are also used in seal coat applications as a stress absorbing membrane (SAM), a stress absorbing membrane interlayer (SAMI), or as a membrane sealant without any aggregate.

After a surge of interest in the early 1990s, partially related to ISTEA mandates, FHWA and RMRC undertook research projects to resolve specific issues. To address problems states experienced in preparing pavements using the crumb rubber modified asphalt binder, including settling of rubber particles during heated binder storage and raveling of pavements that included crumb rubber modified asphalt (CRMA), FHWA's Turner-Fairbank Highway Research Center developed a chemically modified crumb rubber asphalt (CMCRA) that not only eliminates the problem of rubber particles settling while in storage but also expands the useful temperature range of the binder. The latter is particularly important because producers generally improve the low-temperature performance of a binder by using a petroleum distillate that is not "cut" so deeply to produce asphalt during the distillation process. This makes the asphalt softer, but it also requires that needed heating or motor oil distillates be left in the asphalt fraction, something that is both economically and ecologically undesirable. By using chemically modified crumb rubber to improve the low-temperature rheological performance of CMCRA made from regular asphalts, FHWA estimated that refiners potentially can save millions of dollars; savings that inevitably make CMCRA a more attractive product to users. Although production of CMCRA is approximately 60 percent more expensive than conventional crumb rubber asphalt, the additional costs are offset by longer pavement life.(*749*)

In addition to FHWA's User Guidelines for Waste and Byproduct Materials in Highway Construction, available from its Turner-Fairbank Highway Research Center, other resources available on-line include:

- The Rubber Pavement Association maintains a current research library with many downloadable documents.
- Arizona DOT has established a web page Quiet Pavements Pilot Program.
- Recycled Materials Research Center operates a website that includes substantial information on waste tires and other materials in pavements.
- Rubber Manufacturers Association website has a section on scrap tires, with links to suppliers for purchase.
- Rubberized Asphalt Concrete Technology Center is a cooperative effort by the County of Los Angeles, County of Sacramento and the California Integrated Waste Management Board to promote the use of crumb rubber from scrap tires in roadway rehabilitation projects by providing education, training and consultation services to local agencies. The center has an online field inspection guide, asphalt rubber design and construction guidelines, a report on the status of rubberized asphalt traffic noise reduction in Sacramento County, and an asphalt rubber overlay noise study update.
- Asphalt Rubber Design and Construction Guidelines
- An AR overview and table of contents for the design guide can be viewed online, as well as more detailed instructions in the appendices.
- Sacramento County Specification for Asphalt Rubber Hot Mix-Gap Graded (ARHM-GG) is also available on-line
- Better Roads published an in-depth look at Open Grade Friction Courses, called A New Era for Permeable Pavements, April 2003, pp 28-32.

State DOT Experience with Recycling and Use of Recycled Rubber Products

The Oregon Department of Transportation (ODOT) has been monitoring performance of seventeen rubber modified asphalt and asphalt concrete sections constructed on Oregon highways. After five years, the PBA-6GR pavements were performing as well or better than the control sections.(*750*)

The remaining examples are summarized from those available at the Rubber Pavement Association.(*751*) More examples are available there and will be available soon as a result of quiet pavement research by FHWA, Caltrans, ADOT, and the USDOT Volpe Research Center.(*752*) NCHRP Project 1-44, Quiet Pavement Pilot Project Study will begin in 2005.

Arizona DOT Asphalt Rubber Projects

In 1990, the Arizona Department of Transportation designed and constructed a large scale Asphalt-Rubber (AR) test project in Flagstaff, Arizona on the I-40, where 1999 traffic exceeded 20,000 vehicles per day with 35 percent large trucks. The purpose of the test project was to determine whether a relatively thin overlay with AR could reduce reflective cracking. The overlay project was built on top of a badly cracked concrete pavement, constructed in 1969 and exhibiting signs of failure by 1974, for which ADOT maintenance spent approximately $80,000 per year trying to hold the pavement together. By 1988 reconstruction, at a cost estimated to be at least $30 million, appeared to be the only option. Due to money and time constraints, the project could not be reconstructed and various overlay strategies were considered, including many different overlay thicknesses, use of a fabric interlayer, asphalt-rubber interlayer, various mixes, edge drains and cracking and seating. ADOT selected an AR binder to test whether a relatively thin pavement overlay could control reflective cracking. The design section included edge drains, crack and seat the concrete Pavement, a five inch overlay consisting of a three inch conventional dense hot mix asphalt, a two inch gap graded asphalt-rubber mix (AR-AC) with a 6.5 percent binder and a one-half inch AR OGFC with a 9 percent binder content. The design was for ten years, but all involved in the project considered it would last six years given the thin overlay design and the poor condition of the concrete. As of evaluation at nine years of service, the Asphalt-Rubber overlay was virtually crack free, with good ride, virtually no rutting or maintenance and good skid resistance. The use of AR on the project saved about $18 million dollars in construction savings and four years less construction time, and led to a new specification and widespread use of Asphalt-Rubber hot mixes throughout Arizona. Arizona Department of Transportation used approximately 14 million tires between 1988 and 2002. The agency estimates 40 percent of its 7,500 mile highway system is surfaced with AR.

Colorado DOT Rubber Asphalt Experience

The state of Colorado, based on the cold weather performance in northern Arizona placed an Asphalt-Rubber Chip Seal in June 2003. In a final construction report issued by the CDOT Aeronautics Division, the agency said, "the validity of rubber asphalt paving materials had been proven by our sister states of California and Arizona, which rely heavily on the process to provide a significant increase in the longevity of the pavement and the wise recycling of used auto tire products. Reflective cracking has all but been eliminated with the process and the pavement remains flexible and viable long after non rubberized materials have failed. In the past, the acute stresses placed on pavements at high altitude Colorado locations have made it necessary to rehabilitate airport movement areas every two to three years. It is anticipated that the introduction of the rubber asphalt materials will extend the life of the pavements for seven to ten years."

Nebraska Department of Roads Asphalt-Rubber Project

The Nebraska Department of Roads placed its first Asphalt-Rubber project in September 2001 on Highway 2 near Lincoln. The project consisted of a 1/2 inch to 11/2 inch SP5 leveling course and a 2 inch Asphalt-Rubber gap graded mix over a heavily deteriorated concrete pavement that was milled 3/4 inch. January temperatures range from a high of 32F to lows of 10F. Summer temperatures go up to 104F. Since the Highway 2, NDOR has placed Asphalt-Rubber projects on Interstate 80 and Highway 14. According the NDOR Materials Engineer, Robert Rea, the projects are performing well. NDOR, which researched Asphalt-Rubber for three years prior to its first project, is planning an AR OGFC with lower voids and a higher binder content as one of its two upcoming projects.

Maine DOT Use of Tire Chips in Road Base

A 1992 project in Richmond, Maine, assessed the effectiveness of using tire chips as an insulating layer in order to limit frost penetration beneath a gravel-surfaced road that experienced severe deterioration during spring thawing. Thermocouples, resistivity gauges, groundwater monitoring wells, and a weather station were installed to monitor the project. After a year, results indicated that a 152-mm-thick tire chip layer can reduce frost penetration by up to 40 percent.

Embankment and Retaining Wall Construction

Shredded or chipped tires have been used as a lightweight fill material for construction of embankments. However, combustion problems at three locations have prompted a reevaluation of design techniques when shredded or chipped tires are used in embankment construction.(7) Although not a direct highway application, whole tires have been used to construct retaining walls. They have also been used to stabilize roadside shoulder areas and provide channel slope protection. For each application, whole tires are stacked vertically on top of each other. Adjacent tires are then clipped together horizontally and metal posts are driven vertically through the tire openings and anchored into the underlying earth as necessary to provide lateral support and prevent later displacement. As initially performed in California, each layer of tires is then filled with compacted earth backfill.

Slit scrap tires can be used as reinforcement in embankments and tied-back anchor retaining walls. By placing tire sidewalls in interconnected strips or mats and taking advantage of the extremely high tensile strength of the sidewalls, embankments can be stabilized in accordance with the reinforced earth principles. Sidewalls are held together by means of metal clips when reinforcing embankments, or by a cross-arm anchor bar assembly when used to anchor retaining walls. Studies on placement of tires in embankments have shown reduced water quality where ponding can occur; however thermal stability tests found shreds are stable up to temperatures of 200 C, indicating that other mechanisms may be attributed to the exothermic reactions, which occurred in tire fills.(*753*)

Mass Highway is undertaking a two-year study of the performance of tire shreds as mitigation for secondary compression of organic soils beneath a roadway embankment. Two projects, one using 250,000 tires and one using 750,000 tires will use shreds of 2-6 inches in size to reconstruct an embankment underlain by unsuitable organic soils.(*754*) The embankment has been designed to test pavement performance over a soil cover thickness of two feet. Mass Highway has another project to test water quality in relation to use of Tire Shreds as Lightweight Fill Below Groundwater. NCDOT used scrap chipped tires as embankment fill material in two recent projects - one in Davidson County (1,279,000 tires) and another in Catawba County (1,151,077 tires).(*755*)

A Carson City, Nev., company is marketing a noise wall that contains recycled rubber tires and recycled plastics.(*756*) The wall's shell is made of a composite of polyester and glass, and the fill section is made of ground, recycled plastics and rubber tires.

Rubber Spacer Blocks in Crash Barriers

An Evaluation of Recycled Rubber Spacer Blocks is being funded through an RMRC Technical Problem Solving grant. Iowa DOT would like to use spacer blocks made from recycled tires in their crash barriers. However, FHWA needs data to support the use of such hardware on the National Highway System, following the criteria for testing safety hardware defined in National Cooperative Research Program (NCHRP) Report 350, which includes crash testing.(*757*) *FHWA* drafted a Letter of Acceptance for Recycled Spacer Blocks. (*758*) Test results in 12 Midwest states (*759*) will be available soon, as will Iowa DOT specifications for recycled tire spacer blocks.(*760*)

Rubber Buffings for Bridge Approach Expansion Joints

Iowa DOT is also exploring techniques for filling expansion joints by stuffing the gaps with shaved tired particles, instead of foam blocks. Foam blocks had trouble during bridge expansion and contracting and with heavy rains floating them out of joints. Iowa DOT tested the rubber material for density, gradation, compression and rebound qualities, foreign material content, and compatibility with several types of sealant," said Steffes. At the end of the testing, one combination of buffings and sealant performed better than the rest, so that one was recommended back to the bridge crews. Details of the testing were published in the October 2001 Final Report MLR-01-1 "Rubber Buffings for Bridge Approach Expansion Joints." Field testing on repairs of expansion joints began last year with excellent results: the tire buffings will not deteriorate over time because they are heavier than water and won't float away in a strong rain; nor do they pose a significant hazard on the roadway. The cost is less than half the cost of the foam blocks currently specified for these joints. The new standards for use of tire buffings in expansion joints were included in the Road Design Standard update.(*761*)

Rubber Tires to Control Vegetation around Guardrails and Signposts

Anti-vegetation tile are designed to prevent grass and weeds from growing up and around guard rails, fencing, and signs. The 2-ft. x 2-ft. tiles are made from ground-up rubber tires and offer durability, ease of installation and ten years or more of maintenance-free service. They can improve driver sight distance and reduce the need for herbicides and trimming. Anti-vegetation tiles also have a low profile, which keeps them out of the way of a mower blade. Each tile has universal guides scribed on the bottom so they can be easily cut to fit around a post.(*762*)

The Texas Department of Transportation (TxDOT) is installing and evaluating tiles made from tire rubber to control vegetation around guardrails and sign posts in several TxDOT districts. District staff will evaluate the ease and cost of their installation and their long-term performance in diverse climate conditions. The project will also compare life-cycle costs of the tiles to other TxDOT vegetation control systems. The sites' diverse climate and terrain is expected to make the project's findings useful across the United States. If accepted for use in new construction, retrofits, and maintenance to control vegetation, tire-rubber tiles for guardrail and sign posts could consume more than the 500,000 tires' worth of rubber TxDOT operations generate each year.(*763*)

Rubber Posts for Traffic Delineation and Channelization

The Wyoming Department of Transportation uses RubberTough posts in highway stretches plagued by severe weather and low visibility. Made of recycled tires that can snap back because of a patented swing hinge made of rubber, the posts bend but don't break, reducing costs. The posts are secured into the ground via a steel spike and are used mainly for delineation and channelization.(*764*)

Plastics

Plastics comprise more than 11 percent of the total weight of the municipal waste stream and about 12 to 20 percent of its volume; only 5 percent is recovered.(*765*) Recycled plastic has been used for items such as guardrail posts and block-outs, delineator posts, fence posts, noise barriers, sign posts, and snow poles. The Federal Highway Administration has approved the use of a guardrail offset block made of 100-percent recycled wood and plastic. Although the product's initial cost is currently higher than for conventional block material, it is believed that the post will resist damage and deterioration better than conventional materials, thereby resulting in reduced overall life-cycle cost.(*766*)

Plastics in Asphalt

Polyethylene has been added to asphaltic concrete for some time; NOVOPHALT[R] and Polyphalt are newer asphalt cement additives that use recycled low-density polyethylene resin which is generally obtained from plastic trash and sandwich bags.(*767*) The recycled plastic is made into pellets and added to asphalt cement at a rate of 4 to 7 percent by weight of binder (0.25 percent to 0.50 percent by weight of total mix).(*768*)

Base asphalt cement combined with recycled plastic mil bottles, scrap tires, and a paraffinic polymer obtained from coal were found to have a lower viscosity and higher PG than traditional asphalt, allowing successful replacement of traditional Cutbacks using Diesel fuel and Kerosene such as MC 250, 800, 3000. This asphalt mix was successfully used in Germany for chip-seal and crack filling operations using only conventional application equipment.(*769*)

Recycled-Plastic Lumber in Noise Barriers, Posts, Guardrails, and Reinforcing Materials

Recycled-plastic lumber, a material extruded into standard lumber sizes used by the timber industry, has many advantages: it is durable and requires little maintenance, can be cut and fastened like wood, provides several aesthetic alternatives in both color and texture, is highly resistant to insects and graffiti, is readily available, and is thus inexpensive compared to custom-made plastic shapes. Being denser, it blocks noise more effectively than wood sheathing of similar thickness. Increasing public demand for reduced traffic noise levels is also generating a growing need for more and better highway noise barriers. Furthermore, those using conventional materials such as wood, steel, or concrete deplete natural resources and occasionally meet public criticism with respect to aesthetics. Barriers that use recycled plastic thus are not only functional but also environmentally beneficial. A recent TRB paper provides design guidelines for a system competitive with current barriers with respect to initial cost that may have long-term economic benefits because of greater durability, minimal maintenance, and low life-cycle cost.(*770*)(*771*)

Static cantilever bending tests have shown that recycled posts are more flexible than conventional wood and steel posts; however, the ultimate load capacities for several recycled posts are comparable to that of conventional posts. Pendulum test results show that the energy absorption of some of the recycled posts is as high as that of conventional wood posts. As a result, the overall performance of recycled posts compares favorably with conventional posts.(*772*) Studies on the field performance of embankments stabilized with recycled plastic reinforcement observed that slopes are performing better than control sections and that the reinforcing members have significant remaining capacity to maintain the stability of the slopes. (*773*)

In 2000, the Chelsea Center for Recycling and Economic Development (part of UMass Lowell) contracted with Mass Highway Sustainable Solutions to develop a Life Cycle Assessment of three types of offset blocks for use by Mass Highway in guardrail systems. The purpose of the project was to provide MHD with basic information and analyses needed to make environmental and cost comparisons between recycled plastic, recycled steel, and pressure treated wood offset blocks over the course of their life spans from manufacture through disposal. The study concluded that while W-beam guardrails constructed with wood offset blocks have the lowest estimated installation cost, those with plastic offset blocks have the lowest estimated net present cost. However, for three-beam systems, wood offset blocks have the lowest estimated net present cost. Additionally, concerns about wood offset blocks were raised, such as drying, cracking, and loss of structural integrity. As a result of this study, MHD published standard specifications for recycled plastic offset blocks in November 2000. (M8.07.0) (*774*) NCDOT recently installed guardrail on I-95 with 23,283 recycled plastic offset blocks.(*775*)

The Missouri DOT (MoDOT) and the University of Missouri-Columbia started a project in 2002 to develop a plastic soil pin guidance specification for MoDOT for soil nailing. The research will result in a recommendation to AASHTO for a provisional plastic soil pin specification. (*776*)

Plastics in Piles and Bridge Fenders

Using recycled plastic fiber-reinforced polymer (FRP) composites as pile material have been found to potentially eliminate deterioration problems of conventional piling materials in waterfront environments and aggressive soils (solutions with fixed acidic, basic, and neutral pH at elevated temperatures).(*777*)

Caltrans engineers are experimenting with fenders made of recycled plastic and other consumer products that can resist marine borers better than wood and not pose the environmental threat that most wood treatments present. After evaluating different materials, Caltrans found that recycled plastic with fiberglass rebar at the corners or bridge fenders is an acceptable alternative. Although it is twice as expensive as treated wood, initial studies suggest it lasts three times as long.(*778*)

Aluminum Sign Recycling and Chromate Coating Elimination

In North Carolina, aluminum sign recycling is conducted through arrangements between the NCDOT and Department of Corrections. DOC purchased a Hydrostripper that utilizes a high-pressure water system to remove old reflective material from the signs. Because it uses water, the signs are not ground away which allows the aluminum to be used over and over. The most outstanding feature of this method is that the aluminum is not affected during the cleaning process, thereby eliminating the need to reapply the chromate coating.

The Missouri Department of Transportation (MODOT) began their sign reclamation program in 1978. The total cost of the original sign reclamation plant and its operation was $1.1 million. The use of the aluminum sign blanks, which were refinished that year in lieu of purchasing new aluminum sign blanks, saved MODOT more than the total cost of construction and operation of the reclamation operation. In each year of operation the plant has returned to MODOT than the original cost. The original plant was equipped with a metal sander, a press to straighten damaged blanks, along with a metal shear, which was used to cut away damaged parts of a blank in order to create a smaller sign blank rather than scrapping the damaged sign. In 1997, the reclamation operation was turned over to the Missouri Department of Corrections since they could do the work at an even greater savings to MODOT. Since that time various improvements have been incorporated to enhance the operation. A major change involved switching from a sanding operation to remove the sheeting material to a Hydro-Stripper which performs the cleaning operation. This method has an added advantage of not removing the aluminum coating of chromate that is used to provide better adherence of reflective sheeting or paint. The current cost of reclaiming rather than purchasing new sign blanks is a 75 percent savings. For the larger extruded structural signs the saving is slightly less. The saving to MODOT in 2003 was $3.5 million dollars.(*779*)

5.7. MAINTENANCE OF DIRT AND GRAVEL ROADS

Over 1.6 million miles of unpaved roads (53 percent of all roads) are unpaved. Many of these roads will remain unpaved due to very low traffic volume and/or lack of funds to adequately improve the subgrade and base before applying pavement layer(s). In some countries, economic constraints mean gravel roads are the only type that can be provided.

Dirt and gravel roads represent a very small percentage of roadways maintained by state DOTs in almost all cases; counties and federal agencies manage the large majority of the dirt and gravel roads in the United States. Nevertheless, a few state DOTs have become very involved in managing dirt and gravel roads and have developed environmental stewardship practices and partnerships that may be useful for other state DOTs.

General practices for pollution prevention from dirt and gravel roads include:

- Stabilize exposed soil areas to prevent soil from eroding during rain events. This is particularly important on steep slopes.
- For roadside areas with exposed soils, the most cost-effective choice is to vegetate the area, preferably with a mulch or binder that will hold the soils in place while the vegetation is establishing. Native vegetation should be used if possible.
- If vegetation cannot be established immediately, apply temporary erosion control mats/blankets; a comma straw, or gravel as appropriate.
- If sediment is already eroded and mobilized in roadside areas, temporary controls should be installed. These may include: sediment control fences, fabric-covered triangular dikes, gravel-filled burlap bags, biobags, or hay bales staked in place.

Partnerships to Identify and Address the Most Pressing Erosion Problem Areas

The Pennsylvania Task Force on Dirt and Gravel Roads is a cooperative effort between PennDOT and several other state and private agencies to improve the environmental quality of Pennsylvania's streams and waterways. PennDOT started working with Trout Unlimited in the early 1990s to mobilize volunteers to identify sedimentation problem areas from eroding roads and shoulders and areas of adverse impacts to streams. Initial efforts concentrated on Pennsylvania' protected watersheds, designated as either High Quality (HQ) or Exceptional

Value (EV), and including drinking water reservoirs and cold water fisheries. Trout Unlimited's volunteer effort culminated in the identification of over 900 sites, which became the basis for the Dirt and Gravel Road Pollution Prevention Program. In 1999-2000, a statewide committee followed up with a statewide inventory and assessment of all 17,000+ miles of Pennsylvania's dirt and gravel road network. Conducted by County Conservation Districts, this effort identified more than 9600 specific pollution sites impacting more than 3,000 miles of roadway. All 9600+ worksites were mapped, rated (on a 12-step, 100 point scale) and recorded in GIS program files. Top priority in the first three years was given to pollution "trouble spots" identified in watersheds protected as "exceptional value" and "high quality." As of 2000-01, a new allocation formula was used to distribute funding to affected communities statewide, with verified pollution sites on unpaved roads. Pennsylvania's 65 Conservation Districts administer the program at the county level with annual allocations from the State Conservation Commission. With the help of a local Quality Assurance Board (QAB), they:

- Work directly with applicants to develop plans for projects
- Assist with logistics of project work whenever possible
- Keep track of records of projects in their County using GIS system
- Develop a prioritization ranking incoming applications through the QAB
- Decide which project will be funded each year, through the QAB, and
- Conduct project inspections after site work is completed

To be eligible to apply for funding, an official form a municipality must attend a free 2-day training on environmentally sensitive maintenance for unpaved roads that explains basic environmental principles and introduces new techniques and ideas in unpaved road maintenance. The Center for Dirt & Gravel Road Studies at Penn State conducts "Environmentally Sensitive Maintenance," a 2-day course that includes modules on drainage, road maintenance techniques, erosion prevention & sediment control, bank stabilization, roadside vegetation management, and grant procedures.

In assessing progress toward addressing priority erosion control areas statewide, the program tracks:

- Drainage Outlets Stabilized (Sq Ft)
- Eroded Ditch Stabilized (Sq Ft)
- Road Bank Stabilized (Sq Ft)
- Stream Bank Stabilized (Sq Ft)
- Fabric Used (Sq Ft)
- Stream Culverts Replaced (#)
- Cross Pipes Added (#)
- Road Stabilized (Sq Ft)
- Vegetative Management (Sq Ft)
- Length of stream culverts replaced (Ft)
- Length of cross-pipes added/replaced (Ft)

Tools and Techniques for Erosion Reduction/Prevention

PennState's Dirt and Gravel Roads Center provides extensive resources and program information for managing dirt and gravel roads. The Center provides an extensive Dirt & Gravel Roads training program that is available upon request. Technical bulletins available on-line include:

- Aggregate Handbook - Draft version of 2002 Aggregate Handbook.
- Grade Breaks — Surface drainage features that stop concentrated flow and road erosion.
- French Mattress — Method for allowing water to pass under a road through coarse stone.
- Driving Surface Aggregate — Details and differences from other aggregates.
- DSA Specs — Purchasing and placement specifications for Driving Surface Road Aggregate.
- Trail Mix Spec — Purchasing specifications for Trail mix aggregate.
- Surface Maintenance — General information on maintaining unpaved roads.
- Carbide-Tipped Blade — Details on the benefits of a carbide-tipped blade for surface maintenance operations.
- Grading Sequence with a Carbide-Tipped Blade — How-to document detailing a sequence for surface maintenance using a carbide-tipped blade.
- Crown & Cross-Slope — Informational document describing different types of crown and proper cross-slope of unpaved roads.
- Headwalls & Endwalls — General information of the benefits of headwalls and endwalls at pipe installations.
- Natural Stone Headwalls — Details on how to construct headwalls and endwalls of native stone.

The Center's list of environmentally acceptable products for petroleum emulsion dust suppressant, acrylic polymer dust suppressant, road fill materials, soil amendments is also available on-line.

A variety of other technical resources are available from federal agencies, teams, and other states in some instances. The Local Technology Assistance Program maintains a listing which includes the following of potential interest to state DOTs: (*780*)

- Soil Bioengineering - An Alternative for Roadside Management, A Practical Guide from USDA Forest Service San Dimas Technology and Development Center Publications. The center also has a "Road Maintenance Video Set" five-part video series on environmentally sensitive ways of maintaining low volume roads. (Total Running Time: 1 hour 23 minutes).
- National Riparian Service Team
- Riparian Roads Restoration Team - Has slide shows (PowerPoints) and engineering applications available on-line.
- Low-Volume Roads Engineering, Best Management Practices Field Guide, USDA Forest Service, July 2003.

- Recommended Practices Manual: A Guideline for Maintenance and Service of Unpaved Roads (US EPA) - Standard procedures describing and illustrating cost-effective techniques and practices which can be used to enhance stability and maintenance of unpaved roadways while reducing sedimentation and improving the quality of surface waters.
- Best Practices for the Design and Construction of Low Volume Roads - Presents information about the use of the mechanistic-empirical procedure (MnPAVE) in designing hot-mix asphalt pavements in Minnesota. Researchers developed the MnPAVE software program using information from the Minnesota Road Research Project (Mn/ROAD) test facility and from 40-year-old test sections around Minnesota. MnPAVE procedures use Equivalent Standard Axle Loads (ESALs) to evaluate traffic loading, and the report includes methods to estimate these values for design purposes over a 20-year design life, as well as a procedure to measure vehicle type distributions. Presents an evaluation of subgrade soils for each thickness design procedure, summarizes Minnesota Department of Transportation specifications that relate to embankment soil construction and to construction of the pavement section materials, and recommends specific density or quality compaction using a control strip. Includes best practices on setting up projects most effectively to follow specifications.
- Erosion Control Handbook for Local Roads (2003) from the Minnesota LTAP Center.

South Dakota's Gravel Roads Maintenance and Design Manual is a comprehensive manual available in both html and pdf formats that addresses most issues that deal with gravel road maintenance. The practices included in the manual are available via the links below:

Example 14: South Dakota DOT Gravel Roads Maintenance and Design Manual Sections

Section I: Routine Maintenance and Rehabilitation

- Understanding Road Cross Section
- Routine Shaping Principles
  - Operating Speed
  - Moldboard Angle
  - Moldboard Pitch
  - Motorgrader Stability
  - Articulation
  - Windrows
- Crown
- Road Shoulder
  - High Shoulders (Secondary Ditches)
  - Causes of High Shoulders
  - Recovering and Spreading on Roadway
  - Breaking up Sod and Vegetation in Recovered Material
  - Pulling and Covering
  - Benefit of Mowing
- Gravel Road Rehabilitation
  - Reshaping Surface and Shoulder
  - Reshaping Entire Cross Section
  - Erosion Control

CHAPTER 6: MAINTENANCE FACILITIES MANAGEMENT

Facilities management encompasses a broad range of activities, including:

- Storage, repair, and maintenance of vehicles, equipment, and related support materials
- Fueling and washing of vehicles and equipment
- Maintenance of buildings, stormwater drainage systems and landscaping
- Storage of sand, salt, asphalt, rock, and pesticides
- Storage of wastes generated on site
- Bulk storage of sediment, litter and debris generated by road maintenance activities

Environmental stewardship in the course of these activities requires both structural and non-structural management practices. Examples of non-structural practices include procedures for performing operational activities, such as salt/sand mixing/loading that requires removal of all salt from the area surface after loading. The installation of a physical device that alters the release, transport, or discharge of pollutants from surface storm or melt water or facility-generated shop floor drain or washbay effluent is a structural practice.

Many environmental stewardship practices at maintenance facilities have to do with protection of water quality. EPA regulations have long required facilities to obtain National Pollution Discharge Elimination System (NPDES) permits for discharges, especially washbay and shop floor drain effluent discharges to the waters of the State. Such permit obligations arise under the Industrial Permitting portion of NPDES, and have received increased attention as state regulatory agencies have expanded beyond their initial focus on manufacturing facilities in implementation of this program. Brief summaries of federal water quality and wetlands requirements applicable to the transportation community are available at AASHTO's Center for Environmental Excellence.

6.1. PLANNING AND PRIORITIZING ENVIRONMENTAL IMPROVEMENTS AT MAINTENANCE FACILITIES

Maintenance Facility Pollution Prevention Plans

Facility Pollution Prevention Plans (FPPP) are typically developed for each maintenance facility owned or operated by a DOT. The FPPPs describe the activities conducted at the facility and the management practices to be implemented to reduce the discharge of pollutants in stormwater runoff from these facilities. The following practices are recommended:

- District Maintenance Director or Environmental Personnel should be responsible for ensuring that Facility Pollution Prevention Plans (FPPPs) are developed for each maintenance facility.
- The FPPPs should identify the work activities at each facility along with the corresponding BMPs that should be implemented.
- Supervisors should inspect their maintenance facilities monthly to monitor the implementation and adequacy of the BMPs.

- A report that includes the date of the inspection, the name of the inspector, observations, and recommended corrective actions should be prepared by the Supervisor.
- All inspection records should be maintained for a period of 3 years. Any observed instances of non-compliance should be reported to the Stormwater Coordinator.
- In addition to monthly facility inspections conducted by the facility supervisor, the more in depth review should occur in at least 20 percent of each District's facilities each year.
- These reviews should monitor each facility's documentation (e.g., FPPP, monthly inspection reports, etc.) and include a thorough yard inspection.
- Each District Maintenance Stormwater Coordinator should prepare a report including the date of the inspection, name(s) of the inspector, observations, and recommended corrective actions.
- All FPPP records should be maintained for a period of 3 years by the Maintenance Supervisor.
- Any observed instances of noncompliance should be reported in accordance with procedures.
- In addition to inspections conducted by the facility supervisors DOTs may employ an audit program or other supplementary compliance monitoring to support continual improvement.

Environmental Management Systems for Maintenance Facilities

Environmental management systems are increasingly used by state DOTs to avoid generation of pollution and manage operations for continual environmental improvement. Examples follow, some of which are described in greater detail in the section of this report on Environmental Auditing, Roles and Responsibilities.

Maine DOT's EMS for Facilities

Maine DOT has developed and implemented Environmental Management Systems for all MDOT facilities. Combined Environmental and Office of Health and Safety Administration (OSHA) policy and procedure manuals are targeted to the managers who have responsibility for implementation. Quick reference environmental practice guides—written as a companion guide to the policies and procedures—were developed for supervisors and field crews.

MDOT's commitment to conduct annual audits of its facilities to systematically review the effectiveness of these policies and procedures has been an important aspect of implementing new environmental procedures. An Environmental Management Committee is responsible for tracking and timely closure of audit findings and development of a database of Corrective Action Reports. MDOT's audit program and performance measures are discussed in the respective sections of this report.

Massachusetts Highway's EMS for Facilities Management

Mass Highway's EMS for Facilities Management focuses on hazardous waste and hazardous materials, underground storage tank management, wetland and water quality protection, and solid waste management. System Improvement and Implementation plans are developed for each facility.

Mass Highway has developed an implementation manual describing organizational roles and responsibilities relative to environmental compliance management at Mass Highway facilities. Personnel within the major Organization Offices, Divisions, Districts, and Sections that affect compliance with Mass Highway environmental requirements are identified, along with associated training programs to educate staff "how to best carry out their environmental related duties."(33)

Facility Management in PennDOT District 10 Strategic Environmental Management Program (SEMP)

Maintenance District 10 developed Process Maps operations associated with each significant aspect of operations with a special focus on the District 10 Maintenance Facility, providing information to plan, conduct, assess, and complete activities according to "Plan-Do-Check-Act" framework and principles. Process Maps identify responsibilities associated with each action. For example, PennDOT staff developed Quality Assurance Evaluations for Maintenance Stockpiles and Foreman's 15-Minute Stockpile Walkarounds. PennDOT implemented procedures to enhance environmental performance, including annual calibration of spreaders before the onset of the winter services season, use of two-way radios between operators during storms to communicate information about application rates and roadway temperatures, daily electronic leak detection tests in the morning hours before the day shift at garages with corrective action if necessary to prevent leaks, and completion of a Foreman's Erosion and Sedimentation Checklist as part of planning for earth disturbance activities that require control measures.(*781*)

PennDOT's ISO-based SEMP plan resulted in: (*782*)

- Development of information on contractor/supplier procedures and requirements related to significant aspects, which are consistent with department-wide contract terms and conditions, requirements, and procedures.
- Establishment of procedures for emergency response and spill prevention.
- Development of procedures, checklists, and responsibilities in monitoring and measurement activities related to significant aspects.
- Internal development of auditing procedures for SEMP activities performed by trained staff from another district.

Facility Siting and Prioritization of Environmental Improvements

Facility Siting Considerations

Currently, future sites for DOT facilities are usually selected based on cost of land acquisition and operational convenience. Some facility sites have been acquired through "swapping" an existing DOT site for a more desirable parcel. Environmental factors are often not considered and evaluated, unless a procedure specifying such consideration is in place and/or information has been made readily available or a study has been performed.

Information on existing DOT maintenance facilities is needed to allow identification and ranking of sites that are the most environmentally sensitive, to decide which sites to address first. Such information enables DOTs to:

- **Prioritize sites that should be closed or relocated based on environmental concerns**, as funds become available or on a more pressing basis.

- **Identify facilities that require pollution control devices**, such as oil/water separators or implementation of other environmental stewardship practices, and those that need to implement stormwater runoff controls.
- **Identify environmentally appropriate locations for new facilities**, including newly-designed salt storage buildings.
- **Develop and implement appropriate decommissioning policies or procedures**. Many DOT maintenance facilities are currently closed and/or relocated without a decommissioning policy or procedures. This can result in abandoned areas of actual or potential contamination and/or the transfer of hazardous and non-hazardous chemicals and wastes to other DOT facilities without advanced planning and, sometimes, without advance notification.

Environmental Data Needed for Evaluation in Facility Siting

Consideration of the following widely available environmental data is recommended in considering facility siting and future changes that may be needed to improve environmental stewardship. Most of this data is available from state environmental quality or natural resource agencies, or a federal agency if noted: (*783*)

- **Well log data**
- **Soil borings**
- **Surface water intakes and wellhead protection areas for public drinking water systems**
- **High-volume groundwater users**
- **Spill, Superfund, Leaking Underground Storage Tank and other contaminated sites** locations of groundwater aquifers and surface water bodies (USEPA)
- **Environmentally sensitive areas** (e.g., parks, wetlands, reserves) (DNR, U.S. Department of Interior, U.S. Department of Agriculture). Criteria used by INDOT for identifying "sensitive waters" include those waters: (*784*)
    - **Providing habitat for species of concern**; i.e. having state or federal designations of endangered, threatened, rare, extirpated or on a "watch list" identified by generic descriptor (mammal, etc.) or heritage species code.
    - **Used as a public surface water supply intake;** i.e. maintenance facilities are within 1,000 feet, 3,000 feet or one mile of a public water intake.
    - **Used for public recreation**; i.e. within a mile of such a recreation area and not connected to a POTW.
    - **Classified as outstanding state resource waters or high quality waters**
- **Groundwater aquifers and surface water bodies** (U.S. Geological Service)
- **Locations of urban wet-weather and rural** (**agricultural**) **drainage patterns** (U.S. Department of Agriculture – Natural Resources Conservation Service)

For maintenance facilities that are captured under the Municipal Separate Storm Sewer System (MS4) portion of the NPDES program, the DOT is required to assess the water quality of known receiving waters and stormwater outfall discharges and known sensitive areas, and to identify those places having a reasonable potential for causing stormwater problems. In case of the latter, DOTs are expected to implement control measures and conduct operations in ways that will reduce contamination of stormwater discharges. As a result, it is important to:

- Identify facilities that are not currently connected to a Publicly Owned Treatment Works (POTW)
- Attempt to connect to a POTW when new sites are developed.

Criteria for Prioritizing Attention to Maintenance Facilities

Utilizing data such as that discussed above, criteria can be developed to identify maintenance facilities that should receive priority attention. INDOT utilized the following criteria that are applicable to other states, to identify those that provide the greatest potential risk to the environment from stormwater discharge, locations both within and outside MS4 areas: (785)

1. Maintenance facility locations within designated MS4 areas.
2. Maintenance facility locations within 3,000 feet of a community public well.
3. Maintenance facility locations within (1,000 feet) (3,000 feet) (5,280 feet) of a public surface water intake.
4. Maintenance facility locations within one mile of high quality and exceptional use waters.
5. Maintenance facility locations within one mile of federal, state, county, municipal or township recreation facility having a lake, pond, river, or stream.
6. Maintenance facility locations within 3,000 feet of groundwater that is highly vulnerable and very highly vulnerable to contamination by nitrates (as surrogate for chloride).
7. Maintenance facilities within 3,000 feet of a natural area containing Rare, Threatened, or Endangered species.
8. Maintenance facilities within one mile of the "best remaining examples of natural wetland communities," as determined by IDNR.

6.2. Facility Housekeeping Practices

Daily activities occurring at maintenance facilities can involve the use of materials and products that are potentially harmful to the environment. Many DOT "yards" or "depots" are the location of aggregate piles, metal scrap piles, miscellaneous right-of-way trash, and other debris that can potentially contaminate stormwater. Stormwater runoff has the potential to come in contact with and transport sediment and other pollutants from the facility grounds to storm drains or adjacent water bodies. Non-stormwater, from sources such as landscape watering, vehicle cleaning, water line/hydrant flushing, and air conditioning condensation, can also transport pollutants as it flows across facility grounds. Good housekeeping practices are intended to eliminate the potential for discharge of pollutants to drainage paths, stormwater drainage systems, or watercourses by promoting efficient and safe storage, use, and cleanup of potentially harmful materials. The best strategy for minimizing pollutants in discharges from the facility is to control pollutants at the source.

General Stormwater Protection Practices at DOT Maintenance Facilities

Stormwater and non-stormwater can be prevented from coming into contact with potential pollutants by use of the following practices, outlined by Caltrans in their bulletins for maintenance staff: (*786*)

- Cover stockpiles and other materials stored outdoors.
- Use berms or other containment methods to prevent runoff.
- Sweep paved areas to remove sediment and other materials that have been tracked or dispersed across the facility.
- Ensure that paved surfaces are in good condition.
- Prevent non-stormwater, such as condensate water from ice machines and sprinkler overspray, from flowing across facility grounds.

BMPs should be installed at storm drain inlets, catch basins and facility discharge points as final defense measures in the event preventive measures are not fully effective. Since spills and leaks may occur at any time, preparation should be in place, including the following practices:

- Locate raw material stockpiles away from drain inlets and catch basins.
- Do not repair, maintain, or clean vehicles and equipment near inlets.
- Move receptacles, hazardous waste areas, raw materials storage areas, vehicle wash areas, and stockpiles away from drain inlets and areas that are prone to flooding or ponding.
- Do not park vehicles and equipment over or immediately adjacent to inlets.
- If a spill occurs, clean up the area immediately and dispose of cleanup materials properly.
- Stencil drain inlet locations with paint or signs.
- Maintain sufficient emergency materials; such as drain covers, absorbent booms, rags, or sandbags convenient to inlets.
- To prevent flooding, place BMPs so that water will drain while retaining the pollutant on site.
- Inspect culverts, ditches, gutters, underdrains, horizontal drains, downdrains, and outlets annually, and as needed during the rainy season, to determine if cleaning or repairs are needed. This prevents the drainage structure from becoming a pollutant source itself.
- Collect and manage all water and material generated during drainage facility cleaning operations per solid and liquid waste management practices.

Caltrans recommends the following maintenance yard housekeeping practices in their statewide stormwater quality practice guidelines: (*787*)

- Provide facilities for containment of any accidental losses of concentrated solutions, acids, alkalies, salts, oils, or other polluting materials.
- Employ standard operating procedures for spill prevention and clean up during fueling operations, as well as BMPs for vehicular maintenance areas.
- Prohibit equipment or vehicle wash waters and concrete or asphalt hydrodemolition wastewaters from flowing into stormwater run-off, except under an appropriate NPDES wastewater permit.

- Promote recycling and manage solid waste according to the appropriate procedures or stewardship practices.
- Minimize pesticide, herbicide and fertilizer use. Pesticides should be used, applied, handled, stored, mixed, loaded, transported, and disposed according to manufacturer's procedure and any state requirements.
- Use the "first in first out" policy for material storage and control. Avoid ordering more materials than can be stored properly or used in a reasonable timeframe. Properly reuse, recycle, or dispose of empty containers, excess materials, equipment, and parts that are not likely to be used.
- Clean up spills promptly.
- If it is necessary to use a hose for cleaning, wash water should not be discharged to the stormwater drainage systems or watercourses.

Building and Grounds Maintenance

Permanent maintenance facilities require building and grounds maintenance, which includes care of landscaped areas around each facility, cleaning of parking areas and pavements other than areas of industrial activity, and maintenance of the stormwater drainage system. Tasks to perform these activities include equipment operation, litter/trash pickup and maintenance of restrooms/RV dump stations and landscaping, which can in turn result in spills, leaks, trash, sewage, erosion and chemical vegetation control. Potential pollutants include litter, trash, sewage, pesticides, fuel, hydraulic fluid and oil.

Recommended environmental stewardship practices include: (*788*)

- Maintain equipment and buildings to avoid peeling paint, rust, and degradation. Request funding for major repairs.
- Maintain clean, orderly material and equipment storage areas. Provide covers for materials as needed.
- Sweep or vacuum maintenance facility floors and pavement.
- If mopping is used to clean floors or pavement, contain the mop water and dispose of it to the sanitary sewer system according to the following guidelines:
    - Do not dispose of mop water into the parking lot, street, gutter or drain inlet; and
    - If an oil/water separator is available, pour the mop water into the separator so that the wastewater is treated before being discharged to the sanitary sewer system.
- Minimize the possibility of stormwater pollution from outdoor waste receptacles by doing at least one of the following:
    - Use only watertight waste receptacle(s) and keep the lid(s) closed;
    - Grade and pave the waste receptacle area to prevent run-on of stormwater;
    - Install a roof over the waste receptacle area;
    - Install a low containment berm around the waste receptacle area; or
    - Use and maintain drip pans under waste receptacles.
- Utilize the following environmental stewardship practices to protect water quality: scheduling and planning, illegal spill discharge control, safer alternative products, vehicle

and equipment fueling, vehicle and equipment maintenance, sweeping and vacuuming, silt fence, sandbag and gravel bag barrier, straw bale barrier, fiber rolls, wood mulch, compaction, spill prevention and control, solid waste management, liquid waste management, sanitary/septic waste management, hazardous waste management, concrete waste management, material delivery and storage, material use, litter and debris, potable water/irrigation, water conservation practices, maintenance facility housekeeping practices, and compaction.(*789*)

Vehicle and Equipment Maintenance

The following stewardship practices apply to equipment maintenance: (*790*)

- Maintenance should be performed in covered or indoor maintenance areas where potential pollutants cannot be introduced into stormwater drainage systems.
- Inspect equipment for damaged hoses and leaky gaskets and repair or replace as necessary.
- Drip pans or absorbent materials should be used during vehicle and equipment maintenance work that involves fluids.
- Non-stormwater discharges into stormwater drainage systems or watercourses are prohibited.
- Utilize Spill Prevention and Control BMPs for pollution prevention and response measures. Any contaminated soil resulting from vehicle or equipment repair should be addressed.
- Use dry methods (e.g., dry rags, vacuuming or sweeping) for cleaning associated with maintenance in outdoor areas.
- Inspect areas following field maintenance areas to ensure there is no residual contamination that might impact stormwater quality. Clean areas as needed using dry methods, (e.g., sweeping or vacuuming).
- Maintain waste fluid containers in leak-proof condition.

Pre-Operation Inspection

Vehicles and equipment should be inspected for leaks on each day of use. When performing pre-operation inspection, pay particular attention to:

- Ensure that the vehicle/equipment is clean and in good operating condition.
- All equipment has current inspection stickers, as applicable.
- Assignees and operators of motorized vehicles and equipment ensure that preventive maintenance occurs and that all malfunctions, operating problems, etc., are reported for corrective action. Request the repair of vehicles/equipment with leaks. Place a drip pan under any leaking vehicle or equipment. Preventive maintenance should occur in accordance with departmental guidance.
- Clean up spilled or leaked fluids immediately.
- Verify that hoses and clamps are secure and check for evidence of leaking.
- Problematic vehicles or equipment should be removed from the maintenance activity site.

- Daily pre-trip inspection should be logged and kept for 3 months.

Vehicle Fluid Removal

When removing automotive fluids such as used motor oils, coolant, or other oils from vehicles or equipment, the following environmental stewardship practices should be used:

- Transfer removed fluid to a designated used fluid storage tank as soon as possible.
- If possible, remove fluids directly into the holding tank. For example, newer types of used oil tanks can be connected to the vehicle to pump oil directly into the tank.
- If necessary, drain fluids into a drip pan and then transfer the fluids to the designated container. A larger drip pan may be required to catch any unanticipated splashing.
- Properly remove, clean, and store drip pans promptly after use.

Engine and Parts Cleaning

When cleaning engines and parts during vehicle and equipment repair operations, the following environmental stewardship practices should be used:

- Designate specific areas for parts cleaning.
- All parts washing should be performed in designated areas with captured wastewater.
- Use self-contained sinks or tanks when working with solvents. Periodically check for leaks and make necessary repairs as soon as possible. When not in use, make sure covers are secure.
- After rinsing parts, allow them to drain and dry over a solvent sink or tank. This will prevent dripping onto the floor.
- All vehicles and equipment should be washed at an approved area.

Cleaning Up Spills of Vehicle and Equipment Fluids

Accidental releases of vehicle fluids at maintenance sites can potentially discharge into stormwater drainage systems and pollute receiving waters. Typical vehicle fluids include oil and hydraulic fluids leaking from vehicles and equipment, accidental spills from fueling operations, and leaks and spills around storage tanks and containers. Caltrans developed and distributed the following environmental stewardship practices for cleaning up spills of vehicle and equipment fluids: (*791*)

Proper response to a vehicle fluid leak requires preparation:

- Maintain up-to-date spill prevention, control, and response plans.
- Train staff to identify and respond to spills safely and appropriately.
- Maintain appropriate and adequate supplies of cleanup materials at fueling areas, vehicle maintenance areas, cleaning areas, and vehicle and equipment parking areas.
- Regularly inspect vehicle parking, maintenance, cleaning, and fueling areas for leaks and spills.
- Repair or replace vehicles and equipment that consistently leak.
- Repair or replace, as needed, material and waste storage perimeter controls, containment structures, covers, and liners in order to contain spills and leaks.

Evaluate the spilled material to determine the appropriate methods for cleaning up the spill. Vehicle fluids such as oil, fuels, and hydraulic fluids are considered hazardous wastes and require appropriate safety precautions. For spilled material, immediately contain the material to keep it from spreading and clean it up.

- Place absorbent materials or pads around leaks to soak up spills.
- For vehicles/equipment that are leaking, place a drip pan underneath to contain any additional leakage.
- Place a leaking container in appropriate spill containment or transfer the contents to another container.
- For leaks or spills that occur during storm events, to the extent that work can be accomplished safely, cover and protect the spilled material from stormwater run-on.

Once the spilled material has been contained, ensure that all of the material and absorbent has been cleaned up.

- Whenever possible, use "dry shop" methods to clean up spills.
- Avoid hosing down the spill area.
- Use an absorbent-type cloth on fuel pumps or damp mop on pavement in fueling areas.
- If rainwater has accumulated in a contained area where a spill or leak has occurred, the contaminated water might be considered hazardous waste.
- Take additional precautions in situations where dry cleanup methods cannot be implemented to ensure that the water used for cleaning and decontamination is prevented from entering storm drainage systems or receiving waters.
- Dispose of the contaminated wastes (spilled material, used cleanup materials, contaminated rainwater) according to environmental stewardship practices. Contact the DOT's Stormwater Coordinator or HazMat Coordinator for additional assistance.

Sediment Control at Maintenance Facilities

Sediment on facility grounds comes from two primary sources:

- Eroded soil from unpaved areas and slopes is transported onto the facility grounds by gravity, wind or water.
- Mud and dirt are brought onto the facility on vehicle and equipment tires and undercarriages.

Caltrans recommended the following environmental stewardship practices in a bulletin to staff on pollution prevention at maintenance facilities.(*792*)(*793*)(*794*)

Evaluation of Exposed Soil Areas at Maintenance Facilities

Regularly inspect unpaved areas of the facility for signs of erosion and identify factors in selecting appropriate stabilization measures.

- Is the area deficient of vegetation or other conditions or practices to hold the soil in place?
- Is the area subject to run-on, either sheet flow or concentrated flow?

- Does the area have significant slopes that will increase the probability of erosion?
- Is the area being used for equipment storage?
- Do vehicles or equipment regularly utilize these areas?
- Is the area intermittently used for storage of materials or waste?
- Does the area show signs of erosion?

Implementation of Appropriate Erosion and Sediment Control at the Facility

- Maintain existing vegetation and enhance where possible.
- Prevent run on from adjoining areas that can cause erosion using ditches, berms, dikes, or swales, sandbag or gravel bag barriers, or fiber rolls.
- Protect slopes, flat areas, exposed soil areas, or transportation corridors with gravel or pavement, if possible, otherwise use applicable BMPs that best fit the facilities needs, such as wood, straw or hydraulic mulch; seeding; or compaction. Well-maintained mulch provides cost-effective erosion control benefits.
- Do not over-irrigate landscape vegetation. Ensure irrigation systems are in proper working order and not over watering or overspraying areas.
- Inspect unpaved/disturbed soil areas regularly to assure that erosion and offsite sediment discharge is not occurring.
- Minimize use of chemicals to eradicate vegetation from exposed areas.
- Prevent storage of hazardous materials on exposed soil areas.

Inspection and Cleaning

For the most effective program to reduce sediment and raw materials in stormwater, a routine inspection and cleaning program is needed with the following elements:

- Regularly sweep or vacuum the facility grounds to remove accumulated pollutants.
- Regularly inspect drop inlets, facility discharge points, and facility perimeters, for accumulated pollutants. Remove pollutants and implement BMPs as indicated.
- As indicated by the inspection, implement linear sediment barrier controls, i.e., silt fence or gravel bag barrier, etc.
- Maintain sediment controls by removing accumulated sediment and repairing damaged areas as required by the BMPs.
- Regularly inspect facility vehicles and equipment for dirt and mud. Ensure that vehicles are cleaned at designated washing facilities.

Materials Management at Maintenance Facilities

Maintenance facilities store a variety of products that may be harmful to the environment if they come into contact with surface waters. Materials that may be stored include pesticides, petroleum products, paints, cement and solvents, as well as bulky items such as:

- Brush, wood, and untreated lumber
- Treated lumber, poles, ties, including pressure treated or creosote treated

- Scrap metal and obsolete machinery
- Construction materials stored for reuse (culverts, steel beams, guard rail, cable, etc.)
- Old tires, cardboard, signs, sign posts, plastic, bulky trash
- Dirt, road sweepings, ditching material, inert fill, sand and gravel
- Rock or stone
- Old bricks, concrete, or asphalt

Potential pollutant sources are contaminated runoff as well as spills and leaks that may release pesticides, paint, solvents, asphaltic products, cement, epoxy resins, fuel, hydraulic fluid, and oil.

Good storage and handling practices can greatly minimize waste quantities and costs for disposal as well as reduce potential for employee exposure or environmental contamination. Environmental stewardship practices can significantly reduce handling, disposal costs, and future liability from DOT activities. Division Managers/Engineers are ultimately responsible for maintaining all Maintenance & Operations properties in good order, for minimizing the amount of material stockpiled at maintenance lots, and for ensuring that materials are stored, reused/recycled, or disposed in accordance with this procedure. Crew supervisors are responsible for ensuring that maintenance crews know and understand the procedure for storing and disposing of bulk materials.

Stockpile and Materials Management Practices and Procedures

The following items should be considered in the development of a stocking area: (*795*)

- **Blacktop Pad —** of sufficient size to accommodate materials storage, loading and mixing materials if required. Also add curbs on a paved swale section to channel runoff into collection basins. All bituminous surfaces should be sealed to make the surface impervious.
- **Collection Basin —** must be properly placed for easy cleaning and effective functioning.
- **Permanent Covered Chemical Storage Building**.
- **Lighting —** sufficient for loading area plow mounting area, etc.
- **Truck Heaters —** spaced in a row, not bunched on a single pole.
- **Grading and Access Roadway Work**.
- **Signing —** stockpile identification, Maintenance.
- **Fencing and Security**.
- **Planting for Environmental Screening**.
- **Identification of Stocking Area Boundaries**.
- **Types of Bulk Storage Buildings —** ranging from barn type buildings storing a few hundred tons of bulk chemicals to large diameter dome buildings with storage capacities over 5,000 tons.
- **Location**. Columbia County in Wisconsin placed their new salt storage domes in a location that allowed the building of 1,800 ft of railroad-side track. This allowed bringing in the annual salt requirement by train, thus reducing the shipping cost greatly versus trucking. The cost of salt was decreased from $33 a ton to $22.34 a ton.(*796*)

Environmental stewardship practices and procedures in materials management include the following: (*797*)

- **Material should be recycled when possible.** When waste materials are not recycled such materials should be disposed in accordance with regulations and/or department policy.
    - **Untreated wood waste and brush** should be chipped and reused as mulch or fuel.
    - **Scrap metal** should be recycled
    - **Treated wood** should be reused when possible or sent to a licensed disposal facility permitted to accept this material. If new creosote treated timber is being temporarily stored for more than a week it should be covered and lined underneath with an impervious material. The liner should be bermed to catch any leachate. The leachate should be cleaned with absorbent pads that can be disposed of as oily rags. Old, used timber may be stacked without cover or liner.
- **Develop site plans for areas adjacent to or near riparian** areas to identify erosion and sediment control needs, and to ensure stability of the material.
    - Sites should be identified as part of the local disposal plan.
    - All stockpiles should be located away from concentrated flows of stormwater, drainage courses, and inlets.
    - All stockpiles should be protected from stormwater run-on, using berms, dikes or other temporary diversion BMPs.
- **Maintenance facilities should appear generally clean and well organized.**
- **Designate specific areas for temporary stockpiling of various types of bulk materials and wastes**, such as scrap metal, brush/wood, old signs/lumber, or inert fill.
    - Signs, fencing, site plans or other markings should be used to identify stockpile areas.
    - The total bulk and waste material storage area not exceed limits specified by the DOT or state environmental agency.
- **Inspect and organize the storage areas, particularly before rainier seasons.** Remove litter, debris, sediment, and any spilled materials to prevent potential pollutants from being introduced into stormwater runoff. (*798*)
    - **Store materials away from areas that have potential for runoff** into the stormwater drainage system or other watercourses.
    - **Where feasible, cover materials that may have potential to impact stormwater** quality during the rainy season. For materials that are frequently used, keep covers or tarps available for use during rain.
    - **Frequently sweep around storage areas** to remove materials blown, tracked, or washed onto surfaces that may wash off with rain.
    - **Clean any spills or drips collected in secondary containment and spill containment facilities** for above ground tanks and other storage/waste containers to prevent contamination of collected stormwater. Drain plugs and valves should be secure.

- **Clean vehicle wash rack sumps, clarifiers, and oil/water separators** exposed to rain, as needed, to ensure free drainage and to prevent possible overflow.
- If debris, sediment or other materials still have the potential for impacting stormwater runoff even though source controls are in place, **consider installing temporary sediment controls** (sand bags, straw bales, filtration socks, etc.) at inlets, stockpile areas or other sources. Make sure inlet protection will not contribute to flooding. Remember, inlet protection is intended as secondary protection only and may not be needed if source control BMPs are in place.
- **All deployed BMPs should be inspected regularly during the rainy season, particularly before and after rain events.** Inspecting BMPs during rain events can be beneficial in determining their effectiveness and identifying any needed modifications. Re-inspect inlets and drainage facilities after rain events. Clean and repair as necessary to ensure that drainage facilities are functioning properly.
  - **Sediment Controls** - Inspect sediment controls such as sand bags, straw bales, silt fencing, and sediment traps and basins. Remove captured sediment from the sediment controls before the rainy season. Replace or repair degraded sand bags, straw bales, or silt fencing as necessary.
  - **Drainage Facilities** - When inspecting drainage facilities take note of their condition along with the condition of any associated BMPs. If excess sediment, debris, or other potential pollutants are observed in or near the drainage facility, look upstream at the sources and consider modifying or implementing additional BMPs. If needed, implement temporary drain inlet protection.

- **Stockpiles should incorporate erosion and sedimentation controls** and prevent erosion or sediment discharge into rivers, streams, ponds or wetlands. Caltrans has recommended the following stewardship practices for control of sediment from raw material storage areas.(*799*)(*800*)
  - **Water quality, erosion and sediment control BMPs** should be properly implemented and regularly maintained. Interim sediment controls include using temporary sediment controls such as sand bags, straw bales, or silt fences to contain raw materials. Temporary sediment controls, such as sand bags and straw bales can degrade and may contribute to stormwater pollution. Temporary and permanent sediment controls should be inspected regularly and replaced or repaired as needed. Sediment contained by temporary or permanent controls should be removed periodically.
  - **Wind erosion control practices** should be implemented as appropriate on all stockpiled material.
  - In general, **stockpiles should be covered or protected** with a temporary perimeter sediment barrier at all times. Perimeter controls and covers should be repaired and/or replaced as needed to keep them functioning properly.
  - **Berms should be installed around storage areas** to minimize tracking of materials out of storage areas and to contain sediment within the storage area. Permanent rolled berms or ramp berms should be made of hot asphalt or Portland Concrete Cement (PCC). Cold mix asphalt is not recommended for use as raw

material containment berms. Over time, cold mix has the potential to break up and not function as well as hot mix asphalt or PCC. Cover raw materials (especially cold mix) during the rainy season and have covers readily available outside the rainy season when rain is predicted.
    - **Sweep surfaces where material is tracked, blown, spilled or washed** from the storage area.
    - **Reduce the size of stockpiles or the amount of stockpiled materials during the rainy season.**
- **Material that has been contaminated with oil, gasoline or other chemicals should not be used as fill.** Any material suspected of contamination should be reported promptly.
- **Environmental staff should be called for assistance** with materials placement or permitting issues as needed.
- **Approved areas for filling should be marked by stakes or other markings**, and appropriate erosion and sedimentation controls should be used.
    - Filled areas should be graded and stabilized by seeding and/or other appropriate methods when filling is complete.
    - Interim or seasonal stabilization should be used if filling occurs over an extended period.
- **Stockpiles of scrap metal, wood, brush, asphalt, or waste materials having no future use should be completely removed at least annually.** In addition to minimizing environmental impacts, this will help avoid having the site be considered a solid waste disposal facility.
- **Obsolete equipment being stored for salvage or parts should be stored in a designated area and protected from weather, as appropriate.** Fuels, oil, and fluids should be removed or properly contained to prevent spills or leaks.
- **No material should be disposed of or buried on maintenance lots, except inert fill or other authorized material** (such as deer carcass composting in the case of NYSDOT). Avoid burying or disposing of:
    - Old drums or containers (see Drum Management Policy)
    - Chunks of hardened calcium chloride or sodium chloride
    - Paint, paint containers, fuels, oils, or other hazardous materials
    - Rubbish or garbage
    - Pesticides
    - Old culverts

Salt and Sand Stockpile Management

Soil and water contamination may occur around the salt sheds or sand piles if poor housekeeping practices are in place. Recommended environmental stewardship practices include the following practices compiled from Iowa DOT (*801*)(*802*), PennDOT (*803*), NYSDOT (*804*), the Transportation Association of Canada (*805*), and the Alberta, Canada Transportation Authority (*806*):

- **All storage facilities should be inspected and repaired regularly for roof leaks, floor cracks and wall leaks**.
- **All stored material is under roof, on impervious pad, in areas properly sized for truck and loader operations, stocked below fill line.** Piles of salt are not left exposed to the elements.
    - **Salt and mixtures of salt and sand are kept on an impermeable surface** like asphalt or concrete and in salt storage buildings whenever possible.
    - Under some circumstances, temporary (typically, less than one season) **"surge" piles may be utilized if placed on an impermeable surface and covered with adequate (weighted) tarping.**
    - **Doors to the salt sheds and sand domes are kept closed unless salt is being delivered or removed.** Keeping the door closed ensures that the salt remains in the shed, away from snow and rain. Material must be tarped within ten feet of doorway. Maintenance staff at Iowa DOT designed and installed an innovative but basic canvas salt shed door that lifts easily, allows for full access, and provided substantial cost savings.

  Bay Storage Bins and Crib Storage. The front of a barn storage bin is open and when the building is full, the salt is partially exposed. Therefore, the following environmental protection items must be followed to guard against leaching and runoff. These environmental stewardship practices are also necessary for crib storage, to guard against leaching and runoff, as crib storage is not roofed:
    - **The bituminous pad on which the building is placed must extend for a distance of 20 feet past the front of the building**.
    - **The building is not to be overloaded so that salt spills out** past the front of the building.
    - When fully loaded, **the front of the salt pile is to be covered by tarpaulins.**
    - A **sedimentation basin must be constructed to collect runoff.**
    - **The immediate area around the building is to be kept clean of salt spillage** that will normally occur when loading the building with trucks. This is especially important for the pad surface in front of the building.
- **The area must be properly signed.**
- Liquid De-Icer (Magnesium Chloride, Calcium Chloride and/or IceBan/MAGic, etc., which are not included under the Chemical Bulk Storage regulations) is stored in aboveground storage tanks (typically 3,000 - 5,000 gallon).
- **Liquid De-Icer storage tanks are located on level compacted sand bases and protected from traffic by barriers (i.e., ballards, guiderail, etc.).** A basic rule of thumb to determine storage needs is 1.5 times total lane miles to treat x recommended gallons per lane mile = amount of storage (ex: 1.5 x 200 x 50 = 1,500). Iowa DOT normally purchases 2500 gallon storage tanks because their cost per gallon is considerably less than other storage tanks. Other size tanks are available for limited space needs.
- **Area drainage is such that any spills can be contained on site.**

- **Placards or stenciled lettering are used to identify liquid de-icer tank contents.**
- **Drains must be closed.**
- **A minimum of two Stockpile Quality Assurance Evaluations should be completed per year** by District Offices, one in summer and one in winter. QA is performed by Central Office. Each item receiving a score of 3 or less requires a Correction Action Report (CAR) to be completed and entered into a District tracking system to assure improvement is made.
- **A "Stockpile Snapshot" is a cursory stockpile review that can be completed by anyone from the District Office. Any deficiency noted should be addressed within two weeks.** A Foreman's Stockpile Checklist is completed by the assigned stockpile Foreman four times per year and reviewed. A copy is sent to the District Office Maintenance Unit and the Facility Administrator. PennDOT awards Silver and Gold Awards to County Maintenance Organizations for Model Stockpiles meeting certain criteria. If all five are met, a Gold Award is given. If four are met a Silver Award is bestowed. An award for "Most improved" is given as well.
- **Spills are cleaned up immediately, using necessary equipment.**
- **If salty water from the stockpile is caught in a holding pond, the pond must be able to contain the amount of water from the next normal storm.** It should be pumped down to ensure that this level can be maintained. The pond water levels should be monitored and excess salt water should be disposed of in an approved location.
- **Any contractor activities at government-owned facilities should be monitored to ensure that they are following the operating plan for that facility.**
- **Operating plans should be developed by maintenance staff and the contractor**, if appropriate, in conjunction with DOT environmental staff.

PennDOT Salt Stockpile Management, Stockpile Academy, and Quality Assurance Program

PennDOT provides winter materials storage, runoff control, training and quality assurance, with a high emphasis on stockpile management. PennDOT's Model Facilities Task Force (MFTF), comprised of various representatives from Facilities Management Division of the Bureau of Office Services, Bureau of Maintenance & Operations, Bureau of Environmental Quality, Engineering Districts and County Maintenance organizations, indicated a need for PennDOT to reemphasize stockpile management after finding safety deficiencies, improper handling and storage of materials, environmental remedial costs, building damage, and failure to update and implement Preparedness, Prevention & Contingency (PPC) plans.(*807*)

Now, a District-approved, stockpile-specific PPC plan is displayed unobstructed in the staging building and is revised annually. PennDOT uses a 50 element QA review, each tied into a department policy or regulation or a PennDEQ regulation. PennDOT has developed a Stockpile Academy Training Program, which maintenance staff are required to attend on a 4-year rotating basis.

PennDOT inventories winter materials and transfers all environmentally sensitive materials to permanent material storage buildings should begin, starting with any stockpiles located within 500 feet of any wells or streams. PennDOT is moving toward the goal of every county having all salt under roofed storage from May to October. Bins and storage buildings, collection basins, and storage pads are cleaned and repaired in the spring. Prompt spring clean up of anti-skid materials prevents clogging of drains and impairment of surface waters and habitats.

PennDOT requires ongoing evaluation stockpile housekeeping measures, including a list of quality assurance responsibilities, which is included in the Appendix.(*808*)

The procedure for this checklist includes: (*809*)

- Completing the checklist for each stockpile by November 30, January 31, March 31 and June 30 of each year.
- The completed checklists are forwarded to the responsible Assistant Maintenance Manager for their review and signature.
- The Assistant Maintenance Manager forwards the signed checklist to the County Maintenance Manager.
- Within ten days of the completed checklist date the County Maintenance Manager forwards all Stockpile Checklists for his/her county to the Assistant District Engineer/Administrator-Maintenance (ADEM/ADAM) and the District Facilities Administrator (FA).
- The FA will determine appropriate corrective action in cooperation with the ADE/A-M, the County Maintenance Manager, Equipment Manager and Assistant Maintenance Managers.

PennDOT makes use of the following quality assurance evaluation indicators for solid winter materials stockpiles: (*810*)

- Any salt, mixed or treated material not under roof or tarped and anchored with sand bags; or not on an impervious pad.
- Any bagged deicing chemicals not stored on pallets and either under roof or 100 percent covered by tarps and anchored with sand bags.
- All salt, mixed or treated material stored under roof or on an impervious pad, tarp covered and anchored with sand bags. Note: Tarp and sand bags are not required during general snow and ice control operations. Bagged deicing chemicals stored on pallets and 100 percent covered by tarps and anchored with sand bags.
- All salt, mixed or treated material stored under roof, on an impervious pad, below building fill line, and tarp covered and anchored with sand bags. Note: If face of material is more than ten feet from the building doorway, no tarp is required.
- Bagged deicing chemicals stored on pallets and 100 percent covered by tarps and anchored with sand bags.
- All salt, mixed or treated material is stored under roof, on an impervious pad, and below building fill line, and tarp covered and anchored with sand bags. Note: If face of material is more than ten feet from the building doorway no tarp is required. Bagged deicing chemicals stored under roof, on pallets.

As a result of their system, PennDOT has been able to work with PennDEP to have one permit per district with an EMS in place, rather than one permit per stockpile. PennDOT is not required to sample because an EMS and BMPs are in place and salt is stored under cover. Finding covered loading was not considered necessary because loading areas are paved, curbed, and contained.

PennDOT developed the 15-minute Stockpile Walkaround to be performed by the Maintenance Foreman, along with a shorter Stockpile Snapshot as shown in the Appendix. Maintenance stockpile activities have been charted in a Stockpile Activity Protocol Matrix, also listed in the Appendix.

Material Delivery and Storage

Material delivery and storage procedures and practices are designed for the proper handling and storage of materials at the maintenance facility. Such materials may include aggregate, pesticides, fertilizers, detergents, plaster, petroleum products, asphalt and concrete components, hazardous chemicals, concrete compounds, or other materials that may be detrimental if released to stormwater drainage systems or watercourses.

The following procedures and practices minimize or eliminate the discharge of these materials to stormwater drainage systems or waters of the state.(*811*)

- During the initial stocking and following deliveries, special care should be taken to load and pile all solid materials in the approved manner and keep storage locations neat and orderly.
- Store drums in protected (dry) and temperature-compatible manner. Do not store materials that can freeze in unheated areas.
- Containment facilities should provide for a spill containment volume equal to 110 percent of the largest container in the facility.
- Liquids, petroleum products, and substances listed in 40 CFR Parts 110, 117, or 302 should be stored in approved containers and drums and should not be overfilled.
- Containers and drums should be placed in temporary containment facilities for storage. A temporary containment facility should provide for a spill containment volume able to contain precipitation from a 24-hour, 25-year storm event.
- Containment facilities should be impervious to the materials stored there and maintained free of rainwater and spills.
- Rainwater in containment facilities should be inspected prior to discharge. In the event of soil spills or leaks, accumulated rainwater and spills should be collected and placed into drums. These liquids should be handled as a hazardous waste unless testing determines to be non-hazardous. Nonhazardous liquids should be sent to an approved disposal site.
- Repair and/or replace perimeter controls, containment structures and covers as needed to keep them functioning properly.

Proper Handling and Use

- Personnel at maintenance facilities should be trained to ensure that materials are properly handled and stored.
- Use recycled and less hazardous products when practical, reducing or eliminating use of hazardous materials on-site when practical. Substitute a less hazardous or less waste-producing product or process for those that would otherwise have generated a more

hazardous or higher quantity of wastes. As well as potentially resulting in a non-hazardous waste for an indicated activity, such substitution may reduce or eliminate potential employee exposure concerns and additional regulatory burden.

- Use materials only where and when needed to complete the necessary maintenance or construction activity.
- Recycle residual paints, solvents, non-treated lumber, and other materials.
- Do not over-apply fertilizers and pesticides. Prepare only the amount needed. Follow strictly the recommended usage instructions. Apply surface dressings in smaller applications, as opposed to one large application, to allow time for them to work in and to avoid excess materials being carried off-site by runoff.
- Identify container contents and maintain data on its contents. Do not remove the original product label from a container, as it contains important safety and disposal information.
- Keep products in their original containers whenever possible.
- Use all of the product before disposing of the container.
- Label any unmarked containers with permanent markers; include the date when filling first occurred.
- Keep a record of what is stored in each container.
- Retain the material safety data sheets (MSDS) for each product.
- Record any information that relates to a waste, such as "also contains some water" or what activity the waste resulted from, such as "Safe-Strip cleaning solvent from epoxy pavement marking activities."
- Whenever possible, return unused products to the supplier.
- Never mix dissimilar materials and wastes in the same containers.
- Drain valves should remain closed except to release clean rainwater.
- Separation should be provided between stored containers to allow for spill cleanup and emergency response cleanup.
- Incompatible materials, such as chlorine and ammonia, should not be stored in the same temporary containment facility.
- To provide protection from rain, bagged and boxed materials stored outdoors should be stored on pallets throughout the rainy season.
- To provide protection from rain, bagged and boxed materials should be covered prior to rain events.
- Storage areas should be kept clean, well organized and equipped with cleanup supplies for the materials being stored. Perimeter controls, containment structures, covers and liners should be repaired or replaced as needed.
- Check to ensure that designated storage areas are kept clean and well organized.
- Dispose of wastes or empty containers regularly.
- Dispose of waste before knowledge of their contents is lost and before deterioration occurs.

- Keep an inventory of the waste on hand and contact environmental staff to set up disposal contracts for both hazardous and non-hazardous wastes.
- Dispose of empty containers promptly before water or other contamination or deterioration occurs.
- Avoid pollution from oil, paint, solvents, diesel, lead-acid batteries, fuel, hydraulic fluid and oil through use of water quality BMPs such as scheduling and planning, vehicle and equipment fueling, vehicle and equipment maintenance, hazardous waste management, material delivery and storage and spill prevention and control.
- Latex paint and paint cans, used brushes, rags, absorbent materials and drop cloths, when thoroughly dry and no longer hazardous, may be disposed of with other construction debris.
- Mix paint indoors or in a containment area. Never clean paint brushes or rinse paint containers into a street, gutter, storm drain or watercourse. Dispose of any paint, thinners, residue or sludges that cannot be recycled as hazardous waste.
- For water-based paints, paint out brushes to the extent practical and rinse to a drain leading to a sanitary sewer, where permitted or into a concrete washout pit or temporary sediment trap. For oil-based paints, paint out brushes to the extent practical and filter and reuse thinners and solvents.
- Keep an ample supply of spill cleanup material near material use areas. Train employees in spill cleanup procedures.
- Spot-check employees and subcontractors throughout the duration of the job to ensure appropriate practices are being implemented.

Waste Management

Waste management is governed by both federal and state requirements which include Federal hazardous waste management regulations developed under the Federal Resource Conservation and Recovery Act (RCRA), state-level waste management regulations, and regulations developed under other statutes that apply to wastewater discharges and air emissions.

DOTs practice stewardship by complying federal and state waste management regulations and taking measures to reduce or eliminate waste streams, in order to reduce the present and future threat to human health and the environment.

PennDOT practices the following hierarchy for waste management decisionmaking:

1. First, consider REDUCTION — activities that reduce or eliminate the generation of hazardous wastes. Waste reduction may include the following benefits:
    - Lower Operating Costs From The Substitution Of Less Expensive Raw Materials.
    - Lower Energy Costs Through The Use Of Newer, More Efficient Equipment.
    - Reduced Transportation And Disposal Costs.
    - Improved Product Quality.
    - Reduced Long-Term Liability Associated With Handling And Disposal Of Hazardous Wastes.
    - Enhanced Employee Safety From Reduced Exposure To Hazardous Materials.

- Cost Savings From The Reuse Of Materials.
- Revenues From The Sale Of Surplus Materials.
- Fewer Regulatory Compliance Requirements.
- Improved Public Image-The Less Wastes Produced, The Less The Department Is Viewed As A Contributor to environmental problems.

2. Second, consider RECYCLING — the use, reuse, or reclamation of wastes either on-site or off-site after they are generated.
3. Third, consider beneficially using wastes for ENERGY RECOVERY. Some specific wastes can be beneficially used as a fuel under carefully controlled conditions to recover their energy value.
4. Fourth, consider off-site TREATMENT to reduce the toxicity of hazardous wastes.
5. Finally, consider LAND DISPOSAL.

NYSDOT's "Solid and Hazardous Waste Reduction Policy" outlines policies and procedures to reduce its wastes, including the following: (*812*)

1) Recycling - NYSDOT engages in agency-wide programs to recycle such waste materials as used antifreeze and vehicle batteries.

2) Reuse - Whenever possible, NYSDOT reuses asphalt and concrete pavements as a substitute for crushed stone in subbase and other engineering applications.

3) Waste to energy - NYSDOT routinely collects used motor oil and compatible hydraulic fluids that are burned for fuels or space heating.

Standard operating practices that include good housekeeping are the simplest ways to reduce wastes. Other methods to reduce wastes include substituting materials; recycling and reuse; and participating in waste exchanges.

Waste Determination

The requirements for handling and disposal vary significantly for the different categories of wastes. A determination of whether a waste is a hazardous waste should be conducted for all wastes that could possibly be hazardous wastes. The definition of hazardous wastes is found in Title 40 of the US Code of Federal Regulations (CFR) Section 261.3. By definition, wastes are hazardous if they are 1) listed (specifically named) or 2) if they exhibit any of four hazardous waste characteristics (ignitability, corrosivity, reactivity, or toxicity).

The hazardous waste determination may be conducted by using the following:

- Generator's knowledge of the waste and/or testing.
- The product's Material Safety Data Sheet (MSDS) or product label, which should indicate if an unused product would be a hazardous waste.
- Information such as ingredients, flash point, pH and disposal requirements

Testing may be required to determine whether particular wastes are hazardous. Wastes generated by Department maintenance operations which may be classified as hazardous wastes, depending on test results, include: waste paint filters, used antifreeze, used caustic solutions, waste pesticides, spent paint abrasives, waste paints, spent solvents, waste motor oil, old batteries, shop rags, waste asphalt emulsions, or waste inks.(*813*)

DOTs must determine if the waste is a "listed waste" and/or has a "hazardous waste characteristic." Wastes that have certain "characteristics" (ignitability; corrosivity; reactivity; and/or toxicity) are hazardous wastes regardless of their origin. Toxic constituents can be released or leach out upon disposal, as measured by a test termed the Toxicity Characteristic Leaching Procedure (TCLP). The TCLP is an analytical test, which determines the potential of a toxic constituent (currently 40 constituents: metal, pesticide, and organic chemicals) to "leach" and become mobile and contaminate groundwater/waters upon disposal. Metals such as lead and chromium, and possibly benzene (a volatile organic) are the constituents on the TCLP list that most frequently are present in DOT wastes. Lead based paint waste, with the characteristic of toxicity, removed from bridges is one of a DOT's most frequently generated hazardous wastes, see Section 7.3.

DOTs must also consider the contaminants and/or changes to the material that could have been introduced during its use. This type of contamination may not be easily predicted by generators knowledge and may require testing of the typical waste product. Examples could include metal contamination in waste oils, degreasing solvent, or antifreeze that could be added during the vehicle operation that were not present in the virgin product.

Hazardous waste generators must determine how much hazardous waste they generate and maintain records to document the amounts. Most maintenance facilities maintain Small Quantity Generator (SQG) status for Maintenance and Operations facilities by generating less than 220 pounds (100 kg) or about ½ of a 55-gallon drum) of hazardous waste in any one month, or (b) stores less than 55-gallons of hazardous waste at any one time. If the above noted waste generation limits are exceeded, then the facility must comply with regulations for either a Small Quantity Generator Plus (SQG-Plus) or a Large Quantity Generator (LQG).

State DOTs should consult with regulations and procedures particular to the state and agency. General environmental stewardship practices include:

- Hazardous waste should be placed in the proper container/drum.
- All hazardous waste containers should be labeled with the words "Hazardous Waste" and the specific contents or words describing the waste.
- The hazardous waste container label should include the date when waste was first put in the drum and the date when the drum becomes full.
- Drums should be inspected at least weekly while stored on site.
- Arrange for off-site shipment of each full container of hazardous waste within 30 days of filling. Waste should be shipped by a permitted waste transporter with a hazardous waste manifest and disposed of at a permitted treatment/disposal facility for hazardous wastes. Waste should be removed within 90 days for LQGs and 180 days (270 days if it must be shipped more than 200 miles) for SQG.
- Maintain manifests of hazardous waste transport.
- Report spills or leaks of hazardous waste to the State Police or regulatory agency.
- DOTs should provide training at least once to all employees who handle or have responsibility for managing universal wastes on proper handling and emergency procedures and ensure that documentation of training is maintained. Training records should be kept for a minimum of three years or for the length of employment, whichever is longer, and cover the name of the person receiving the training, the date of the training

and the information covered during the training. A copy of the documentation should be sent to the DOT's central training office.(*814*)

- Limitations on storing hazardous wastes at the facility's central accumulation area are dependent upon the quantity of wastes generated, with different regulations for small and large generators.
- Maintenance facilities should never exceed these time and quantity accumulation limits; otherwise the facility will be considered a Treatment, Storage, and Disposal Facility (TSDF) and be subject to extensive additional RCRA regulatory requirements.

Hazardous Waste Management Practices

Each DOT should follow guidelines and practices developed by their state and agency specialists. Environmental stewardship practices include: (*815*)

Container Storage

Best practices for storage include containers:

- In good condition.
- Compatible with the wastes contained in them.
- Opened only to add or remove wastes.
- Separated from other containers holding different wastes which could cause dangerous chemical reactions.
- In compliance with container requirements for shipping wastes off-site.
- Marked with the date accumulation begins and with each subsequent date waste is placed in the container labeled with the words "hazardous wastes".
- Segregated by waste type and clearly marked to identify their contents.
- Kept within a secured area permitting access by authorized personnel only.
- Recorded in a running log of wastes accumulated in each container.
- Inspected for leaks and container deterioration weekly with the inspection results recorded.

Storage Area Practices

- Reactive or ignitable wastes located at least 50 feet from the facility property line.
- Wastes with flashpoints under 100of located at least 60 feet from any adjoining buildings or property lines.
- Incompatible wastes segregated.
- A base and dike capable of containing leaks, spills, and accumulated rainfall.
- Adequate containment capacity necessary to hold a spill amounting to the volume of the largest container, or ten percent of the total volume of all containers, whichever is greater, plus a reasonable amount for precipitation.
- Adequate space around containers to ensure access in the event of a spill or emergency.
- Proper emergency equipment, as needed, such as alarms, telephones, or fire extinguishers.

- A design consistent with department publication 284 titled “handbook for acquisition, development, and maintenance of the model stockpile”. and
- Spill and leak response measures incorporated in the PPC Plan.
- Storage of hazardous wastes in aboveground storage areas is preferred. Wastes generated by parties other than the DOT are stored at DOT maintenance facilities rights of- way unless approved by the district maintenance engineer.

Packaging

Best practices for hazardous waste packaging and transport include: (*816*)

- Packages meet the USDOT or UN specifications for the wastes.
- Packages are sufficiently tight to prevent releases of materials.
- Mixing of reactive or combustible gases is prevented.
- Packages adequately closed. and
- Liquid containers should have sufficient free space above the liquid to accommodate expansion of the liquid to 130 degrees Fahrenheit.

Product containers may be reused once for shipping wastes if the product containers:

- Are acceptable USDOT or UN specification drums for the wastes.
- Are in good condition and free of rust, damage, or leaks.
- Do not contain any incompatible residues.
- Do not carry any old marking labels that incorrectly identify the contents.
- Reused containers must be thoroughly cleaned to avoid combining incompatible wastes producing toxic vapors or explosions as well as waste mixtures that are even more dangerous than the individual wastes.
- Small items may be packaged in drums which are commonly referred to as lab packs. In general, lab packs should be packaged as noted below. The specific packaging requirements should be reviewed with the disposal contractor.
- Outside packaging should be an USDOT specification metal or fiber drum with a removable head.
- Drum construction should be compatible with the materials being packaged.
- Outside packaging should contain only one hazard class.
- Inside packaging may be one or more glass packagings not exceeding one gallon, or one or more metal or plastic packagings not exceeding five gallons. and
- Inside packaging of liquid should be surrounded by compatible absorbent material capable of absorbing the total liquid contents.

Marking

All containers used to ship hazardous wastes should exhibit a USDOT hazardous waste marking completed with waterproof ink and showing:

- The proper USDOT shipping name of the waste.
- The UN or NA number.

- Generator information including name, address, and EPA ID number.
- The EPA waste number.
- The accumulation start date. and
- The manifest document number.

Labeling

All containers used to ship hazardous wastes should exhibit a USDOT hazardous waste label and may require an USDOT shipping label if it meets a hazard class definition.

Manifesting

A hazardous waste manifest is a multicopy shipping document that is filled out and accompanies all hazardous waste shipments. Hazardous waste manifests are designed to track shipments from the point of generation to their final destination. All generators, except conditionally exempt small quantity generators, must use manifests to ship their hazardous waste.

- The hazardous waste manifest should be completed before shipping hazardous wastes. The manifest becomes the written record of the hazardous waste disposal. Upon shipment, forward a copy of the manifest to both the state of generation and the state of destination and retain a copy. A copy of the signed receipt manifest must be returned by the disposal facility to the generator state, disposal state and the generator.
- Copies of the manifest that are signed and returned by the treatment or disposal facility are maintained on file for five years for small quantity generators and twenty years for large quantity generators.
- If a copy of the signed manifest is not received from the waste facility within 35 calendar days, the transporter and waste facility should be contacted to determine the status of the shipment and the state/environmental agency notified of the status.
- An exception report may be required for wastes not received after 45 days. Manifests may not be required when reclamation of the material is occurring but as a best practice the DOT may want to manifest all hazardous waste shipments because it simplifies record keeping and reporting.

Shipping

A licensed disposal contractor should provide the following services:

- Contract with a facility authorized by the EPA or the state permitting agency to treat or dispose of hazardous wastes.
- Package and label the wastes and prepare the manifest. - prepare a hazardous waste characterization report.
- Prepare a land band notification advising the treatment or disposal site of the standard to which the hazardous wastes should be treated. and
- Transport the hazardous wastes to the treatment or disposal facility.

Verify that the wastes were received at the waste facility by reviewing the signed manifest received from the waste facility. Liability does not end when hazardous wastes have been shipped and are no longer in the Department's possession. The Department is liable for any mismanagement of its wastes, at the current time and in the future.

Inventory and Record Keeping

Maintaining hazardous waste records is a very important part of regulatory compliance. Good record keeping proves operating compliance and may avoid problems with regulatory agencies and minimize future cleanup liabilities. Facilities judged out of compliance face legal and enforced actions, fines, and bad publicity. The following minimum records should be maintained by small quantity generators for a minimum of five years.

- Test results or waste analyses made to determine if wastes generated are hazardous.
- Monthly summaries of wastes generated which substantiate the generator category.
- This summary should indicate the final disposition of the wastes, including those not manifested.
- On-site waste accumulation records, including the date accumulation began and the quantity accumulated to date.
- In-house inspections, including deficiencies noted and when such deficiencies were resolved.
- Records of employee training.
- Generator's copies of the manifests and those returned from the destination facilities.
- Copies of land ban notifications.
- Copies of reclaiming contracts.
- Spill or leak reports.

Large quantity generators should maintain the above records and copies of quarterly reports, biennial reports, and exception reports for a minimum of twenty years.

In addition some DOTs have established Safety Coordinator positions, which with they have charged the following responsibilities: (*817*)

- Ensure that an inventory of *all* hazardous chemicals is completed annually, including the product/chemical name, type of container, volume, and location of the hazardous chemicals. The Division Safety Coordinator should confirm that a current MSDS is on file for all chemicals in the inventory. Where applicable, the inventory should include Reportable Quantities for CERCLA hazardous materials and Extremely Hazardous Substances (refer to 40 CFR 302.4 and 40 CFR 355 for Reportable Quantities).
- Update inventory reports between annual inventories following any significant change in status (*e.g.,* removal of a tank).
- Maintain a MSDS for each hazardous chemicals used or stored in each M&O facility, and should ensure that copies of MSDS are kept at each location where chemicals are used. MSDS are to be readily available to employees, so that an employee should be able to find the appropriate MSDS within 5 minutes MSDS must contain information about the chemical including:
    - Chemical product
    - Exposure controls and company identification personal protection
    - Composition, information or ingredients properties
    - Physical and chemical
    - Hazard identification

  - Stability and reactivity
  - First aid measures
  - Toxicological information
  - Fire-fighting measures
  - Ecological (environmental)
  - Accidental release measures information
  - Handling and storage
  - Disposal considerations
  - Transport information
- Based on the annual inventory, the Division Safety Coordinator should create a list of all hazardous chemicals that exceed 10,000 lbs., or Extremely Hazardous Substances (EHS) that exceed 500 lbs. or certain Threshold Planning Quantities (refer to 40 CFR Part 370.20 and 355). This list, hereafter referred to as the "Reportable List" should be provided to the MTS Petroleum and Hazardous Waste Management Superintendent and the Division Manager/Engineer. Petroleum products, such as diesel fuel or motor oil, are typically the only hazardous materials used by M&O in the quantities described above; 10,000 pounds equals about 1,500 gallons. M&O does not routinely use Extremely Hazardous Substances at its facilities (e.g., sulfuric acid, chlorine, formaldehyde and phenol).
- In order to comply with EPA SARA 311 and 312 reporting requirements, the Petroleum and Waste Management Superintendent should complete the following for each chemical on the Reportable List:
  - Submit a copy of the state Chemical Inventory Reporting Form and MSDS for each chemical to the local fire department, the Local Emergency Planning Committee and Maine Emergency Management Agency;
  - Pay chemical inventory and facility registration fees by March 1st and October 1st, respectively to the Maine Emergency Management Agency; and
  - Update chemical inventory reports within 90 days of a significant change in chemical inventory status (e.g., adding new chemicals).

Non-Hazardous Industrial Wastes

Some wastes, that do not meet any criteria for definition as a hazardous waste, but result from work activities are considered industrial-commercial wastes and may be disposed at municipal/commercial disposal facilities, similar to routine nonhazardous solid waste, at recycling facilities and at specialized facilities for that type of waste. Shipment, however, requires transport by permitted waste transporters, if transported in greater than exempt quantities (500 pounds/shipment). Such waste includes used tires; non-hazardous used oil, non-hazardous waste antifreeze; other waste vehicular fluids and filters that do not meet the criteria of hazardous waste; unused products containing chemicals (that are not hazardous wastes); and empty drums/containers for disposal, not recycling

Permitted C&D landfills can usually accept the following types of wastes:

- Uncontaminated bricks, glass, asphaltic pavement, concrete and masonry materials.

- (Pavement containing routine intact traffic markings or that has come into contact with petroleum products through normal vehicle use of the roadway are considered clean)
- Uncontaminated soil, rock and land clearing debris
- Wood and wood products
- Wall coverings, plaster and drywall
- Plumbing fixtures, electrical wiring and components containing no hazardous liquids, nonasbestos insulation, plastics that are not sealed in a manner that conceals other wastes, roofing shingles and other roof coverings
- Empty buckets and containers (ten gallons or less) with less than one inch of residue in the bottom
- Pipes or metal that are attached to or embedded in these waste materials

Non-Hazardous Solid Wastes

Routine garbage, office trash, and most litter collection are considered non-hazardous wastes. Most of the adopt-a-highway trash, excluding tires and other items that are industrial or possibly hazardous wastes, are non-hazardous solid wastes. These wastes should be sent to municipal or commercial landfills or trash burning plants, and no special haulers or manifests are needed.

Specialty Waste Disposal Procedures

Specialty wastes include hazardous wastes, chemical products (including partially- used products), and/or other materials that are not disposed of by routine trash collection and require a special waste contract for disposal. Disposing of specialty wastes is generally a two-step process:

1. Identify specialty wastes and if necessary perform laboratory testing - Known unused materials with sufficient information on their characteristics from material safety data sheets (MSDSs) or other information sources can be identified adequately for disposal. Examples include unused containers of toluene or paint with labels intact and MSDSs available. Sufficient information may also be available to identify used materials of known characteristics such as antifreeze where the waste had previously been tested and the process generating the waste has not changed; or fluorescent bulbs which are known to be hazardous due to mercury content. For waste of unknown or uncertain identity or where contamination could be added at unknown levels to the material upon use, testing may be required to adequately identify the waste for disposal. The DOT has contracts with analytical laboratories and standard procedures for confirming suspected drum contents. The contracts with these labs are designed to characterize wastes for disposal and will meet regulatory standards without adding unnecessary testing. Call the Regional Maintenance Office or the Environmental Specialist for assistance in inventorying, identifying and testing materials for disposal.
2. Specialty waste disposal contracts - A specialty waste disposal contract can be developed for the removal and disposal of the specialty wastes as identified on the inventory. The contracts should include MSDSs and analytical results to assist the contractor in providing proper handling, record-keeping and disposal of the wastes. It is generally most cost-effective to arrange for disposal of all waste materials within a DOT Region at one time, but smaller or periodic disposal contracts may be required if storage time limits or

storage space are issues. See the DOT's procedures for Storing and Handling Products and Wastes (Waste storage time limits and inspections).

Specific Guidance for Certain Waste Management Issues

NYSDOT, PennDOT, and Maine DOT guidance for specific waste management issues is included below: (*818*)(*819*)(*820*)

Abrasives

Spent abrasives from construction projects should not be stored at maintenance facilities.

Aerosol Cans

- Disposal: Empty aerosol cans may be thrown in the regular trash or thrown in the metal recycle bin. Aerosol cans are empty when product can no longer be sprayed out from them. This does not include cans that have product but do not function.
- Aerosol cans that are broken, clogged or otherwise unusable must be disposed of as hazardous waste. They *must* be stored in a small container with a *lid that closes tightly and* a hazardous waste label that includes a start date and identification of the waste as aerosol cans. The container should be stored in the same area as other hazardous wastes (if there is a drum at the facility), and should be transported at the same time when regular hazardous waste pickups occur. *The small container may be any 5-gallon pail or bucket with a lid that closes.* Labels should be provided by the Petroleum/Waste Management Superintendent.
- Aerosol cans with contents no longer usable or needed must also be disposed of as hazardous waste OR the contents may be exhausted into the 30 gallon hazardous waste drum, and the empty aerosol can may be thrown into the regular trash or metal recycling bin.

Antifreeze (*Coolants*)

New antifreeze would not be a listed hazardous waste or fail any characteristic for hazardous waste. However, any contaminants such as chlorinated solvents, benzene, or metals that could be introduced during use must be considered to determine if the waste antifreeze could be a hazardous waste. Generator knowledge and/or representative testing of the typical waste is required to determine if it is classified as hazardous waste. Used antifreeze should be collected in dedicated drums or tanks and clearly labeled. Disposal should preferably be by a commercial recycler who will reclaim the material.

Used Antifreeze

Used antifreeze should be collected in drums that are clearly labeled as containing "Used Antifreeze." Drums should be kept tightly closed when material is not being transferred in or out; funnels should not be kept in tank openings when not in use. Used antifreeze should be collected and recycled by the DOT.

Asbestos

Asbestos is a mineral that breaks up into very small fibers and was used for many years in making fireproofings, roofing, siding, flooring, ceiling tile and others building products. Only certified asbestos handlers can disturb, remove or package for disposal any asbestos-containing material. Any renovations or demolitions involving buildings, bridges, and utility lines that could contain asbestos must be evaluated by a certified asbestos handler. Hauling of friable (able to flake) asbestos waste requires a waste transporter permit, manifesting and waste disposal at special landfills. (Non-friable asbestos, however, may be transported and disposed of as C&D waste). OSHA requires a visual inspection to identify materials that may contain asbestos, for future reference. If this inspection has not been performed at the facility, or if there is the possibility of finding asbestos waste along the ROW, contact the DOT environmental specialist for help and further instructions and see the DOT safety guidance.

Ballasts (*PCBs*)

Some older fluorescent lamp (light) fixtures have ballasts that contain an oily insulating liquid that contains PCBs (Polychlorinated biphenyls) which must be disposed of as a PCB hazardous waste. PCB-free dielectric oil contained in newer ballasts can be handled and disposed of as used oil. Assume the ballast contains PCBs unless it is marked "does not contain PCBs". The ballasts can be disposed of using specialty waste contracts or by using the Office of General Services contracts for disposal of lighting wastes from state facilities. The ballast should be separated from the lampbulb and disposed of separately. (See "Fluorescent Bulbs" for bulb disposal).

Batteries

Requirements vary for batteries dependant upon their type and content and may require specialty recycling or disposal due to metal content or corrosivity. The federal Battery Act of 1996 required the phase out of mercury in alkaline batteries and required the development of recycling programs for nickel cadmium, lead and certain other batteries. Review the information marked on the battery or provided with it and, unless supplier information indicates otherwise, handle by the following general guidelines:

- **Lead Acid Batteries:** Typically vehicle batteries and small sealed batteries in electronic equipment, contain acid liquid and lead and must be recycled or disposed as hazardous waste. NYS law requires retailers/distributers to accept used automotive/truck/RV batteries back for recycling at no charge (two per month maximum without new battery purchase). Turn in the old batteries when new batteries are installed. Licensed waste transporter, manifesting of shipment, or inclusion of the battery quantities in site hazardous waste generation amounts and generator status calculations are not required.
- **Nickel-Cadmium rechargeable batteries** must be recycled or managed under the "Universal Waste Rule". The Rechargeable Battery Recycling Corporation (RBRC) at 800-8- BATTERY can provide assistance in recycling; alternatively, specialty waste disposal contracts could include the recycling of these batteries in their requirements.
- **Nickel Metal Hydride batteries** are not specifically required to be, but should also be similarly recycled. Silver Oxide and formerly available Mercuric Oxide batteries must also be recycled or disposed of as hazardous waste due to silver or mercury content, respectively.
- **Alkaline batteries and carbon-zinc batteries** are now made with no intentionally added mercury and are considered acceptable for disposal as routine municipal waste.

- **Used lead acid batteries** that have no cracks should be stored in a designated area, protected from the elements, with primary and emergency containment constructed of impervious material, and segregated from non-compatible materials and wastes. Used lead acid batteries should be disposed of within ninety days, but should be disposed of within one year. Lead acid batteries that have cracks are a hazardous waste.

Brush and Tree (*Clearing and Grubbing*) *Waste*

Chip and mulch, convert to compost if possible. Last choice is disposal as (C&D Debris - Exempt C&D)". Burning is usually not allowed.

Concrete Sealers

Unused virgin concrete sealers typically have a flash point below 140° F which would classify the product as an ignitable hazardous waste. The product upon use, however, with the volatile components evaporated, would no longer meet the criteria of ignitable/flammable.

Contaminated Soil or Sediment

Contaminated soil is an industrial waste and requires disposal at municipal/commercial disposal facilities (such as sanitary landfills) reclamation facilities or at specialized facilities for the type of contamination present. The potential for the contaminated soil to be a hazardous waste due to characteristics such as flammability or toxic metal content must also be considered. If soil or sediment contamination is suspected, call the RLA/ESU to help arrange for further investigation and possible testing. Soil or sediment may be contaminated if it is discolored or stained, or smells like fuel or sewage.

Culvert and Catch Basin Cleaning

Uncontaminated grit and sediment from culverts and catch basins is normally disposed of as C&D waste and is not considered contaminated unless it smells like petroleum, fuel, or solvents, or is mixed in with other wastes like roadside trash.

Degreasers

See "Parts Washer Wastes".

Drums and Containers

Drums and containers that have had all of the contents removed by common practices and have less than 1 inch and less than 3 percent of the original product are considered "empty" and nonhazardous, even if the material they contained (such as solvents or coatings with flashpoints below 140 degrees F) would otherwise be classified as a hazardous waste. "Empty" containers may be returned to the manufacturer or sent to a reconditioner or handled as scrap metal, cardboard, etc. and are exempt from waste transporter requirements when destined for such reuse. "Empty" containers are nonhazardous industrial wastes when otherwise disposed.
Small containers of up to ten gallon capacity are, however, considered C&D debris and can be disposed of as such. The original product label and hazard warnings must be left on drums or containers until they are empty as described above and no longer pose the indicated hazard. Remove or obliterate the label and mark the drum "empty" as soon as the drum is empty by these

criteria. The hazard markings must be removed from an empty drum meeting these criteria prior to removing from the facility.

Drums are considered empty when there is less than one inch of product remaining and less than three percent of the original product in the drums. Empty drums should be stored neatly in a designated area with lids and bungs secured with end drums blocked to prevent rolling. The empty drum storage area should be in a location that does not permit surface water to collect or wash through the storage area. Empty drums should be disposed of at least annually. Abandoned drums or containers of unknown substances that are found along the ROW are handled similarly to spills of hazardous substances on the ROW and may need to be reviewed by police. Further details are available in the following section addressing Drum management within Facilities.

Fills

Suitable fills are environmentally inert, uncontaminated, non-water soluble, solid materials. Only suitable fills should be used to level an area or bring it to grade provided the area is not located in a wetland. Suitable fills may be commingled with other suitable fills at maintenance stockpiles while being stored prior to placement in a fill area. Examples of suitable fills include:

- Shoulder cuttings
- Bituminous asphalt excavations pipe excavations (but not metal or plastic pipes)
- Crushed portland cement concrete without exposed reinforcement bars
- Bricks and solid masonry blocks
- Clearing and grubbing vegetation

Fluorescent Bulbs

Typical spent fluorescent bulbs (lamps) are hazardous wastes due to mercury content. Intact (not crushed or broken) fluorescent lamps are eligible to be handled as “universal wastes” allowing for somewhat reduced regulation (See “Universal Wastes”). Some manufacturers are marketing lamps with lower mercury content; these lamps may not be hazardous wastes when spent. Unless the lamps are marked (or otherwise identified) as low mercury content lamps, assume that the lamps must be handled and disposed of as a universal or hazardous waste. The waste bulbs can be disposed of using specialty waste contracts or by using the Office of General Services contracts for disposal of lighting wastes from state facilities. Lamps that are marked or identified as low mercury must be evaluated to determine if they are a hazardous waste; manufacturer’s data may be used to support a determination that particular lamps are not a hazardous waste. Note: The ballast should be segregated from the lamp and may also be a hazardous waste due to PCB content (See “Ballasts”).

Fuel Filters

Used gasoline or diesel fuel filters are classified as hazardous wastes because they typically have the characteristic of ignitability or toxicity for benzene. These should be stored in closed containers, separate from other wastes, and labeled, handled and disposed as hazardous wastes. However, if the fuel filters can be drained of all free liquids, they can qualify as scrap metal and be recycled at a scrap metal facility, under the scrap metal exemption.

Grease and Tar

Collect grease and soft tar in separate containers with proper labeling. Include these containers for disposal by a specialty waste disposal contract. Greasy rags should be collected along with oily rags and absorbents and properly disposed by arrangement with the Petroleum/Waste Management Superintendent. Greasy rags should not be disposed of in the regular trash. Any waste grease should be disposed of as special waste by arrangement with the Petroleum/Waste Management Superintendent.

Hazardous Substances in Equipment

Some equipment contains hazardous substances that may require special handling and disposal. Examples include switches or thermometers that contain mercury, or ballasts and light fixtures with PCBs (See “Universal Wastes” and “Ballasts”). Call the environmental specialist or landscape architect with specific questions.

Herbicides

Herbicides are regulated pesticides. See “Pesticides”

Hydraulic Fluid

Hydraulic fluid products such as brake fluid, transmission fluid and power steering fluid are chemically different from motor oil, but NYSDEC Used Oil regulations considers them used oil and allows mixture and recycling along with used oil. The recycler/disposal firm should be consulted, however, on their specific requirements. The fluids also must not be contaminated with any solvents or other materials that could cause them to be hazardous wastes.

Lighting Waste

See “Ballasts” and/or “Fluorescent Bulbs”.

Litter

See “Adopt-a-Highway Waste”

Medical Waste (*Used Syringes or Needles*)

Used hypodermic needles and syringes are sometimes discarded at rest areas or along ROW. They are classified as household waste, not as ”regulated medical waste” as defined in the Public Health Law when they are found at public recreation spots such as rest areas. Used needles and other “sharps” can poke workers, and some bloodborne diseases like hepatitis can be transmitted if the virus is present. (The AIDS virus is unlikely to live more than an hour outside a human host, but should also be considered a risk.) CAREFULLY place the syringe in a container and label with a biohazard sign (or use red containers). Disposal should be at a local hospital or other facility that can accept medical waste.

Oil

Environmental stewardship practices for used oil include the following:

- Collection: Used oil produced at M&O facilities should be collected for recycling or burning in approved used oil furnaces. The DOT should collect used oil in drums or tanks clearly marked “USED OIL” for transportation to locations with used oil burners.

Care should be taken not to contaminate the used oil with hazardous materials, or other non-approved materials.

- Storage: Oil storage tanks or drums should be located in areas with an impervious floor (such as concrete). Tanks should have secondary containment where risk of damage (*e.g.*, by vehicles) is high, or where the impacts of a spill would be severe (*e.g.*, proximate to floor drains). Metal tanks or drums should not be in direct contact with the ground (contact with a dry floor is permitted); only tanks with double-walls and a leak detection system maybe placed on or below the ground surface.
- Used oil tanks or drums should be clearly labeled as such, and should be posted with a list of what is permitted to be dumped into the tank. All used oil tanks that could be accessible by the public (outside) should be locked to prevent unauthorized dumping of hazardous or non-approved materials into the tanks.
- Storage tanks should be inspected by the Petroleum/Waste Management Superintendent and/or Division personnel at least annually for structural integrity. The supervisor should keep a record of the inspection at the facility. The DOT should arrange for recoating or replacement of tanks that are rusting and/or pitted. Existing spill containment structures should be inspected annually for structural integrity and repaired if necessary (such as filling in cracks in concrete).
- Suspected contamination of oil waste: If the used oil is suspected of containing contaminants, such as solvents, brake cleaner, or toxic metals, then the contaminated oil should be contained separately and disposed of as hazardous waste (see Bureau of M&O *Hazardous Waste Management Procedure*).

Used oil filters are considered a non-hazardous waste if the used oil is removed from the filter. The filter may then be preferentially recycled as scrap metal or otherwise disposed of as non-hazardous waste. Environmental stewardship practices for used oil include the following:

- Oil filter recycling should be available at all M&O facilities.
- Collection procedures should be established for each location.
- The drained oil should be combined with other used oil from the site for recycling. See "Used Oil".
- Properly drained or crushed filters should be placed in a container marked "used oil filters" and disposed of every ninety days.

In order for the oil to be considered removed, filters should be gravity hot-drained by one of the following methods:

- Puncturing the filter and hot draining. EPA recommends that hot draining occur at or near engine operating temperature for at least 12 hours.
- Hot draining and then crushing the filter.
- Dismantling and hot-draining.
- Any other equivalent hot draining method that will remove used oil.

Environmental stewardship practices for use of oil absorbents include the following:

- *Types and use of absorbents:* Maintenance workers should be provided with, and trained in the use of, spill pans and absorbents to minimize spills or drips on shop floors, and to reduce the quantity of absorbents used. Absorbent pads and pans should be provided as appropriate for the following:

  - Under spigots on oil dispensing drums and tanks;
  - Under leaky hydraulic valve boxes and hoses (hoses should also be capped and elevated where possible);
  - Around used oil collection tanks and associated filter pipes and drainage racks; and,
  - Under vehicles and machinery undergoing repair or maintenance.

- *Collection of used absorbents*: Oily absorbents (including Speedi-Dry) should be collected in a sealable container (such as a drum) and properly disposed by arrangement with the Petroleum/Waste Management Superintendent. Oily waste should not be disposed of with regular trash.
- *Substitute absorbents:* When possible, M&O should use substitute absorbent materials which are not clay-based. DOTs should maintain an approved list of absorbent materials.

Paint

Most unused paints, including waterborne, have a flashpoint below 140 F and therefore require handling and disposal as an ignitable waste. If the paint contains lead or chromium, the potential for the waste to have a toxicity characteristic for lead or chromium must also be considered. Yellow waterborne traffic marking paint may contain significant amounts of lead chromate. Limited testing of the waterborne yellow paint, however, has indicated that it did not fail the toxicity characteristic tests. Consult the Material Safety Data Sheet (MSDS) and the RLA/ESU for further information.

Dried Paint Chips and Flakes

Dried pavement marking paints and other non-lead dried paint are non-hazardous industrial wastes, requiring disposal at a municipal landfill. These dried paints would include markings purposely removed/milled from the road surface, but would not include the paint markings incidentally present on an entire removed section of roadway which would qualify as C&D debris. Some dried paints containing lead such as former lead- based bridge paint removal debris are considered a hazardous waste for their lead content and must be disposed of as hazardous waste. Testing of typical dried yellow pavement marking paints (waterborne and epoxy), however, has indicated that, although lead and chromium are present in significant concentrations, they are under regulatory levels for hazardous waste. Note: Landfills, however, may be unwilling to accept paint waste and/or may require additional testing. Dried paint wastes may also be collected, stored and disposed of by the specialty waste disposal contract.

Paint Thinner

Most paint thinners are organic solvents that would be listed or ignitable wastes. Store and handle these as hazardous wastes.

Parts Washer Wastes

Spent solvents from parts washers may be hazardous wastes due to ignitability. The solvent used in Safety Clean parts washers typically has a flashpoint below 140 degrees F and would be an ignitable waste upon disposal. Any contaminants such as metals that could be added through use must also be considered. Typical spent filters (bag and cartridge filters) from Zep parts washers have been tested for contaminants including metals that could be introduced during its operation and were under regulatory limits and are therefore determined to be a non-hazardous waste.

Parts Cleaner Waste

- *Parts cleaner solvent:* All M&O facilities should use parts cleaner solvent, approved by the Petroleum/Waste Maintenance Superintendent, that would not be classified as a hazardous waste if contamination by metals or other chemicals did not occur during use. For example, do not use solvents that contain chlorinated compounds (*e.g.*, trichloroethylene) or have a flash F° point less than 140.

  Maintenance personnel should not contaminate the parts cleaner with hazardous materials, such as chlorinated solvents often contained in spray cleaners (*e.g.*, some brake cleaners).
- *Disposal of used parts cleaner solvent*: Spent parts cleaner and parts cleaner filters will be disposed of as hazardous waste (note: used solvent may be hazardous even if the virgin product is not hazardous, due to contamination during use.) See M&O *Hazardous Waste Management Procedure*.
- *Registration of parts cleaners*: The DOT Safety Coordinator should register any parts cleaners containing volatile solvents with the state environmental agency. At a minimum, the DOT should keep an inventory of parts cleaners in service, and will notify the environmental agency of the size or volume and type of parts cleaner, and the type of solvent used. The DOT should determine if additional requirements apply depending on the volatile organic content of the solvent.

Pesticides (*Includes Herbicides and Insecticides*)

Keep all pesticides in their original, labeled containers, and keep its Material Safety Data Sheet (MSDS) on file at the facility. Partly used containers should be saved for next use. Pesticides that can not be used must be disposed of by a specialty waste contract. Empty containers of non-combustible pesticides may be disposed of as non-hazardous waste after triple rinsing (with the rinse water used to make up the next batch of herbicide); or, for ready-to-use (do not require dilution) pesticides, after draining for one thirty second period. (See also “Empty Drums and Containers”).

Petroleum Contaminated Soil

Soil materials contaminated with petroleum products, including (but is not limited to) gasoline, heating oils, diesel fuel, kerosene, jet fuel, lubricating oils, motor oils, greases, and other fractions of crude oil are considered petroleum contaminated soil and require disposal as industrial waste (See “Contaminated Soil and Sediment”).

Refrigerants

Refrigerants such as Freon are used in air conditioning systems and contain chlorofluorocarbons (CFCs) which pollute the air. Freon and other refrigerants must be removed and recycled by workers with EPA-approved training. Maintain records that show the name of the recycling facility that removed the refrigerants.

Shop Rags (*or Shop Towels*)

When rags are used to clean up known nonhazardous waste materials such as non-hazardous cleaning solvents or hydraulic fluid or motor oil, the rags would not be a hazardous waste. If, however, rags were used to soak up a material that would be a hazardous waste (toluene or chlorinated solvents for example), the rag could be a hazardous waste. Hazardous waste rags are not regulated as hazardous wastes if they are sent out to be cleaned and returned for re-use. All used rags, shop towels, and clothing soiled with parts cleaner, gasoline or diesel fuel, used oil, etc. should be stored and managed in fire-proof or fire-resistant containers and must not be so saturated that they can drip any free liquid. Since DOTs should avoid using chlorinated solvents or hazardous waste cleaning solvent or other listed materials, rags for disposal should not be non-hazardous industrial wastes. Any rags, however, that were used for potentially hazardous waste materials could be hazardous wastes requiring disposal as specialty hazardous wastes and should be kept separate from non-hazardous waste rags. Contact the DOT environmental specialist for assistance in determining if non-routine rags for disposal are hazardous wastes.

Solvents and Degreasers

See "Parts Washer Wastes" or "Paint Thinner".

Sorbents (*Speedi-Dry or Sorbent Pads*)

When sorbents are used to clean up spills from known nonhazardous sources such as hydraulic fluid or non-flammable (non-chlorinated) parts washers, the used sorbent is not a hazardous waste and may be disposed of as routine nonhazardous waste. Sorbents used to clean up known hazardous wastes, however, would also be a hazardous waste. When sorbents are used to clean up spills from unknown sources, they could be hazardous wastes and should be tested. Call the RLA/ESU to arrange for testing and/or disposal as specialty wastes.

Street Sweepings (Shoulder Maintenance) — Routine street sweepings are not considered contaminated and can be handled like fill or sent to a C&D (construction and demolition) or municipal waste landfill. Street sweepings should be handled as contaminated soil if they smell like petroleum or solvents, or contain considerable roadside litter such as paper, cigarette butts, plastic, etc. Contaminated street sweepings must be sent to a municipal landfill. This topic is covered in greater detail in roadside, non-vegetative management practices.

Tires

Waste tires and scrap tires collected along state highways can be stored for up to 18 months. A permit is often required to store more than 1,000 tires. Waste tires can be sent to a landfill, recycler, or trash-burning incinerator, but some landfills do not accept scrap tires because they are bulky and tend to "float" to the top of the waste pile. Some cement kilns or burn plants can burn tires for fuel. Check with the local waste hauler or landfill to see how to dispose of waste tires in the area. Used tires should be stacked by size, type of construction and vehicle use and stored under roof or tarped. Used tires should be disposed of annually or whenever they number 500 in count, whichever comes first.

Routine trash and Adopt-A-Highway Waste is considered non-hazardous waste and can be disposed of as routine refuse at municipal/commercial landfills or disposal facilities. Some wastes need special handling. Such wastes include Abandoned Drums and Containers, Medical Waste, Tires, etc. See pavement and materials recycling section.

Universal Wastes

Certain common hazardous wastes that were considered to be low risk have been designated as "universal wastes" with somewhat reduced regulation. Universal wastes currently include spent batteries, certain unused pesticides, fluorescent bulbs containing mercury and mercury thermostats. Manifests are not required for shipment (although permitted waste transporters are required for transport of >500 pounds/shipment) and wastes may be accumulated on site for up to 1 year. Small quantity handlers (up to 5,000 kg at one time) do not need an EPA ID number.

Used Oil (Waste Oil) — Used oil that is destined for recycling or burning for energy recovery is not regulated as a hazardous waste. Examples of used oils include spent motor oil, hydraulic oil, cutting oil, transmission fluid, fuel oils, gear oil and greases (Note: waste fuel oil is not regulated as used oil). Used oil should be collected into clearly labeled tanks or drums. Do not mix any other materials such as solvents, antifreeze or gasoline with the used oil. (If some type of hazardous waste such as solvents, degreasers, etc. are mixed with the used oil, then the entire volume may be classified as a hazardous waste.) The used oil should be sent to an authorized recycler or fuel blender using a permitted Waste Transporter.

Drum/Container Management

Drum or container management applies to any used metal, plastic, fiberglass or laminate drums/containers, typically 5 gallons in capacity or larger, used for bulk storage of liquids, solids or waste materials. The Maine Department of Transportation developed the following procedure and environmental stewardship practices for managing drums and containers: (*821*)

- Establish a procedure for managing drums and smaller containers (such as 5-gallon pails) on Maintenance and Operations facilities. Procedures should be audited (checked for compliance and improved) annually.
- Ensure personnel are trained to properly manage used drums/containers to prevent releases of drum/container residues (e.g., oil or chemicals) to the environment and to maintain a safe, neat working environment. All employees who use or manage drums/containers should be trained at least annually and easy-to-follow guidelines for proper management of used drums/containers should be prepared. Training records should be kept in a central location.
- Routine inspections of facilities by the Division Manager/Engineer, Division Safety Coordinator, or the Environmental office should include a review of drum/container management practices.
- Crew supervisors should have primary day-to-day responsibility for compliance with drum management policies and procedures.

Drum/Container labeling

- **All drums/containers should either be labeled "empty" or with the intended contents**, such as "trash" or "oily rags."
    - Empty drum/containers need not be labeled if they are neatly stockpiled in a designated area marked with a sign "Empty drums".

    - Labels may be adhesive type (waterproof if exposed to the weather), or painted. Painted labels should be legible. Old labels should be removed or completely covered.
    - Drums containing inert metal parts do not need to be labeled.

Drum/Container purchasing

- The DOT should not purchase or obtain drums/containers from any source other than a vendor supplying new or properly reconditioned drums; i.e., an approved vendor.

Recycling, Reuse, and Disposal of Used Drums/Containers

- Only sound drums/containers in good condition, free of substantial rust, cracks or dents, should be used by maintenance and operations
- Drums/containers should be thoroughly drained so that no "flowable" product remains. Product should be used for its intended purpose, or, if obsolete, disposed properly based on the waste type.
- Only drums/containers that formerly contained the following should be reused:
    - Motor oil
    - Hydraulic oil
    - Gear oil
    - Transmission fluid
    - Grease
    - Antifreeze
    - Soap/detergents

  Drums containing other materials should only be reused if approved by the Division Manager/Engineer in consultation with the Environmental Office (ENV) and Office of Human Resources, Safety Section, if appropriate. See Section 6.7 below for special requirements for containers from pesticides or herbicides.
- Prior to reuse, drums/containers should be cleaned by wiping or another approved method that does not result in the release of drum/container residuals to the environment (soils, groundwater or surface water).
    - Cloths or other materials used for wiping should be cleaned and reused or disposed of properly. For example, oily rags should be disposed in the facility oily waste container.
    - Alternatively, arrangements can be made with an outside vendor for reconditioning of used drums.
- Empty drums/containers, containing no residual product but not suitable for DOT reuse should be recycled for scrap metal as part of a metals recycling program.
- Drums/containers that contain residues of oil, chemicals or other waste should be disposed properly in accordance with the waste type.

Spills and Leaks

Numerous federal and state regulations specify extensive requirements for the prevention of spills and leaks of hazardous wastes at DOT facilities. In addition, many federal, state, and local agencies should be immediately notified of a hazardous waste release. Severe penalties and fines are often imposed for failure to notify. The first and most important step in a spill or leak response is to safely contain the spill and stabilize the situation by following the methods described in the facility's PPC Plan, and then to notify the proper authorities.

Spill prevention and control procedures and practices are typically implemented to prevent and control spills in a manner that minimizes or prevents the discharge of spilled material to drainage systems or watercourses. Spill prevention and control procedures are typically implemented wherever chemicals and/or hazardous substances are stored. Substances may include, but are not limited to, soil stabilizers, dust palliatives, herbicides, growth inhibitors, fertilizers, de-icing chemicals, fuels, lubricants and other petroleum distillates. To the extent that the work can be accomplished safely, spills of oil, petroleum products, substances listed under Title 40 of the Code of Federal Regulations (CFR) Parts 110, 117, and 302, and sanitary and septic wastes should be contained and cleaned up immediately.

Caltrans and NYSDOT employ the following spill prevention practices: (*822*)(*823*)

- To the extent that this action does not compromise cleanup activities, spills should be covered and protected from stormwater run-on during rainfall.
- Spills shall not be buried or washed with water.
- Used cleanup materials, contaminated materials and recovered spill material that is no longer suitable for its intended purpose should be stored and disposed of in conformance with these special provisions.
- Water used for cleaning and decontamination shall not be allowed to enter storm drains or watercourses.
- Water overflow or minor water spillage should be contained and shall not be allowed to discharge into drainage facilities or water courses.
- Proper storage, cleanup and spill reporting instructions for hazardous materials stored or used on a project site should be posted at all times in an open, conspicuous and accessible location.
- Waste storage areas should be kept clean, well organized and equipped with ample cleanup supplies that are appropriate for the materials being stored. Perimeter controls, containment structures, covers, and liners should be repaired or replaced as needed to maintain proper function.
- Spill control cleanup materials should be located near material storage, unloading, and use areas.
- Update spill prevention and control plans and stock appropriate cleanup materials whenever changes occur in the types of chemicals stored on-site.
- Inform and remove unnecessary employees from the area.
- Determine the identity and hazards of the material and any personal protective equipment such as impermeable gloves required for handling.

- If the spilled material is flammable, remove any open flames or sources of ignition. Use non-sparking tools and grounding wires if needed.
- Stop additional material from spilling at its source if possible. For example, plug a leaking hole in a barrel or turn the barrel so that hole is on top.
- Plug any drains that may be impacted.
- Contain the spill by placing absorbent "socks" or sand to prevent the spill from running into storm drains, bare soil, large surface areas, etc.
- Pump large quantities to an empty drum that will hold the material.
- Collect smaller quantities and/or remaining liquid by absorbing liquid with absorbents or sand. Gently scoop or sweep up the residue and place in empty container.
- Label all containers of spill collection and debris as soon as possible.
- Do not try to clean up spills of unfamiliar materials if adequate hazard communication information is not in place.

Emergency Preparedness and Response Planning

Emergency preparedness and response plans are typically required by law, regulation, or DOT policy for each facility/depot.

- Each emergency preparedness and response plan should show the issue and revision date, a list of holders of the copies and their locations, and a log of revisions issued.
- Division Manager/Engineers should establish a schedule to test the effectiveness of the emergency preparedness and response plans, using drills or mock emergencies. At least one test or drill should be conducted annually. (A real emergency may be considered as a test.)
- Division Managers/Engineers should hold a debrief session after each real emergency, test or drill, and prepare a written summary of lessons learned and any necessary revisions to facility operations, or to the plan.
- Emergency plans should be reviewed by the Division Manager/Engineer in consultation with environmental staff at least once per year, or when significant changes are made in operations or facilities, to determine if the plans require revision. Revisions should be distributed to holders of all copies, and revision dates will be noted in the revision logs.

Communication and Training for Emergency Preparedness and Response

- DOTs should provide for emergency preparedness and response training for new employees, and annual refresher training for current employees, based on the current emergency preparedness and response plans. Major revisions of a facility plan will require training updates in a timely fashion.
- Current copies of each emergency preparedness and response plan should be provided to crew supervisors, to appropriate local emergency response agencies (fire, rescue, police, local emergency management agency, etc.) and to appropriate state and federal agencies as required.
- A copy of the plan(s) should be kept at strategic locations in the facility so it can be easily accessed in an emergency.

- A current copy of each emergency preparedness and response plan should be provided to major contractors who will be operating on site for an extended period of time, as well as emergency preparedness and response training, as appropriate. Contractors working on site may be required to provide a copy of their own emergency preparedness and response plan for their own work (*e.g.* a spill prevention plan for equipment operated on site).

Finding and Resolving Illicit Connections, Illicit Discharge, and Illegal Dumping

Illegal dumping and spills can encroach on DOT properties. Accessible DOT properties, such as safety roadside rest areas, vista points, turnouts, and weigh stations, provide tempting places for illegal dumping. Illegally dumped and spilled materials have potential to flow into receiving waters. This section reviews environmental stewardship practices for minimizing the impact of illegal dumping and spills that are outlined in the Caltrans Stormwater Quality Handbooks, Maintenance Staff Guide.(*824*)

Illegal Dumping may occur at drain inlets and must be reported.

- Look for potential dumping at drain inlets, open channels, and municipal storm drain system tie-ins. Warning signs can include:
- Visible signs of staining or unusual colors to the pavement or surrounding adjacent soils.
- Pungent odors coming from the drainage system.
- Discoloration or oily substances in the water or stains and residues detained within ditches, channels or drain boxes.
- Dumping of debris or medical waste at a particular location, where the proximity to the drain system could impact water quality.
- When any field maintenance employee witnesses or discovers a suspected illegal dumping to a DOT storm drain system, it should be report it to the supervisor.
    - If the substance is known to be hazardous, suspected of being hazardous, or cannot be identified, notify the District Maintenance HazMat Manager immediately.
    - If an illegally dumped substance within DOT right-of-way has the potential of entering a municipal drain system, notify the supervisor and the District Maintenance Stormwater Coordinator so that the downstream municipality can be contacted.
    - Provide protection for adjacent drain inlets to prevent entry of the illegally dumped substance, if it is safe to do so.
- Perform cleanup and corrective actions for illegal dumping and spills on DOT right-of-way in accordance with DOT procedures and District *HazMat Spill Contingency Plan*.
- Maintenance supervisor should follow up on the incident to ensure the appropriate agencies have been contacted and corrective actions have taken place.

DOT Contribution to Local Spill Prevention Initiatives

In some cases, DOT maintenance staff have taken the initiative to contribute to local environmental protection and conservation initiatives. The Skaeneateles Lake Watershed provides drinking water to a quarter million people and is completely encircled by highways. NYSDOT's Region 3 Maintenance Group formed a partnership with the City of Syracuse Board of Water Supply, NYS Department of Environmental Conservation (NYSDEC) and local officials and took the lead in addressing spill-related water quality concerns. NYSDOT identified 15 sites and potential contaminant pathways that most directly threaten water quality. and mitigated those sites through the installation of stone check dams/retention basins to treat daily runoff and to temporarily retain any spills that may occur at these sites. Also, all Department maintenance staff working in the 20-square-mile watershed have been provided sensitivity training and spill clean-up materials. In addition, local DPWs in the watershed have been provided with similar spill control materials and the local fire department has been provided with culvert plugs, absorbent materials and a commercial grade spill containment boom.(*825*)

Ventilation and Exhaust Systems at Maintenance Facilities

Some operations and process ventilation that can release contaminants to the air may require an air permit from a state regulatory agency. For example, paint spray booths are likely to require an air quality permit if: (*826*)

- More than 25 gallons of paint and solvents (combined) are used in a month,
- The paint spray booth is located where air quality is poor for ozone, or
- Exhaust gases from sanding and painting do not pass through filters or other emission control devices.

Facility Inspection and Reinspection to Achieve Environmental Goals and Continuous Improvement

Facility inspection and reinspection programs are discussed in detail under the Organization Practices section on Performance Measurement and Auditing. Maine DOT and Mass Highway boast excellent examples of facilities auditing procedures and practices.

Caltrans' reinspection program has found that follow up on initial inspection results has improved housekeeping, spill cleanup, hazardous materials and waste storage and documentation practices. Specific criteria were defined for selecting facilities for reinspection: (*827*)

- Number of compliance action items identified from the initial inspection
- Progress made on action items based on documentation submitted by the facility
- Size of the yard and number of crews
- Proximity to the nearest downstream watercourse
- Types of materials stored at the facility

Caltrans identified the following reasons for follow up inspections of maintenance facilities:

- Enhance compliance at facilities considered to be facing the greatest stormwater management challenges.

- Provide facility-specific training to improve staff understanding of stormwater requirements and Environmental stewardship practices.
- Prepare facilities for regulatory agency inspections.
- Review and offer assistance in filing procedures for stormwater documentation.

DOTs that employ such audits and inspections, often do so on a rotating five year basis, so 20 percent of facilities are audited or reinspected in any given year.

6.3. Yard and Floor Drain Management

Many DOT facilities have floor drains in buildings and surface drains in the "yard" that discharge washwater and stormwater through underground pipes or open ditches, a ditch, or a right-of-way culvert, or off-site to a neighboring property and, potentially, to the waters of the state. Shop floor drain effluent can include motor vehicle fluids spilled as a result of vehicle maintenance and repair, and washbay washwater, especially from salt truck and salt bed washing during snow and ice season. Flows off of maintenance yards may ultimately reach waters of the state, either indirectly or via direct discharge into a side ditch.

Discharges from floor drains to surface and groundwaters are generally regulated through the National Pollutant Discharge Elimination System (NPDES) and state administered NPDES programs, often called SPDES. NPDES/SPDES permits are issued and required for discharges to waters of the state. Some facilities have installed oil/water separators as interceptors; however, such separators are not effective in removing soluble contaminants such as salt from the discharge.

Procedural Practices and Other Non-Structural BMPs

Stormwater/Washwater BMPs for Surface Runoff

Much of the impact from surface stormwater/meltwater runoff can be significantly reduced by removing contaminants from the path of the sheet flow and point discharges.

- The salt/sand mixing/loading area should be swept clean after each load.
- The salt/sand mixing/loading area should be bermed to contain the material until it can be cleaned or the mixing/loading is performed inside the salt storage facility or under a roof. Where paved berms have not been installed, Indiana DOT recommends that A windrow of abrasives [sand] should be placed around all outside stockpiles [salt, salt/sand mix piles].(*828*) While minimally effective as a deterrent to stormwater/meltwater runoff, especially from a sloped surface, on level surfaces such windrows can allow pooling that would otherwise sheet flow around stockpiles causing migration of salt-contaminated stormwater off-site.
- Containers of petroleum and liquid wastes stored outdoors are on a roofed pad enclosed by secondary containment.
    - Herbicide and paint mixing and loading should be done in designated, bermed areas, preferably on a pad.
    - Any spill or residue should be immediately cleaned up.

- Right-of-way trash and construction debris should be taken to a permitted landfill and not allowed to accumulate on site.
- Salt bed washing should be performed in a washbay, not outdoors, and salt bed oiling, paint chipping and painting—if performed at the salt bed rack—should be done with the ground protected by a tarpaulin.

Structural BMPs

Structural BMPs are installed at most DOT facilities to reduce the offsite impacts of contaminated stormwater/washwater migration, though most of these have been added since construction.

- Standard specifications for new salt storage buildings should include sufficient area for:
    - sand storage and salt/sand mixing/loading indoors
    - brine making
    - storage and bulk tank loading outdoors on a pad protected with secondary containment.
- The exterior pad (to the salt storage building) should be sloped away from the building to its outer limits and the water retained by means of a curb or slope reversal of the pad itself in order that the runoff may be directed into a collection system.(*829*)
    - The design of the exterior pad (where the mixing/loading operations are performed) should be mandated, not recommended, because the lack of exterior pad curbing has created over half of the salt contaminated stormwater problems observed in at least one DOT survey.(*830*)
    - The curbing should only be used to allow pooling or to direct stormwater to a collection system. It should not be employed to direct stormwater offsite, as a point source discharge.
- Roofs should be extended on old salt domes to provide a protected area for mixing/loading and for replacement of smaller salt storage facilities.
- Design and specification of structural BMPs should include central office staff and adherence to specification, with input from field personnel to avoid stormwater/washwater collection/discharge problems resulting from poor design.

The following practices are recommended for stewardship of water quality, runoff from maintenance yards and potential discharges from floor drains.

Floor Drain Management

Caltrans, Maine DOT, and NYSDOT utilize some of the following environmental stewardship practices for floor drain management.(*831*)(*832*)

- Direct discharges from floor drains to groundwater through leach fields, septic systems, or dry wells should not be allowed.
- Consider whether a floor drain discharge is truly necessary. If not, plug the floor drains with a plumber's plug or concrete. If the drain is permanently closed and no discharge can occur, a grit collector, oil/water separator and NPDES/SPDES permit would not be

required. A permit would be required for a grit collector and oil/water separator that discharge floor drain waters to surface water. Such permits may involve requirements to change vehicle parking patterns and perform vehicle maintenance only in areas away from the floor drains.

- At facilities that do not discharge shop floor drain effluent to a Publicly Owned Treatment Works (POTW), oil/water separators should be used for washwater. Oil/water separators are effective at removing nonsoluble oil and other petroleum products, but do not remove substance in solution, such as antifreeze and chlorides from road salt. At some facilities, the oil/water separator is connected to a tank, catch basin or holding pond where the washbay effluent collects before being conveyed offsite. A hazardous waste or liquids recycling contractor pumps the contents of the separator or the holding tank, when needed.
- Shop floor drains should be segregated from washbay drains and the flow should terminate at the oil/water separator or, beyond, at a holding tank. Shop floor drains are intended to capture any spills of automotive fluids occurring during vehicle maintenance. No other liquids, including washwater, should be allowed to enter the drain.
- Centralize vehicle repair and maintenance at a subdistrict or district shop where possible, to avoid contamination of facility stormwater discharge.
- Where possible install a grit collector and oil/water separator and connect to a municipal sewer system which eliminates the need for a NPDES/SPDES permit.
- All floor drains should be are constructed with an oil/water separator as part of the system. All floor drain effluent must be forced to pass through an oil/water separator prior to being discharged from the system (i.e. before flowing to a tank, sewer district pipe, or infiltrated onto the surrounding grounds).
- Division Managers/Engineers are responsible for knowing where floor drains discharge, and for compliance with the Department Floor Drain Policy. Division Engineers/Managers should keep a current database of the method for managing wastewater from garage floors. This database should include, at a minimum, the presence and type of construction for floor drains and the method of managing effluent. Any changes to the construction or management of this effluent must be reported to the Highway Maintenance Engineer.
- Hazardous waste containers should be provided with secondary containment where risk of damage is high (such as from vehicles) or where impacts from a spill would be severe (such as spills to floor drains that discharge to the ground). Secondary containment must be capable of holding 110 percent of the waste container volume.
- Weekly inspections of hazardous waste storage areas should be performed.
- An Emergency Action Plan should be developed in accordance with Bureau of Labor Standards/OSHA (29 CFR 1910.38) requirements for Hazardous Waste Operations and Emergency Response (29 CFR 1910.120(a)(i)(v)) state Emergency Response Planning Procedures for each facility storing hazardous waste.
- Good spill prevention practices should be used. These include, at a minimum:
    - Keeping waste containers closed when not in use;

- Protecting containers from damage from vehicles or other equipment;
- Use of containers that are in good condition (not severely dented or rusty);
- Use of funnels when pouring liquids into waste containers; and
- Conducting periodic inspections of waste storage areas.

Management of Oil/Water Separators

Oil/water separators are tanks that collect oily vehicle wash water that flows along corrugated plates to encourage separation of solids and oil droplets. The oily solids or sludge can then be pumped out of the system through a different pipe. The sludge can be hauled off site, and the wash water can be discharged to vegetated areas or to a treatment plant. There are two types of oil/water separators, one that removes free oil that floats on top of water, and one that removes emulsified oil, a mixture of oil, water, chemicals, and dirt. Choose the separator that fits the needs of the vehicle wash facility.

Each oil/water separator should be cleaned of all liquid and grit at least annually.

- Once all free-floating petroleum products are absorbed, the liquid may be decanted to the municipal sewer system or to a tank, for final disposal at a waste water treatment facility or hazardous waste location.
- If there is reason to believe that hazardous materials, other than oils, are in the liquid portion of the oil/water separator, then the Division Engineer/Manager must be notified and arrangements made by a licensed hazardous waste contractor to collect the liquid.
- All grits are to be treated as special waste and disposed of at a special waste landfill (Norridgewock, Hampden, etc.)
- Once empty, oil/water separators must be filled with clean water above the bottom of the outflow pipe.
- Oil-only absorbent materials are to be used to capture free-floating oils that may accumulate in the oil/water separator.

Management of High Risk Effluent

Stewardship practice calls for both high risk and low risk effluent to be managed in one of the following ways:

- Discharged directly to a municipal sewer system, with knowledge and permission of the local district.
- Captured in a tank, then transported off-site for final disposal.
  - Highway/Bridge/Traffic Superintendents are to make arrangements for the transport and disposal of the tank contents with either a waste water treatment facility or hazardous waste contractor. Superintendents make arrangements for any analytical testing of the effluent, as may be required by the waste water treatment facility or hazardous waste contractor.
  - Within 4 days of a tank alarm sounding, Crew Supervisors should notify their Superintendent that the contents of a tank need disposal.

    - Bills of Lading, manifests, or other receipts for disposal shouldbe kept at the Division Office for a minimum of 3 years.
- Crew Supervisors should test the tank alarm system monthly. A log of such tests will be kept on-site for a minimum of three years.
- The floor drain can be eliminated and the shape of the floor modified such that no liquids exit the garage through a drain system.

Further options exist and are detailed below for management of low risk effluent.

Management of Low Risk Effluent

In addition to the options available for high risk effluent, low risk effluent can also be managed in one of the following ways:

- When Division Engineers/Managers choose to manage floor drain effluent by separation of activities and bays, the Division Engineer/Managers are to ensure that garage areas where activities could create High Risk liquid effluent are physically separated from the areas where activities create Low Risk liquid effluent. Physical separation includes walls and concrete or polyethylene berms. Berms should also be constructed in a manner that does not allow any waste that could be considered high risk to enter the areas where liquid effluent could be considered low risk. These berms must be constructed in a way that meets OSHA standards for tripping hazards (i.e. meet slope requirements of ADA and are striped as a hazard).
- Captured in a melt-water only holding tank, pumped to the surface of the ground, and allowed to infiltrate only if the following conditions are met:
    - Connection to a municipal sewer system is not an option.
    - The infiltration area must be accessible for inspection.
    - The effluent must not discharge directly into a ditch, stream, wetland, pond or other surface water body.
    - There must be no significant potential for pollutants to drip, leak, spill or wash into the floor drains from which the effluent originates. Engine maintenance activities are prohibited from areas which feed floor drains discharging to pipes on top of the ground or melt-water only holding tanks. All containers of oils, engine fluids, cleaning products or other liquid pollutants must be removed or separated by means of an impermeable berm from the area containing the floor drain.
    - Oil-only absorbent materials are to be used to capture free-floating oils that may accumulate in the melt-water only holding tank.
    - Discharges must be done in a way that prevents erosion and the creation of pools of standing water. Discharge onto frozen ground is not allowed.
    - Effluent must not be discharged within 300 feet of a private well or water intake or within 2500 feet of a public well or water intake.
    - If there is reason to believe that the contents of the melt-water only holding tank has received oil, diesel or other hazardous materials due to a spill or leak, then the contents cannot be discharged on the surface of the ground. The contents of the

tank must them be treated as high risk effluent and disposed of in a manner as described in the previous section.

- Discharged directly from the floor drain onto the surrounding ground (daylighted) only if the following are met:
    - Connection to a municipal sewer system is not an option.
    - The pipe must discharge on top of the ground to an infiltration area that is accessible for inspection.
    - The pipe must not discharge directly into a ditch, stream, wetland, pond or other surface water body.
    - There must be no significant potential for pollutants to drip, leak, spill or wash into the floor drains. Engine maintenance activities are prohibited from areas which feed floor drains discharging to pipes on top of the ground or melt-water only holding tanks. All containers of oils, engine fluids, cleaning products or other liquid pollutants must be removed or separated by means of an impermeable berm from the area containing the floor drain.
    - Proper erosion control methods are used at the end of the pipe.
    - Effluent must not be discharged within 300 feet of a private well or water intake or within 2500 feet of a public well or water intake.

Floor Drain Maintenance and Sludge Removal

- Supervisors at garages that contain floor drains are to ensure that floor drains are cleaned a minimum of once per year. The residue removed from the floor drains is assumed to be special waste. Bills of Lading for this disposal are to be kept at the Division Office for a minimum of three years.
- Crew Supervisors should be responsible for ensuring that all floor drains, oil/water separators, and melt-water only holding tanks have oil absorbent socks maintained in them at all times. These petroleum socks, placed in the floor drains, oil/water separators, and melt-water only holding tanks, are to be changed when they show evidence that oil has been absorbed.

Holding Tanks and Maintenance

Environmental stewardship practice for holding tanks may include: (*833*)

- The minimum holding tank capacity must be 1,000 gallons.
- Holding tanks and piping must be watertight and sealed with materials compatible with the liquid or sludge being stored.
- Access must be provided to each compartment of the tank for inspection and cleaning by means of either a removable cover or manhole (minimum diameter 20 inches). Manholes must extend to finished grade.
- The tank must be designed for the expected maximum structural load and ballast must be provided when necessary to prevent structural damage when the tank is emptied.
- The volume between inlet cover and the maximum water depth must be equal to approximately 20 percent of the liquid volume stored below the maximum water depth.

An alarm with both visual and audio signals must be activated once the water level reaches the maximum water depth.

- A year-end record of pumping events should be produced each year the holding tank is in operation.

Leaks into Floor Drains

- If, in the unlikely event, a spill or major leak occurs that allows petroleum or antifreeze liquid to enter a floor drain that was considered low risk, steps must be taken immediately to insure that none of the liquid contaminates the environment through the daylighted pipes, or, tank overflows. If contamination occurs, the steps for major spills must be followed.

Vehicle Washing

After a storm, equipment cleaned to reduce corrosion damage and to prepare for the next storm. Water used in washing cars, trucks, and other vehicles may contain a wide range of contaminants, including oil, other hydrocarbons, metals, detergents, road salt, and grit. Discharged into surface waters, these contaminants can degrade water quality and harm aquatic life. Discharged into groundwater, potable water may be rendered unpotable.

Various states (e.g., Georgia, Wisconsin, California, Virginia) are currently conducting studies designed to test the effectiveness of various structural BMPs and investigate the costs of design or purchase, as well as installation and maintenance. State DOTs are exploring some of the following options and environmental stewardship practices: (*834*)

- **Reduce the sources of potential contamination throughout the state by centralizing saltbed and truck washing at facilities already connected to POTWs amenable to accepting brine discharge.** This involves extra driving, and POTWs to which washing facilities are connected may have imposed limits on the volume of washwater or the levels of chloride and cyanide discharged from the facility. Washing facilities may be at such a distance from the others that moving trucks for washing is inconvenient or impractical, regardless of the cost; however, when usable facilities are accessibly located, this is a cost effective option.
- **Connect every truck washing facility to an amenable POTW.** Costs of extending the line can be shared with other dischargers in some cases, though some facilities are too remote to make this a practical option.
- **Contain wash water in holding tanks and haul to an amenable POTW.** INDOT found this is the most cost effective option for facilities that 1) cannot afford to connect to a POTW; 2) cannot discharge washbay effluent to a POTW because of prohibitions; 3) will install brinemaking equipment and can use washwater as "make-up" solution or 4) will continue to spread road salt for all or some snow/ice events. Vacuum trucks or bulk tank trucks (with a pump), if available, can be used to reduce hauling costs. While some POTWs will not accept transported liquids, a pick-up service might be arranged where amenable POTWs can be located.(*835*)
- **Line existing and newly constructed holding ponds with a clay layer or plastic impervious liner** and design the structure to hold the maximum volume of meltwater,

washwater and precipitation that can conceivably collect while evaporation is depended upon to reduce the volume (no overflow is allowed).

- **Install catch basins, settling tanks and holding ponds to remove suspended particles.** Dissolved chlorides cannot be removed in this fashion. According to an INDOT/Purdue study, the holding pond should be sized to hold the maximum volume of washbay effluent, surface area stormwater/meltwater runoff (unless the pond is bermed) and precipitation (roofing over a holding pond retards evaporation). Difficulties are encountered removing sediment from any holding pond, but especially one lined with plastic. Unless properly maintained, holding ponds can collect debris and serve as a harbor for algae blooms, wild fowl and reptiles. The cost of constructing a holding pond as a BMP must be weighed against the costs of cleaning and maintenance and the potential for groundwater contamination via a perforated or breached liner. Also, evaporation cannot be relied on to reduce the total volume contained because it is periodically replenished by precipitation. Prohibiting any discharge from a pond will mean that the contents will need to be pumped and hauled to an amenable POTW every other year; a longer cycle will increase the probability that no POTW would accept the contents because of the increased brine concentration. Alternatively, the unevaporated content can be pumped to tanks, if available, and used as brine makeup solution or hauled to another facility for this purpose.(*836*)

Design and Operation of Washing Facilities

New Hampshire, Oregon, and other states have identified environmental stewardship practices for vehicle washing facilities.(*837*)(*838*) The following environmental stewardship practices can be added to existing and or new DOT facilities to minimize the potential for environmental contamination from polluted runoff:

- **Warning signs should be posted for customers and employees instructing them not to dump vehicle fluids, pesticides, solvents, fertilizers, organic chemicals, or toxic chemicals into catch basins.** Catch basins are chambers or sumps which collect runoff and channel it to the stormwater drain or to the sanitary sewer. Vehicle wash facilities should **stencil warnings on the pavement next to the grit trap or catch basin**. All signs should be **in a visible location and maintained for readability**.
- **Care should be taken to minimize wash water run-off from cleaning operations.**
    - Minimize water use to reduce potential for unpermitted non-stormwater discharges (e.g., provide a positive shutoff type of hose nozzle).
    - When possible, truck beds should be cleaned using a dry cleanup technique (sweep up or shovel out).
- **No detergents should be used**, as they emulsify oil in the oil/water separator and make the separator ineffective and may violate a DOT's NPDES/SPDES permit by introducing new chemicals. Using alternative cleaning agents such as phosphate-free, biodegradable detergents for vehicle washing can also reduce the amount of contaminants entering storm drains.
- **Where possible, indoor wash facilities with controlled floor drainage should be utilized.** Where wastewater is not to be disposed to a sanitary sewer, grassed swales (shallow, vegetated ditches) or constructed wetlands (retention ponds with emergent

aquatic vegetation) can be used to hold wastewater and allow contaminant removal through infiltration and filtration.

- **Washwater may otherwise be collected in a sump, grit trap, or containment structure to be pumped or siphoned to a vegetated area so that complete percolation into the ground occurs.** A portable collection system will provide the collection of the contaminants provided the collection system is large enough to capture significant amounts of the overspray. Washwater runoff can also be disposed of into an infiltration basin/trench. The use of a bioswale with an oil/water separator will virtually eliminate the total suspended solids, oil and grease, and heavy metals discharged provided both are properly sized. (*839*)
    - **Disposal of washwater should occur on ground surfaces with vegetated cover, preferably grasses, a minimum of 250 feet in length before a surface water body.** A distance of 250 feet was based on a hydraulic conductivity of 0.2 gal/ft/day, volume per day of 150 gallons, and a swale with a width of 3 feet.
    - **Complete percolation in the swale should occur with no direct discharge** to the surface water. Discharge into a grassy swale for treatment should not occur within 24 hours after a rainfall event or if water remains ponded in the swale.
- **W ash areas should be located on well-constructed and maintained, impervious surfaces (i.e., concrete or plastic) with drains piped to the sanitary sewer or other disposal devices.** The wash area should extend for at least four feet on all sides of the vehicle to trap all overspray. Enclosing wash areas with walls and properly grading wash areas prevent dirty overspray from leaving the wash area, allowing the overspray to be collected from the impermeable surface.
- **The impervious surfaces should be marked to indicate the boundaries of the washing area and the area draining to the designated collection point.**
- **Washing areas should not be located near uncovered vehicle repair areas or chemical storage facilities**; chemicals could be transported in wash water runoff.
- **Regularly inspect and maintain the designated areas**, facility wash racks, designated cleaning areas, wash pads, clarifiers, oil-water separators, sumps and sediment traps. **Regularly clean wash areas, grit traps, or catch basins to minimize or prevent debris discharge,** such as paint chips, dirt, cleaning agents, chemicals, and oil and grease into storm drains or injection wells.
- **A washwater treatment sequence may include such elements as a grit trap, an oil/water separator, a dosing tank with siphons or pumps, and a multi-media filter bed with underdrains.**
    - Discharge from underdrains must meet effluent limitations.
    - Maintenance of a multi-media filter should consist of cleaning, removing the top inch of sand once every six months; when the total depth of filter sand fall below 18-inches, the sand should be replaced. If clogging and/or short circuiting occurs as observed by uneven infiltration in the filter or formation of surface cracks, the sand should be replaced.

- A Spill Prevention, Control and Countermeasure (SPCC) Plan, in accordance with 40 CFR 112, should be prepared and implemented to prevent the entry of pollutant loads beyond the capabilities of the treatment system.

- **Contractual provisions should require contractors to use cleaning practices consistent with DOT requirements**.

Recycling Wash Water

Recycling systems reduce or eliminate contaminated discharges to stormwater drains and injection wells by reusing the wash water until the water reaches a certain contaminant level. The wastewater is then discharged to a collection sump or to a treatment facility. Collection sumps are deep pits or reservoirs that hold liquid waste. Vehicle wash water accumulates in the collection sumps, and is pumped or siphoned to a vegetated area (such as a grassed swale or constructed wetland). Sediment traps can also be used to strain and collect the vehicle wash water, prior to pumping or siphoning the wash water to a vegetated area. The use of a recycling system can reduce or eliminate the contaminant discharge to stormwater or sanitary sewer while greatly reducing the amount of water used in the process. Some DOTs are installing brinemaking at truck washing facilities so washwater can be used as “make-up” solution. This solution can also be used to “spray the load” of salt/sand mix and/or to fill saddle tanks for spraying the mix as it passes through the salt spreader. The cost of brinemaking equipment is relatively affordable, though adding brine application equipment to existing trucks is more costly.

A recycled wash water has been successfully used by one of the largest bus transport companies operating in Borsod County, Hungary. In 1985, they installed a new, water-saving wastewater treatment facility for wastewaters resulting from washing at the central service plant. The commercial transportation system uses detergent-free, high pressure, hot water to remove dirt and grime from the car bodies and engines of the buses. The resulting wastewater is mechanically treated with filters consisting of sand and activated carbon. For disinfection, a 1 to 3 mg/l NaOCl solution is used. The filters are backwashed with recycled water every 3 to 4 days. The polluted backwash water is returned to the treatment plant. Oily rainwater from the yard is also directed into the treatment plant. The system uses fine sand filtration after pretreatment of the wastewater to remove grit, sand and oil. After this pretreatment, about 15 percent to 20 percent of the wastewater is discharged into a conventional sewerage system. This discharge prevents the accumulation of TDS and organic substances in the remaining water which is recycled for use in the carwash. This discharged water meets the water quality requirements for all categories. The remaining water that is to be recycled is subjected to ozonation to prevent anaerobic digestion of organic materials which produces foul odors. After ozonation, the remaining, pretreated water is conveyed through a fine sand filter by pump. Once filtered, the water is resupplied to the carwash by means of a rubber membrane hydrophore at a pressure of between 2 and 8 bar. For the commercial vehicle washing recycling facility, the initial investment costs are about $80,000, with a further investment of $1,600 for reconstruction after about tenyears of operation. Maintenance costs were about $4,000/year. The estimated period for recovery of this investment is about 1.3 years based upon typical usage within the region. The technology achieved 80 percent recycling of water.(*840*)

In addition to the recycling of washwater, environmental stewardship practices associated with recycling washwater include: (*841*)

- Recycling treatment equipment should be properly operated and maintained to achieve compliance with all conditions of the permit.
- Backwash water or concentrate water should be properly discharged to sanitary sewer.
- Liquid concentrate discharged to the sanitary sewer should meet all pretreatment standards and other requirements of the local Sewer Authority.
- Solids, grit, or sludge should be disposed in a manner that complies with State administrative rules.

6.4. UNDER AND ABOVE-GROUND STORAGE TANKS

Above ground storage tanks are used at Maintenance facilities to store fuel, oil, antifreeze, deicing agents and asphalt emulsion. Underground tanks most often contained fuel. These materials can pose potential threats to water quality if spilled or mixed with stormwater runoff. Environmental stewardship practices for preventing and addressing storage tank leaks and spills include those reviewed below.

Tank Registration Practices

Fuel/petroleum tanks are generally registered with the state environmental agency when they can hold in the range of more than 1,100 gallons in a total combined capacity of any aboveground and/or underground tanks which store petroleum products, gasoline, diesel, kerosene, used oil or heating fuel. All fuel/petroleum tanks storing used oil are registered regardless of tank size or site capacity. One exception to this registration requirement -- small tanks that are not manifold and hold less than 1,100 gallons of heating oil for on-site use are exempt from this regulation. (*842*)

- Petroleum Bulk Storage (PBS) Registration certificate should be posted near the tank location and renewed every five (5) years.
- The PBS certificate should be updated whenever a tank removed or modified or added to reflect all current tanks.
- The state environmental agency is notified prior to any tank removals.

Tank Equipment and Recordkeeping Practices

- In both aboveground and underground petroleum storage tanks color-coded fill ports are used per the American Petroleum Institute’s color and symbol code
- In both aboveground and underground petroleum storage tanks the color and symbol code is identified on each fill port
- Typical DOT petroleum storage tank port colors and codes are: Diesel - Yellow; Unleaded Gasoline - White with Black Cross; Kerosene – Brown
- In both aboveground and underground petroleum storage tanks operating valves are present on all gravity-drained tanks
- In both aboveground and underground petroleum storage tanks automatic shut-off valves such as solenoid valves on gravity-fed systems and shear valves on pumped dispensing systems are present to prevent any leaks in case of a pipe or hose failure

- In both aboveground and underground petroleum storage tanks check valves are present for backflow prevention on tanks filled by pumping
- For underground petroleum tanks monitor the inventory by measuring use, deliveries, losses or gains, and bottom water levels daily.
- For underground petroleum tanks record inventories to the nearest tenth of a gallon if feasible,
- For underground petroleum tanks reconcile records every ten days and retain all records for at least five years.
- For underground petroleum tanks report inventory losses or gains of product that are more than:
    - 0.75 percent of the tank volume in a ten day period
    - 7.5 gallons for every 1,000 gallons delivered over a ten day period or 0.75 percent of the throughput or amount dispensed over a ten day period
    - Or if water seems to be accumulating during any ten (10) day period
- When the cause of losses or gains in underground petroleum tanks cannot be explained within 48 hours, the Department of Environmental Conservation's Regional Spill Engineer is contacted and the tank is taken out of service
- Tightness testing is required every five (5) years when underground tank systems are not protected and hold more than 1,100 gallons. (Protected systems are those that were installed with corrosion-resistant tank and piping and a leak monitoring system)
- For underground petroleum tanks monitor corrosion-resistant tanks and pipes at the manufacturer's recommended schedule.
- Steel USTs with corrosion protection should comply with the following requirements to ensure that releases due to corrosion are prevented for as long as the UST is used to store regulated substances.
- For underground petroleum tanks inspect leak detection systems or double-walled tanks at least weekly, and other monitoring systems monthly
- For underground petroleum tanks check any cathodic protection systems at least annually
- Tanks (tanks for on-site heating are exempt) that hold 110 gallons or more are required upgrade to meet federal underground tank storage requirements. These federal standards included leak detection systems, corrosion protection, and spill/overfill prevention features.
- For aboveground petroleum tanks inspect monthly the exterior surfaces of tanks, pipes, valves, leak detection systems and other equipment to identify any cracks, wear, corrosion, settling, separation or other problems. Keep records with the date and signature of the inspector for ten (10) years.
- For aboveground petroleum tanks perform secondary containment and internal inspections every ten (10) years conducted by qualified firms for any tanks of greater than 10,000 gallon capacity that rest on the ground. Secondary containment may be required for smaller tanks that could reasonably be expected to discharge to waters of the state.

- For aboveground petroleum tanks gauges accurately showing the product level are present unless a high level alarm or a cutoff controller is present. The design and working capacities and tank identification number must be clearly marked on the tank and at the gauge.
- Erosion is the main concern with earthen emergency spill containment. Dried weeds and grass present a fire hazard. Animals can burrow through earth dikes. Concrete structures are susceptible to cracking and frost damage. A weekly inspection schedule should be developed to address these problems so they can be repaired promptly. Individual site-specific checklists should be developed to reflect site specific concerns. The following is a list of key items to be addressed in the periodic inspection of ASTs. Each AST should be inspected at least weekly.
    - Presence and/or volume of oil or water in the containment area
    - Soil color changes; noticeable sheen on water puddles
    - Visual observance of tanks, pumps, valves, and pipe connections
    - Unusually strong odor of stored material
    - Storage tank overflowing
    - Determination of accumulated liquids contained in area (i.e. uncontaminated stormwater, contaminated runoff, or pure product.)
- New UST systems should be properly installed in accordance with industry codes of practices. At a minimum, new underground storage tank systems including piping should be:
    - Properly designed, constructed, and protected
    - From corrosion
    - Equipped with leak detection devices
    - Equipped with spill/overfill protection
    - Installed by a state certified installer
    - Inspected by a state certified inspector during installation
    - Registered with state upon installation.
- Record keeping is necessary to ensure compliance with the federal, state, and local regulations. Records of a tank system should be maintained for the operating life of the system and at least 5 years after its permanent closure. The original documents should be maintained on site, if possible. The following records are often necessary to document appropriate environmental stewardship: (*843*)
    - Inventory Records
    - Installation Details
    - Modification/Repair Details
    - Operation Records
    - History of usage
    - Physical inspection checklists/reports
    - Monitoring records

- Leak/incident documentation
- Tank Handling Activity Report
- Legal Records
- Permits, notifications, and certificates
- Agency correspondence
- Consultant/Contractor Reports
- Engineering assessments/surveys
- Tank and line testing results
- Environmental sampling results
- UST Inspection Report
- Tank Closure Records
- UST Closure Notification Form
- UST Closure Report Form
- Registration of Storage Tank Form
- Notification of Reportable Release/Notification of Contamination

- Prior to releasing rainwater from secondary/ spill containment of an AST, inspect the water for contamination. If there is evidence of spilled or leaked material, or captured rainwater in the spill containment exhibits a surface sheen, contact the District Stormwater Coordinator or District Hazmat Manager for appropriate actions to be taken.
- Make sure the drain valve or plug is properly secured to contain any future leaks or spills.
- Be prepared to respond in the event of a leak or spill from an above ground tank:
    - Maintain an appropriate spill kit near each above ground tank.
    - Replenish spill kit supplies as they are used.
    - If the type of material being stored changes, replace spill kit contents with supplies appropriate for the new material.
- For cleaning spilled materials, particularly hazardous materials, follow procedures from the product MSDS (Material Safety Data Sheet) or the *North American Emergency Response Guidebook* (Federal DOT document).
- For facility-specific procedures related to spills, refer to the *Spill Prevention Control and Countermeasures* (SPCC) Plan, Title 40, Code of Federal Regulation, part 112 or the Hazardous Materials Business Plan.

Vehicle and Equipment Fueling Procedures and Practices

Vehicle and equipment fueling procedures and practices are designed to minimize or eliminate the discharge of fuel spills and leaks into stormwater drainage systems or watercourses during equipment fueling and the bulk delivery of fuel.(*844*)

Bulk Fuel Delivery

- All aboveground and underground storage tanks should be equipped with automatic overfill shutoff valves.
- Spill Prevention and Control BMPs should be implemented to prevent spillage.

Fueling Area Maintenance

- Label drains at fuel dispensing areas to indicate if they discharge to the storm drain or to the sewer.
- Storm drain inlets may be temporarily covered with spill pads and/or mats during fueling operations.
- Absorbent spill cleanup materials or drip pans should be stored in fueling and maintenance areas and used materials should be disposed in accordance with hazardous waste management BMPs.
- Immediately clean up leaks and drips.
- Hosing off the fueling area is prohibited. Dry shop clean up practices should be used.
- Manage wastes to reduce adverse impacts on stormwater quality. Fueling areas should be kept free of litter and debris that might become contaminated with petroleum products.
- Maintain and implement a current spill response plan for fueling operations.
- Inspect fueling facilities daily and correct deficiencies.
- Keep a supply of spill cleanup materials on site.

Refueling Practices

- Fueling operations should not be left unattended. Fueling in the field should not be performed near unprotected drainage facilities or watercourses. See Spill Prevention and Control BMPs.
- Drip pans should be used during vehicle and equipment fueling unless the fueling is performed over an impermeable surface in a dedicated fueling area. Dedicated fueling areas should be protected from stormwater run-on and runoff and should be located at least 15m from downstream drainage facilities or watercourses.
- Nozzles used in vehicle and equipment fueling should be equipped with an automatic shutoff to control drips.
- Warnings against "topping off" fuel tanks should be posted at fuel dispensers.
- Fueling operations should not be left unattended.
- Absorbent spill cleanup materials should be available in fueling and maintenance areas and should be disposed properly after use.
- Vehicles and equipment leaks should be inspected and cleaned up on each day of use.
- Leaks should be repaired immediately or problem vehicles or equipment should be removed from the project site.

A SPCC Plan outlining procedures and measures to prevent and respond to a petroleum spill is required if:

- The underground tanks at the facility can store more than 42,000 gallons
- 660 gallons or more can be stored in a single aboveground tank
- 1,320 gallons or more can be stored in some combination of smaller aboveground tanks,
- Portable containers (i.e., drums), and oil filled equipment or transformers.

Stewardship Practices for Known or Suspected Groundwater Contamination On-Site

The potential for groundwater contamination raises the need for action at a site to a high priority level. The RCRA environmental indicator for controlling migration of contaminated groundwater requires the following documentation: (845)(846)

- Consideration of all available, relevant or significant information on known and suspected releases to the groundwater at the facility;
- Determination whether groundwater is contaminated above appropriately protective levels (i.e., applicable promulgated standards, other appropriate standards, guidelines, guidance, or criteria) anywhere at, or from, the facility;
- Determination whether the migration of contaminated groundwater has stabilized (remains within the previously determined existing area of contamination);

Environmental stewardship of suspected groundwater contamination from runoff at maintenance sites or other DOT facilities should include the following, which parallel environmental indicators used by EPA to measure progress toward groundwater remediation at RCRA sites subject to corrective action. (847)

- Where groundwater contamination is known or suspected, the DOT controls the migration of contaminated groundwater plumes, through:
    - Consideration of all available, relevant or significant information on known and suspected releases to the groundwater at the facility.
    - Determination whether groundwater is contaminated above appropriately protective levels (i.e., applicable promulgated standards, other appropriate standards, guidelines, guidance, or criteria) anywhere at, or from, the facility.
    - Determination whether the migration of contaminated groundwater has stabilized (remains within the previously determined existing area of contamination).
    - Determination whether contaminated groundwater discharges to surface water.
    - Determination whether any discharge of contaminated groundwater to surface water is "significant" (the maximum concentration of the contaminant in the surface water is more than tentimes the appropriate groundwater level).
    - Determination whether the discharge of contaminated groundwater into surface water is "acceptable" until a full assessment and a final remedy decision can be made. Factors to be considered in the interim assessment include surface water body size, flow, use/classification/habitats, contaminant loading limits, other sources of surface water/sediment contamination, effects on ecological receptors (e.g., via bio-assays, benthic surveys or site specific ecological risk assessments performed by trained specialists).

    - Decision whether groundwater monitoring measurement data and surface water/sediment/ecological data will be collected in the future to verify that contaminated groundwater has remained within the existing area of contaminated groundwater.
- Where groundwater contamination is known or suspected, the DOT controls human exposure to contaminated groundwater, through:
    - Consideration of all available relevant or significant information on known and suspected releases to soil, groundwater and surface water at the facility.
    - Determination whether the soil, groundwater or surface water is contaminated above appropriately protective risk-based levels.
    - Determination whether there are complete pathways between contamination and human receptors such that exposures can be reasonably expected under the current land, groundwater and surface water use conditions.
    - Determination whether the exposures resulting from the complete pathways (above) are "significant." Here, "significant" means: 1) greater in magnitude (intensity, frequency and/or duration) than assumed in the derivation of the "acceptable levels" used to identify the contamination, or 2) the combination of exposure magnitude (perhaps though low) and contaminant concentrations (which may be substantially above the "acceptable levels") that could result in greater than acceptable risk.
- The design and implementation of Best Management Practices is a DOT priority at sites where contaminated groundwater is suspected, in order to prevent further degradation and, possibly, migration to surface water, including sources of drinking water.

This documentation meets or exceeds that required by the Phase I Environmental Site Assessment Standard (ASTM E 1527-00), which may be utilized at some sites, and can serve as the foundation for further, Phase II investigations of "recognized environmental conditions" (RECs) identified during Phase I assessments.

CHAPTER 7: BRIDGE MAINTENANCE

Bridge construction and rehabilitation projects are complicated by the environmental sensitivities of working in riparian areas, including restricted work times to accommodate spawning periods of various aquatic species.

The majority of the steel bridges in the interstate highway system were constructed between 1950 and 1980; up until the mid 1970s, virtually all steel bridges were protected from corrosion by three to five thin coats of lead and chromate containing alkyd paints, creating dramatic complexity and cost increases for major and routine level bridge paint maintenance.(*848*) Lead-based paint abatement and the related issues of environmental, worker, and public protection came to the forefront of the U.S. maintenance painting industry in the mid-1980s to early 1990s when regulations on hazardous waste disposal and lead exposure to workers were promulgated by the U.S. Environmental Protection Agency and the Occupational Safety and Health Administration. The changes wrought by these rules still shape the direction of maintenance painting in the bridge industry.(*849*)

NHI has developed a training course, "Hazardous Bridge Coatings: Design & Management of Maintenance & Removal Operations - NHI Course # 13069" for FHWA and State bridge engineers in the area of bridge coatings maintenance and specification. This course includes guidance on coatings selection, surface preparation specification, and environmental and worker safety issues and covers some of the information in a number of the following sections.(*850*)

In addition to coatings and coating removals, bridge maintenance activities include repairing bent or damaged steel beams, cracked or spalled concrete, damaged expansion joints, and bent or damaged railings. These activities can entail operation of support vehicles and equipment, pavement repair, welding and grinding operations, and associated pollutants. Environmental stewardship practices under paving, structural pavement failure (digouts), pavement grinding, and concrete slab and spall repairs may be pertinent for bridge repairs.

7.1. PREVENTATIVE BRIDGE MAINTENANCE PRACTICES

Preventative bridge maintenance avoids larger scale work in stream environments, and thus makes sense from the standpoint of stewardship of both natural and financial resources. Preventive maintenance is defined as a planned strategy of cost-effective treatments applied at the proper time to preserve and extend the useful life of a bridge. Bridge maintenance encompasses:

- Cleaning activities, including annual water flush of all decks, drains, bearings, joints, pier caps, abutment seats, concrete rails, and parapets each spring.
- Preventive maintenance activities such as painting, coating and sealant applications and for routine, minor deck patching and railing repairs.
- Technical and specialized repairs, including jacking up the structures, crack repairs, epoxy injection, repairing or adjusting bearing systems, repair and sealing of expansion joints, repair or reinforcement of main structural members to include stringers, beams, piers, pier and pile cap, abutments and footings, underwater repairs, major deck repairs, and major applications of coatings and sealants.

- Stream channel maintenance including debris removal, stabilizing banks and correcting erosion problems.

Life Cycle Decisionmaking and Accounting for Ecological Risks

Transportation Asset Management is driven by policy and performance and considers alternatives and trade-offs, evaluating competing projects and services based on cost-effectiveness and anticipated impact on system performance. As such it employs systematic, consistent business processes and decision criteria and makes good use of information and analytic procedures.(*851*)

In order to maintain and repair bridges within limited budgets, DOTs are establishing procedures for early detection of problems, timely repair, good preventative maintenance routines, and consideration of long term effectiveness of dollars spent.(852) NCHRP Report 483-Bridge Life Cycle Cost Analysis. Part one establishes guidelines and standardizes procedures for conducting life-cycle costing. Part two is the guidance manual for using the software to evaluate maintenance, repair, and new bridge alternatives. The AASHTO bridge management software, Pontis, can be used to: inventory elements of a bridge (such as coated steel girders); run deterioration and cost models to determine long term preservation policies; determine preservation needs and schedules; and provide network-level performance measures.

European models have gone further in incorporating environmental aspects. The LIFECON Life-Cycle Management System (LMS) is a European model of a predictive and integrated LMS for concrete infrastructures, on both a short term and a long term basis, developed to facilitate decisionmaking. The system is divided into three levels of structural hierarchy: component and module, object, and network, with component- and module-level systems that address structural components such as beams and columns and their combinations in modules. The object-level system deals with complete structures or buildings. The network-level system treats networks of objects such as stocks of bridges or buildings. Besides a structure's observed condition and evaluated urgency of repair, the life-cycle costs, user costs, minimum requirements of structural performance, structural risks, traffic and other operational requirements, aesthetics, environmental risks, and ecological pressures can be taken into account for multiple-attribute planning on all hierarchical levels of the system. The life-cycle analysis and optimization module involves the data applications for studying the economy of the life cycle and cost-effectiveness of optional maintenance, repair, and rehabilitation strategies. Alternative strategies are compared as life-cycle activity profiles over a defined time frame. The purpose of life-cycle analyses is to find the optimal activity profiles to reach the targets.(*853*)

In January 2002, FHWA announced that Highway Bridge Replacement and Rehabilitation Program (HBRRP) funds can be used to perform preventive maintenance on highway bridges. Preventive maintenance activities eligible for funding include sealing or replacing leaking joints; applying deck overlays that will significantly increase the service life of the deck; painting the structural steel; and applying electrochemical chloride extraction treatments to decks and substructure elements. FHWA is currently in the process of clarifying language and restructuring the National Bridge Inspection Standards.(*854*) Proposed changes will reorganize the standards into a more logical sequence and make them easier to understand for inspectors, and state and federal highway administrators.

Bridge Inspection and "Smart Bridges" for Preventative Maintenance

In order to conserve fiscal and natural resources and ensure safety, DOTs are investing in bridge inspection for preventative maintenance and "smart bridges" that may forestall larger construction projects in and adjacent to streams. An increased emphasis on bridge safety and more rigorous inspection protocols followed the December 1967 collapse of a bridge over the Ohio River near Point Pleasant, WV, which claimed more than 50 motorists' lives. As a result of the incident, Congress began to require the inspection and inventory of all bridges on the National Highway System, with a specific provision that each bridge's load-carrying capacity be determined. More than 40 state DOTs and 100 engineering consulting firms now use the Bridge Rating and Analysis of Structural Systems (BRASS) software suite developed by the Wyoming DOT. Programs within the BRASS suite now include applications specific to steel, timber and concrete girders, steel girder splices, piers, trusses, culverts, and poles, as well as for illuminated signs and signals. The culvert design portion of the package comes from the North Carolina DOT; pre-stress girder design from Kansas; steel-field splice design from Nebraska; pier analysis and design program work by the Portland Cement Association, Georgia DOT and Montana DOT; truss rating from New York; and, cantilever pole analysis and design from Louisiana.(*855*)

FHWA's Construction and Maintenance Fact Sheet on Bridge Preservation identifies best practices in bridge preventative maintenance, highlighting PennDOT's program.(*856*) PennDOT maintains the third largest number of State bridges in the Nation, spending $300 million on 250 bridge projects each year. To keep costs down and ensure safety, PennDOT has found that it is vital to have both proper and frequent inspections and a good preventive maintenance program. PennDOT's team of 50 bridge inspectors and numerous other consultant inspectors inspect all of the agency's bridges at least once every two years. The bridge data is then stored in a management system, allowing engineers to prioritize the maintenance and rehabilitation needs and make sound decisions as to how to best take care of the bridge infrastructure.

Connecticut DOT has been using electronic monitoring systems to keep tabs on the condition of some of its bridges. Systems of linked sensors provide data on structural integrity and wear, and contribute to bridge life and stress assessment data. Portable and continuous systems have been installed on 11 bridges since 2002, allowing for early repair in sites that need it, and saving an estimated $2.7 million.(*857*) Likewise, high-tech optical sensors embedded in concrete beams in a bridge in Las Cruces, N.M. relay information to New Mexico State University researchers about the performance of the bridge's design and materials, letting them track structural soundness as the bridge ages.(*858*)

Recent research has concluded that truck weight is one of the most significant factors in the repair and replacement life of bridges.(*859*) TRB Special Reports 225 and 227, Truck Weight Limits: Issues and Options and New Trucks for Greater Productivity and Less Road Wear: An Evaluation of the Turner Proposal, respectively, noted that trucks produce significant damage to highway bridges. A truck's gross weight, axle weights, and axle configuration directly affect the useful life of highway bridge superstructures. Damage typically occurs in the bridge deck and in the superstructure elements including floor beams and girders, diaphragms, joints, and bearings. Bridge costs associated with increased truck weights are the result of the accelerated maintenance, rehabilitation, or replacement work that is required to keep structures at an acceptable level of service.(860)(861)(862) While prestressed concrete I-girder bridges and modern steel-girder bridges could withstand a 20 percent increase in truck weight, such an increase would reduce the remaining life in older steel-girder bridges by up to 42 percent.(863)

The “smartest” bridge to date, in terms of density of sensors, is under construction in Star City, West Virginia; it contains 770 sensors, 28 data-collection boxes, and a central data processing unit.(*864*) WVDOT is counting on the investment to “help the state make smaller, less costly repairs while problems are still manageable,” said Deputy Commissioner Norman Roush, as well as conserve resources that may be spent through overdesign.(*865*) Engineering data collection will be able to be correlated with continuous environmental data collection on-site. West Virginia’ existing “smart” structures have already yielded valuable information, such as that concrete slabs 20 feet long are prone to cracking, while those 15 feet long are not.

Small Bridge Maintenance Activities that Can Eliminate the Need for Larger Inor Over-Stream Work Projects

Some of the bridge maintenance activities that provide the biggest benefit for the smallest level of investment generally include:

- Eliminating deck joints in old bridges
- Repairing or installing new expansion dams on bridge decks
- Repairing bridge decks
- Maintaining proper deck drainage
- Restoring or replacing bridge bearings
- Repairing or replacing bridge approach slabs
- Repairing bridge beam ends and beam bearing areas
- Bridge painting

Successful control of pollution from bridge maintenance and repair involves minimizing the potential sources of pollutants from the outset.

Maintaining Drainage from Bridge Decks

Effective bridge deck drainage is important because deck structure and reinforcing steel is susceptible to corrosion from deicing salts; moisture on bridge decks freezes before surface roadways, hydroplaning can occur more easily; and drainage occurs over environmentally sensitive areas. Bridge deck drainage is often less efficient than roadway sections because cross slopes are flatter, parapets collect large amounts of debris, and drainage inlets or typical bridge scuppers are less hydraulically efficient and more easily clogged by debris. Because of the difficulties in providing for and maintaining adequate deck drainage, the following practices should be used: (*866*)

- Gutter flow from roadways should be intercepted before it reaches a bridge.
- Zero gradients and sag vertical curves should be avoided on bridges.
- Runoff from bridge decks should be collected immediately after it flows onto the subsequent roadway sections where larger grates and inlet structures can be used.

Bridge Cleaning

Bridge cleaning consists of cleaning all bridge components that are susceptible to dirt, debris, bird dropping and deicing salts. Drainage systems and components subject to dirt or bird droppings accumulation need to be cleaned regularly by hand tools, air blasting or preferably water flushing.

- Dust or any material that could be inhaled should be avoided by the use of a proper respirator.
- Other components such as bare concrete decks, pier caps, abutment seats, bearing systems, non-sealed or open expansion joints, joint drainage troughs, head walls, wing walls, select beam flanges, truss joints etc. should receive a thorough water flush every spring (after applications of deicing salts have ceased) as a bare minimum.
- Personnel should become familiar with various types of bearing devices. Mechanical bearing devices should be lubricated after cleaning to prevent rusting and assist in their movement.
- Clearing of weeds, float debris, brush and overhanging limbs from the vicinity of the bridge should be performed according to best practices in channel maintenance.

7.2. AVOIDING AND MINIMIZING IMPACTS TO FISH AND WILDLIFE AND ENHANCING HABITAT

Scheduling Maintenance and Repair

There are times of the year when the effects of pollution from bridge maintenance and repair would cause the most damage and times when the damage would be minimal. The exact timing depends upon the site and the species involved.

- Schedule bridge maintenance to avoid egg incubation, juvenile rearing and downstream migration periods of fish.
- Call upon state DOT fish and wildlife specialists or local fish and wildlife agencies for assistance in scheduling to avoid aquatic impacts.

Maintenance modifications TxDOT has undertaken to protect bats in bridges include postponing tree trimming and/or bridge maintenance work until outside of bat season.(*867*)

Using Pre-Fabricated Bridges to Help Accommodate Stream/Fish Timing Restrictions

Using prefabricated bridge elements and systems makes construction less disruptive for the environment. As traffic and environmental impacts are reduced, constructability is increased, and safety is improved because work is moved out of the right-of-way to a remote site, minimizing the need for lane closures, detours, and use of narrow lanes. Prefabrication of bridge elements and systems in a controlled environment without concern for job-site limitations can increase quality and lower costs, especially where use of sophisticated techniques would be needed for cast-in-place, such as in long water crossings or higher structures, like multi-level interchanges. NCHRP Synthesis 324 recently concluded that while prefabricated bridge components are more expensive in some cases, environmental impacts are reduced, quality is generally higher, and costs may fall as standardization increases in the industry.(*868*)

In February 2003, FHWA and AASHTO sponsored a conference showcasing the successful uses and benefits of prefabricated bridge elements and systems. Along I-40 in Oklahoma where the cost of labor and materials to replace a collapsed bridge across the Arkansas River was $11.8

million, while the cost to control traffic and detours around the construction zone was $12 million, the higher upfront costs of prefabricated materials were offset by the amount of money saved by reduced construction times. In San Juan, Puerto Rico, construction crews were able to minimize traffic delays and reduce construction times by using prefabricated bridge modules, while building four bridges at a congested intersection of a four-lane arterial. Crews completed the first bridge within 36 hours, and construction of each of the other three bridges took only 26 hours, using prefabricated elements. The conference profiled several new technologies and construction techniques, including new specifications for high-performance concrete and steel and self-compacting concrete, and contracting procedures that ensure that bridges are built within one day and charge high penalties for any delays.(*869*)

Using prefabricated substructure elements reduces the amount of heavy equipment required and the amount of time required on-site for heavy equipment, causing less disruption to sensitive environments.(*870*) For example, the Hawaii DOT's Keaiwa Stream Bridge minimized environmental disruption because deck topping did not require shoring or falsework in the streambed, and minimized traffic disruption because precast planks were fabricated during pier construction. Photo: Hawaii DOT. (*871*)

Figure 7: Prefabricated Bridge Construction - Hawaii DOT

In North Carolina, to avoid placement of heavy equipment in a sensitive environment on the Blue Ridge Parkway, the Linn Cove Viaduct on the Blue Ridge Parkway was built in one direction from the south abutment to the north almost entirely from the top down. The only exceptions to the top down method were construction of the initial span on falsework and construction of a temporary timber bridge that enabled the micropile foundation drilling machine to prepare several of the foundation sites ahead of the superstructure erection. Precasting each segment of the bridge allowed construction workers to assemble the bridge with little impact to the most environmentally sensitive section of Grandfather Mountain. This bridge proved that a design could be environmentally sensitive in addition to being utilitarian and economical. (*872*)

The Wolf River Bridge in Fayette County, Tennessee, crosses sensitive wetlands and carries the only east-west route through its geographic region. TDOT designers selected precast prestressed beams to facilitate speedy construction and allowed optional stay-in-place precast prestressed concrete deck forms. TDOT and the contractor developed details for precasting bent caps in two pieces to suit staged construction. Construction of the 1,408-foot long, 46-foot wide bridge was completed in eleven months without putting any equipment in the surrounding wetlands. Photo Credits: Tennessee Department of Transportation. (*873*)

FHWA's segmental concrete bridge technology website offers resources and best practices in SCBT bridge use, a method of joining multiple cast-in-place or precast bridge elements to form a continuous span. The site addresses engineering issues and construction methods, and features a photo gallery and an archive of "Ask the Experts" questions that have been submitted by site users and answered by team members. Geosynthetic Reinforced Soil (GRS) abutments and walls can help reduce the access needed for large equipment.(*874*)

Reducing the Space Needed for Large Equipment Access

Geosynthetic Reinforced Soil (GRS) abutments and walls can reduce the space needed for access by large equipment in building bridge abutments. FHWA has completed a substantial amount of research on this technology and feels it has great potential for future application. (See www.tfhrc.gov, geotechnical programs, "Performance Test for Geosynthetic-Reinforced Soil Including Effects of Preloading, FHWA-RD-01-018" and "Effects of Geosynthetic Reinforcement Spacing on the Behavior of Mechanically Stabilized Earth Walls, FHWA-RD-03-048.)"

Bird and Bat Roosts in Bridges

Virginia Department of Transportation Program Key in Comeback of Peregrine Falcons

Peregrine falcons were classified nationwide as an endangered species from 1970-1999. In the 1980s, the falcons began showing a preference for VDOT's coastal bridges. At that time, VDOT began working with the Virginia Department of Game and Inland Fisheries and the College of William and Mary to aid bridge-nesting efforts. VDOT installed nesting boxes on tenbridges and video cable on one. From 1978 through 1985, the Department of Game and Inland Fisheries led a recovery effort that released 115 young birds on the Eastern Shore. Rather than moving to western Virginia as anticipated, VDOT bridges became one of the most popular nesting sites. Native to Virginia's Allegheny and Blue Ridge mountains, peregrine falcons were nearly wiped out by unintended side effects of pesticide use by the early 1960s. All known breeding pairs east of the Mississippi had disappeared and their numbers were drastically reduced worldwide by the mid-'90s.

The Department reports falcon activity to wildlife experts, and limits maintenance work to avoid disturbing nesting pairs or their young. In 1998 VDOT's Environmental Division earned a Federal Highway Administration Award for Excellence in Highway Design for Environmental Protection and Enhancement for the effort. VDOT employees have been recognized by the Board of Directors of Virginia Game and Inland Fisheries.

VDOT has continued its habitat enhancement and sensitive maintenance practices even after the species was delisted. In the spring of 2001, VDOT and eight other public and private agencies began FalconTrak, a three-year program to protect eggs and hatchlings, track young falcons via satellite, and monitor nests with video cameras for researchers and the public to view on VDOT's web site, VirginiaDOT.org. Pairs of peregrine falcons are currently nesting on eight VDOT bridges and offspring are thriving.(*875*)

Protecting and Increasing Bat Roost Habitat in Bridges

Bats are primary predators of vast numbers of insect pests that are extremely costly to farmers and foresters. One bat can easily eat 20 female corn earworm moths in a night, and each moth can lay as many as 500 eggs, potentially producing 10,000 crop-damaging caterpillars. Yet as few as eight caterpillars per 100 plants can force a farmer to apply pesticides.(*876*)

A number of bat species nationwide are listed as threatened or endangered under the federal Endangered Species Act. Bats are especially susceptible to extinction because most species form large colonies in vulnerable locations, such as caves that are sometimes inadvertently sealed. In addition, bats usually produce only one pup per year. As a consequence of losing natural roosts in caves and old growth forest snags, bridges and culverts have become havens of last resort. Bridges from Canada to Florida are being used by at least 24 of the 46 North American bat species; it is estimated that within the southern United States alone, 3,600 highway structures are being used by approximately 33 million bats.(*877*) State DOTs can contribute to bat recovery at little or no cost, through proactive measures. Most bat species that will roost in bridges choose concrete crevices that are sealed at the top, at least six to 12 inches deep, .5 to 1.25 inches wide, and ten feet or more above the ground, typically not located over busy roadways. Day roosts are places that protect bats from predators and buffer weather conditions while resting or rearing their young. Such roosts are usually in expansion joints or other crevices. In contrast, night roosts, where bats gather to digest their food between nightly feeding bouts, are often found in open areas between bridge support beams that are protected from the wind. Retrofitting existing bridges and culverts proved highly successful in attracting bats, especially where bats were already using them at night.

Citizens have gotten involved as well. When 33,000 Mexican free-tailed bats became a nuisance in the school attic at Canadian Middle School in Canadian, Texas, teachers and students purchased materials, constructed, and installed alternate roosts for up to 50,000 bats in a nearby highway bridge by collaborating with Bat Conservation International (BCI), the TxDOT and local businesses.

Figure 8: TxDOT Bats in Bridge Retrofit Partnership

Bats have the largest surface area to body mass of any mammal, and this requires greater energy to maintain body temperatures. Sun-warmed bridges help adult bats to conserve energy and foster development of their young. During the summer months, sun-exposed bridges act as thermal sinks, often achieving and holding temperatures above the ambient average for most of the 24-hour cycle.

Bat Conservation International cooperated with 20 state DOTs in a national study of bats in bridges and found 217 highway structures used as day roosts and 714 highway structures used as night roosts. Information from this study is summarized in this section and those following, pertaining to construction and retrofit recommendations.(878)

The study found that the higher, more consistent bridge temperatures are especially important in mountainous or desert regions where ambient temperatures fluctuate dramatically within a 24-hour cycle. An Oregon study found that bats prefer bridges with greatest sun exposures. Bridges receiving no sun had little or no bat use. This preference was especially obvious within partially shaded bridges, where roosting activities occurred only in the sun-exposed halves of bridges.(*879*) The northernmost day roost discovered in this study was occupied by a maternity colony of roughly 300 little brown myotis in an Idaho bridge at 44 north latitude. However, the number of day roosts appears to drop rapidly above 42 north latitude.(*880*)

Bats use parallel box beam bridges as day roosts more than any other kind. The next most preferred bridges are cast in place or made of prestressed concrete girder spans. These designs are the most likely to contain spaces suitable for bats. Although parallel box beam bridges were rarely encountered during the survey, they can provide numerous crevices of suitable width. Metal and small concrete culverts are the most frequently encountered highway structures and are the least preferred as roosts. Even ideal structures were rarely used by bats in areas dominated by open plains, perhaps due to a lack of appropriate habitat. Creation of day-roost habitat for bats in new or existing highway structures is easy, often at little or no extra cost to the taxpayer. For new structures, the minimum needs for day-roosting bats can be met by specifying the proper dimensions for crevices such as expansion joints.

Night use of highway structures is even more common; 29 percent of all structures surveyed had signs of night-roost activity. In some regions of the southwest, all suitable structures were used by night-roosting bats. Night-roosting bats are believed to be attracted to bridges that provide protected roosts and have a large thermal mass that remains warm at night. Bridges constructed of prestressed concrete girder spans, cast-in-place spans, or steel I-beams are preferred. Vertical concrete surfaces located between beams provide ideal protection from wind and are especially used when they are heated by full sun exposure. Bats typically do not use bridges with flat bottomed surfaces that lack inter-beam spaces. They will avoid small culverts but will roost at night in the long concrete box culverts that often pass under divided highways, if the culverts are at least 5 feet (1.5 m) tall. Night roosts appear to play important roles in body temperature regulation and social behavior.

Figure 9: Night Roosts Located in Open Spaces between Bridge Beams. Credit: Bat Conservation International

TxDOT Study and Bridge Modifications to Support Bat Usage

TxDOT and Bridge Engineer, Mark Bloschock, have received an award of excellence from Bats Conservation International, the first given to a person outside the field of wildlife conservation. Bloschock began a study with BCI in 1994 after a large colony of Mexican Free-Tailed bats settled under the Congress Avenue bridge in Austin and each wanted to determine why the bats settled there, whether bats might damage the bridge, and if there might be potential effects on human health. The study determined that slot-shaped crevices under the bridge were similar in size to spaces found in bat caves and uncovered bat roosting preferences in both bridges and culverts throughout the state. The study indicates that minor modifications to highway structures can maximize or minimize the potential for use by bats, and that less than 0.01 percent of Texas highway structures currently meet the day-roosting requirements for bats. In central, southern, and western Texas, there is a 62 percent chance that structures with suitable characteristics will be used by bats. The Mexican free-tailed bat (*Tadarida brasiliensis*) was found to be the most frequent bat species day roosting in highway structures. Bridge characteristics preferred by day-roosting bats were defined by a paired comparison study where bat-occupied and unoccupied bridge characteristics were statistically compared.

Today, 1.5 million Mexican Free-Tailed bats migrate from Mexico every year and stay from March to October under the popular Austin bridge. It's estimated the bats eat ten to 15 tons of insects on their nightly flights. The sight of the bats taking flight at dusk from beneath the Congress Avenue bridge had another unexpected benefit as thousands of tourists visit the bridge to see the nightly flights. The bridge is listed as a top tourist attraction on the City of Austin web page. Each year, the bridge attracts tens of thousands of tourists from all over the world, and has been estimated to generate more than $8 million for the local economy.(*881*)

Based on the success of the bat habitat in Austin, Bloschock established the Bats and Bridges program, which has spread to 24 states and 17 countries. Overall, TxDOT has 218 structures currently used as roosts, almost three times as many habitats for bats as any other state taking part in the program.(*882*)

Practices to Incorporate in Design, Construction, and Retrofitting of Bridges for Bats

TxDOT performed a statewide evaluation used to identify the distribution of highway structures used by bats. Day-roosting bats prefer concrete bridges and culverts with secluded locations such as crevices that are 0.5 to 1.25 inches-wide(1.2 to 3.2 cm), especially those that are 12 inches deep (30 cm), have covered tops, and are located in central, southern, and western Texas. Additional experiments further supported the results of the paired comparison and statewide evaluations. Bat colonies, even large ones, do not damage highway structures and water sources under roosts are not negatively impacted. Human health risks are minimized by educating people not to handle bats.(*883*) In sum, the study found that:

1. Highway structures that incorporate crevices between 0.5 and 1.25 inches wide (1.2 and 3.2 cm) can provide ideal roosting habitat for several of the most rapidly declining and valuable bat species in Texas, especially if these crevices are 12 inches (30 cm) or more in depth and covered at the top.
2. Bats typically use only concrete or wooden roosting surfaces, preferring the highest, darkest locations.
3. Structures can be retrofitted with Bat-Abodes or concrete panels to create bat habitat.
4. Large concrete culverts under divided highways can provide excellent roosts for threatened and endangered bats, though most would require provision of roughened ceiling cavities during construction.
5. No structural damage, aquatic pollution, or disease transmission to humans has been associated with even the largest bat colonies living in Texas bridges and culverts, but warnings not to handle downed individuals or inhale dust associated with bird or bats droppings are recommended.
6. Where bats are unwanted, simple elimination of preferred crevice widths can prevent potential nuisance problems.

Incorporating characteristics into new structures specifically for bats can be relatively inexpensive and easy to do. TxDOT has developed a bat-friendly domed culvert, for which customization costs are minimal; modifications can even be implemented during construction.(*884*)

As part of their national study, Bat Conservation International determined in consultation with state DOTs that bat-friendly habitat can be provided in either new or existing bridges or culverts, at little or no extra cost to taxpayers. During construction planning, there are no costs for an engineer to specify the appropriate crevice widths of 3/4 to 1-inches (1.9 to 2.5 cm) for expansion joints or other crevices. Existing structures can be retrofitted with bat-friendly habitats using the designs described in the following sections. Signs of bat use in nearby bridges and culverts increase the chances of success for habitat enhancement projects.

Ideal day roost characteristics for crevice-dwelling bat species that use highway structures, include (in descending priority): (*885*)

- Location in relatively warm areas, primarily in southern half of the U.S.
- Construction material: concrete
- Vertical crevices: 0.5 to 1.25 inches (0.25 to 3 cm) wide
- Vertical crevices 12 inches (30 cm) or greater in depth
- Roost height: ten feet (three meters) or more above the ground
- Rainwater-sealed at the top
- Full sun exposure of the structure
- Not situated over busy roadways

Culverts:

- Location in relatively warm areas
- Concrete box culverts
- Between five and ten feet (1.5 and 3 meters) tall and 300 feet (100 meters) or more long
- Openings protected from high winds
- Not susceptible to flooding
- Inner areas relatively dark with roughened walls or ceilings
- Crevices, imperfections, or swallow nests

The Texas Bat-Abode, Big-eared Bat-Abode, and the Oregon Bridge Wedge bat roosts are designed for day-roosting bats in bridges and culverts. In the protected environment of a bridge or culvert, a properly constructed and installed bat habitat made of quality materials should last as long as the highway structure. BCI would appreciate photographs of the installation and especially of bats using any bat-friendly modifications. For more information on adapting the designs to specific bridges, or to report occupied units, please contact Bat Conservation International (BCI), Inc., at 512/327-9721. BCI maintains a list of bats, documented bridge/culvert use, potential use, roost type (crevices or open beams), preference, U.S. distribution, and status at: http://www.batcon.org/bridge/ambatsbridges/index.html.

Texas Bat-Abode

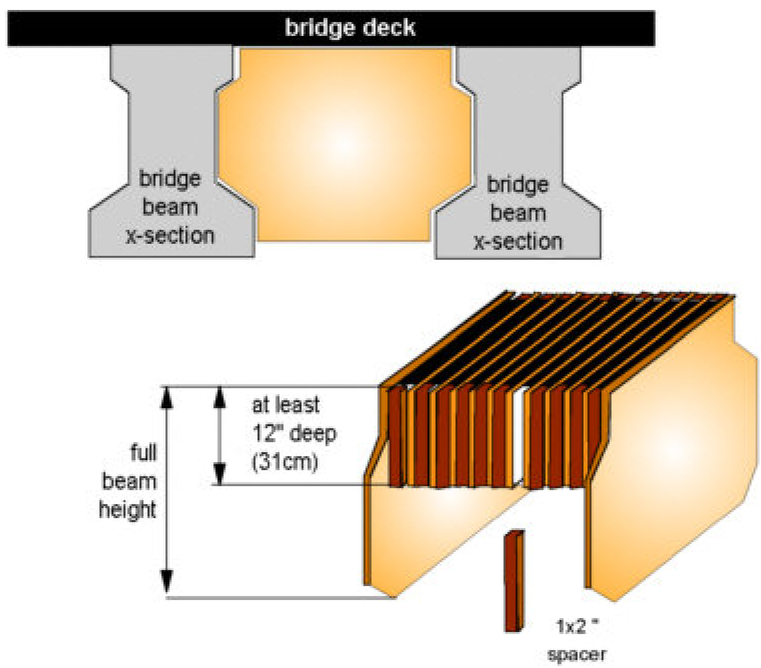
The Texas Bat-Abode is designed to retrofit bridges with bat habitat for crevice-dwelling species. It has an external panel on either side and 1x2-inch (2.5 to 5.1 cm) wooden spacers sandwiched between 0.5 to 0.75 inch (1.2 to 1.9 cm) plywood partitions (Figure 29). Recycled highway signs are ideal construction materials. Note that only the external panels need to be cut to fit the bridges' inter-beam spaces. The internal partitions should provide crevices 0.75 inch (1.9 cm) wide and at least 12 inches (31 cm) deep.

Smooth roost surfaces need to be textured to provide footholds for bats on at least one side of each plywood partition (preferably both), creating irregularities at least every 1/8 inch (0.3 cm). Many methods have been tested to create footholds, such as

- Using rough-sided paneling
- Coating the panel with a thick layer of exterior polyurethane or epoxy paint sprinkled with rough grit
- Attaching plastic mesh with silicone caulk or rust-resistant staples
- Mechanically scarifying the wood with a sharp object such as a utility knife
- Lightly grooving the wood with a saw (do not penetrate to the first plywood glue layer)
- Lightly sandblasting the wood with rough-grit

The use of rough-sided paneling or polyurethane sprinkled with grit have provided the longest lasting results. Rust resistant wood screws should be used to assemble the spacers and partitions.

Figure 10: Texas Bat-Abode for crevice-dwelling species. Credit: Bat Conservation International



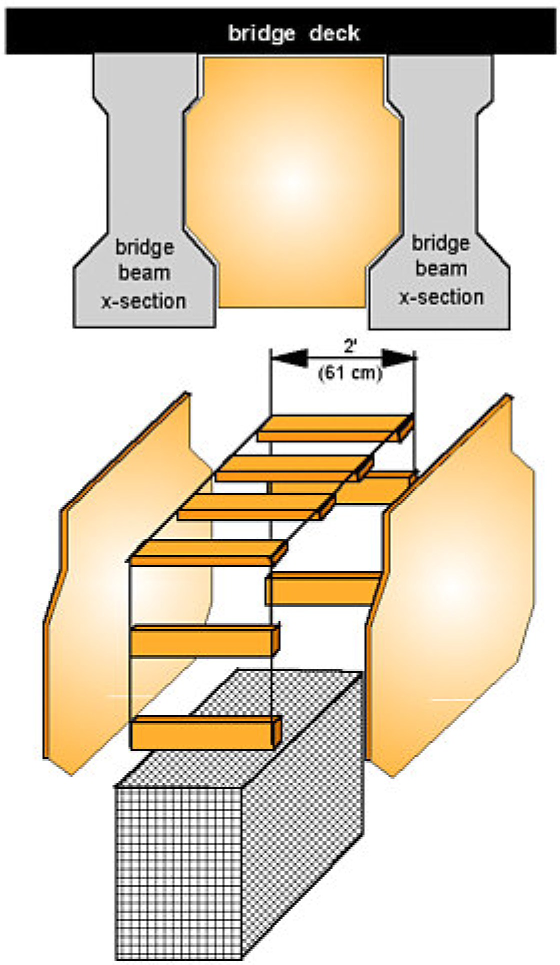
The Texas Bat-Abode should be installed in bridges that are at least ten feet above ground, free of vegetation, and not susceptible to flooding or easy vandalism. Measurements of the exact location where the Bat-Abode is to be placed will ensure a proper fit. The number of partitions is arbitrary and limited only by availability of materials and support for the weight of the Abodes. Because of the weight, it may be easiest to assemble the cut pieces in the bridge. In wooden bridges, the unit should be anchored to the structure with heavy-duty rust-resistant lag-bolts.

Big-eared Bat-Abode

Big-eared bats are frequent bridge users in both the eastern and western United States. They prefer open roost areas such as cave entry rooms, large hollow trees, darkened undisturbed rooms in abandoned houses, or between the darkened beams of quiet bridges over streams. The Big-eared Bat-Abode creates these conditions.

The Big-eared Bat-Abode has two external panels with 1x2-inch spacers that are used as braces to hold the panels together with a plastic mesh lining to provide footholds for bats. The netting should be attached using rust-resistant staples (Figure 30). The other methods of creating footholds mentioned above would also be effective.

Figure 11: Big-eared Bat-Abode. Credit: Bat Conservation International.



Several designs of the Texas Bat-Abode, such as this one modified for a steel I-beam bridge, have been used to attract thousands of bats. Complements of TxDOT and BCI.

It may be easier to partially assemble the structure on the ground leaving one end panel off until it is placed in its chosen location. Units installed in wooden bridges can be anchored using heavy-duty rust-resistance lag bolts. Because big-eared bats are very sensitive to disturbance, units should be placed in areas of low activity and painted a color that does not attract attention.

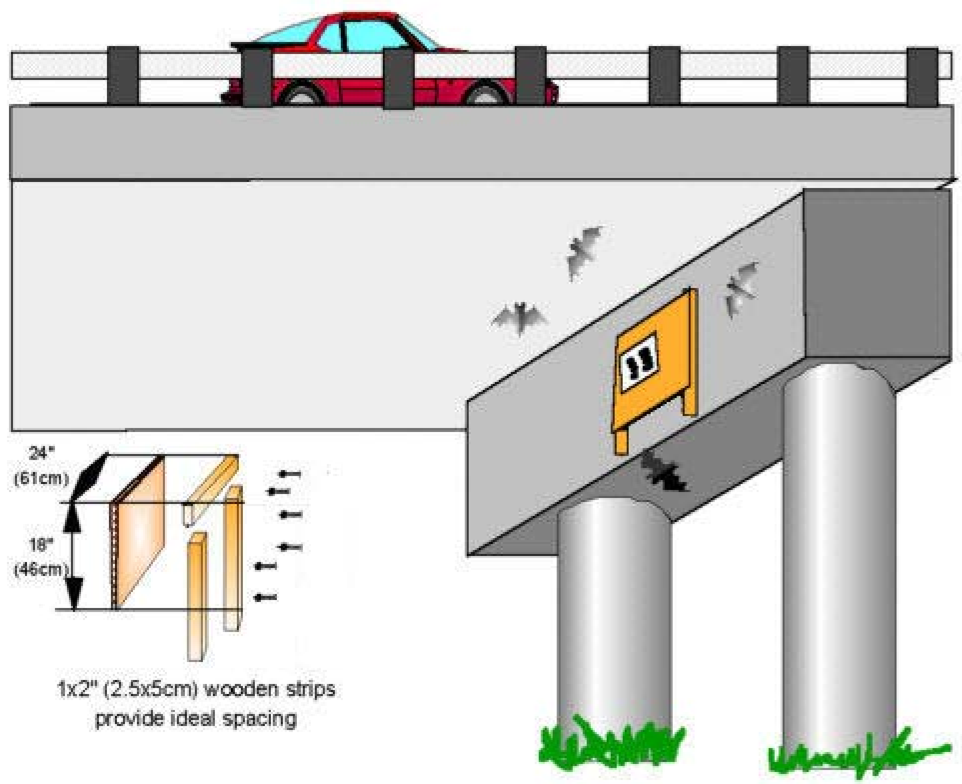
Big-eared bats are often found in low bridges darkened by thick vegetation growing along the sides. The Big-eared Bat-Abode should be placed at least six to ten feet (two to three meters) above the ground in a secluded portion of the bridge. However, access to the fly-way entrance should not be blocked. Other bat species are likely to use this structure.

The Oregon Wedge

The Oregon Wedge (Figure 12) is an inexpensive method of retrofitting bridges or culverts with day-roost habitat for bats. The Wedge is made from an 0.5 to 0.75 inch (1.2 to 2 cm) exterior grade plywood panel that is at least 18 inches high and 24 inches wide (46x61 cm) with three 1 x 2 inch (2.5x5 cm) wood strips attached along the top and sides, leaving an opening along the bottom. If larger panel sizes are used, vertical wooden pieces should be placed every 24 inches (61 cm) to support the plywood and prevent warping. The pieces should not run from the top to the bottom so that bats can move about within the panel.

The Wedge can be attached to a vertical concrete portion of a bridge or culvert using concrete anchor-bolts or a fast-drying environmentally safe epoxy cement (such as 3M Scotch coat 3-12). The transportation department should install the panels if anchor bolts are used. If the panel is to be attached to wood, then use appropriate rust resistant wood screws. Before applying the epoxy, check the preferred installation site to make sure the support strips fit flat against the concrete surface.

Figure 12: Oregon Wedge



Designs courtesy of David Clayton and Dr. Steve Cross and Bat Conservation Int'l

Wedge placement is possible on any adequately sized, flat concrete or wood surface. However, we recommend that the panels be placed near the sun-warmed road slab (preferably as high as possible between heat-trapping bridge beams). They should be at least ten feet (three meters) above ground, with a clear flyway (at least ten feet), and be out of view or reach of vandals. The Wedge can be installed in the middle sections of culverts higher than five feet (1.5 cm). A Wedge should not be placed in structures that flood. As a precaution against flooding, a 1.5 inch (3.8 cm) gap can be left at each corner where the support strips join to act as an escape route in the event of fast-rising water.

Bat-domed Culverts

The Bat-domed culvert is a modified concrete box culvert designed to accommodate large colonies of bats. The dome has several bat-friendly characteristics:

- The height is increased
- Warm air is trapped
- Light intensity is reduced
- Air movement is reduced

Figure 13: Bat-domed culvert. Graphics courtesy of TxDOT and BCI.

Bat-domed culverts should be at least 5 feet (1.5 m) in height with an additional 1 to 2-foot (0.6 meter) raised portion centered in the culvert. The raised area can be any length from 2 to 50 feet, depending on the colony size preferred. The walls and ceilings of the raised area should be roughened to provide footholds for bats. The following method was used to produce suitable wall and ceiling textures. Using a crowbar, thin strips were removed from the surface of recycled plywood. The resulting roughened wood was then used as the form for pouring the concrete, which produced the desired textured surface within the domed area of the culvert. In addition, a method of attaching panels or partitions, such as female threaded inserts, can be incorporated into the raised walls and ceiling to create more surface area once the culvert is completed.

Bat-domed culverts should not be placed in areas susceptible to flooding. However, in the event of rising water, the dome may serve as a temporary air-trap. Almost any cave-dwelling species may use these, including several that are endangered.

Success in Retrofitting Bridges to Accommodate Bats

Retrofitting habitat into existing highway structures has become a popular and successful method of accommodating bats. Pre-surveys to look for bat signs in nearby bridges are useful to predict the success of proposed enhancement projects. Four bridges in Oregon and five bridges and two culverts in Texas with signs of night roosting were retrofitted with ideal crevices, and all were occupied by bats within the first year. All retrofit designs tested in bridges and culverts so far have successfully attracted bats, and at least six states are already using retrofitting projects to accommodate bats. Retrofits are adaptable to almost any structure and can be placed where they will have a high potential for success and that will minimize disturbance from maintenance or vandalism. Retrofits are generally inexpensive and can be sized to accommodate small or large colonies, with potential expansion by adding more units if initial efforts are successful. Retrofits are usually highly beneficial to local agricultural and can be easily moved if necessary.

Figure 14: TxDOT's Concrete Version of the Oregon Wedge

Two basic designs can be used to retrofit almost any bridge or culvert. Texas Bat-Abodes can accommodate thousands of bats each, and have been modified to fit three different bridge designs. Four of the five tested were fully occupied, one within the first month.

The Oregon Wedge can house several hundred bats and has been accepted for day roosting by 12 species, including a maternity colony of Yuma Myotis (*Myotis yumanensis*). This design has been successful in both bridges and culverts in Oregon, Arizona, and Texas. The Texas Department of Transportation developed a concrete version that attracted bats within a year.

Preserving Portions of Old Bridges as Habitat

When old bridges must be replaced, some of those occupied by bats have been retained as wildlife sanctuaries. The Santa Barbara Public Works Department and Caltrans are collaborating to preserve a colony of 10,000 Mexican free-tailed bats and 200 pallid bats (*Antrozous pallidus*) by retaining a portion of an old bridge that is surrounded by agricultural fields (Storrer, 1994). It is calculated that these bats consume roughly 10,000 pounds (4,540 kg) of insects each summer, many of which are pests. Bridge habitat enhancement techniques are being developed in other countries. In Australia, the roost portion of an old wooden bridge was retained and incorporated into the underbelly of a new replacement bridge.

Further DOT Efforts to Identify Characteristics and Design Features of Roost Bridges and Conservation Efforts

FDOT is in the process of undertaking a survey of bridges with bats to help FDOT predict and control where bats will roost. At least five species of bats in Florida use concrete highway bridges as roosting sites. Because many natural roosts such as caves and large hollow trees are rare, bridges serve as the most common or primary roosting sites for bats in some areas. The objectives of this project are to: 1) identify FDOT maintained bridges in Florida that are occupied by roosting bats; 2) summarize characteristics and design features of roost bridges, and correlate bridge features with presence, number, and species of roosting bats; 3) prepare guidelines for FDOT employees to record the presence of bats during routine activities; and 4) identify all bridges that support bat roosts and are planned for replacement by 2020, and to identify ways to conserve the roosts when these bridges are replaced.(*886*)

Likewise Georgia DOT will 1) identify the highway bridges and select culverts in Georgia that are occupied by roosting bats; 2) evaluate the characteristics and features of bridges being used as roosts, including an assessment of surrounding habitat features; 3) recommend bridge design elements that provide the roost features preferred by bats; and 4) prepare standard procedures for assessing the presence of bats, minimizing disturbance to the bats, and preserving the existing or potential roosting opportunities during management, repair, and demolition of highway bridges by the Georgia Department of Transportation (GDOT). Those research results will be available in mid-2005.(*887*)

7.3. Bridge Painting/Coating/Sealing and Containment Stewardship Practices

Bridge painting/coating/sealing covers all protective and preventative maintenance activities designed to prevent deterioration of structure components. Components made of non-weathering steel are generally painted with a multicoat paint system to protect the steel from rust and corrosion. Bridges painted prior to 1975 typically used lead, cr, or cd pigmented paints, which if removed must be removed according to strict EPA and OSHA guidelines and disposed of as a hazardous waste.

The 1990s saw great increases in the costs and complexity associated with steel bridge maintenance painting. While a low-tech, least cost approach to combating corrosion and deteriorating aesthetics prevailed as recently as 15 years ago, the increasing age of the infrastructure, increasing needs for immediate maintenance, over the past few years, environmental regulations have become the single most influential force affecting the bridge painting industry; specifically, the regulations regarding the VOC content of protective coatings and the environmental and worker health and safety regulations associated with the removal of lead-containing paint have had a significant impact on the bridge painting industry.(*888*)

Table 16: Regulations Impacting the Bridge Painting Industry

Impacting Regulation	Effect on Coating Operations
OSHA; CFR 29 1926.62, Lead in Construction	Establishes guidelines for protection and monitoring of workers removing lead paint from bridges. Requires lead training and monitoring for workers.
EPA; Resource Conservation and Recovery Act (RCRA)	Regulates the handling, storage, and disposal of lead (and other heavy metals) containing waste. Can increase the cost of disposal of waste from bridge paint removal by 10 times.
EPA; Comprehensive Environmental Response Compensation and Liability Act (CERCLA or Superfund)	Assigns ownership of and responsibility for hazardous waste to the generator “into perpetuity.”
EPA; Clean Water Act	Regulates discharge of materials into waterways.
EPA; Clean Air Act Amendments	Mandates restrictions on allowable volatile-organic- compound (VOC) content of paints and coatings. Regulates discharge of dust into air from bridge painting

The impact of regulatory compliance has spurred a shift in focus to achieving long-term effectiveness for the dollars spent, both to maximize the return on DOT investment and minimize environmental impacts. A number of FHWA research projects with regard to bridge coatings have addressed the life-cycle cost issue in detail. Research on the removal of lead-containing paint considered the relative cost increases associated with changing regulations that deal with removal and handling of hazardous debris during bridge maintenance painting operations. Research on environmentally compliant materials and testing of low volatile-organic-compound (VOC) coating systems focused on the relative cost/benefit of the durability of various paint systems based on performance data and relative costs of material and application. Materials testing projects — such as those on Performance of Alternative Materials in the Environment, Comparison of Laboratory Testing Methods for Bridge Coatings, and Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges — have had a direct influence on regulatory development and the development of measures for compliance by bridge owners. These projects provided critical, long-term performance data for many new, environmentally compliant bridge paint materials and provided justification for bridge owners to move away from technologically old, lead-containing paints to new, more durable formulations that contain little or no toxic pigments and significantly less solvent. A project on Issues Impacting Bridge Painting, performed an extensive life-cycle versus initial-cost analysis for various bridge painting scenarios and presented results in a spreadsheet program, to facilitate comparison of the various maintenance painting options based on a life-cycle cost analysis. The projects Performance of Alternative Coatings in the Environment (PACE), Environmentally Acceptable Materials for the Corrosion Protection of Steel Bridges, Effects of Surface Contaminants on Coating Life, Maintenance Painting of Steel Bridges, Issues Impacting Bridge Painting, Methodology for Evaluation of Corrosion Control Coatings, and Comparison of Laboratory Testing Methods for Bridge Coatings have had aspects that addressed the need for higher quality and shorter term coating-durability data. Common findings of these programs with respect to cost considerations were: (*889*)

1. The relative cost of paint material is almost always insignificant when viewed in terms of the overall cost of the bridge maintenance job; and
2. The advantage in the relative durability of the better coating systems often far outweighs the nominally increased cost of these materials at the time of application. In general, for moderately to severely corrosive environments, the most durable options in the coating material and in the surface preparation system will be the optimum choices from a life-cycle cost standpoint.

Guidance and Specifications for Bridge Painting, Coatings, and Removal

Some states routinely involve state and federal environmental regulators in bridge painting design to help them satisfy the regulations. This has reduced compliance problems, cost increases associated with contractor force account work, and time delays; however, environmental regulators look for transportation agencies to come to them with good bridge painting plans and specifications. They are often reluctant to suggest specific methods and techniques, because it could compromise their regulatory role in the event of pollution problems. The FHWA website, allows searches of specific state highway agency specifications using key words such as paint, coatings, and recycling. The site has a discussion feature to facilitate questions. Also, the FHWA users guide and spreadsheet, *Cost Effective Alternate Methods for Steel Bridge Paint System Maintenance-Cost Model Users Guide* (FHWA Contract No. DTFH61-97-C-00026), can be used to evaluate cost effective bridge painting approaches. DOTs often use multiple factors such as adhesion test results, structure life, maintenance needs, layers of coatings, costs, and available funding to make bridge painting program decisions.

The FHWA Publication No. FHWA-RD-94-100, *Lead-Containing Paint Removal, Containment, and Disposal,* provides information on the environmental and health regulations affecting the removal of lead-containing paints from steel bridges and includes a guide for waste reduction, control and disposal of the hazardous material generated by bridge paint removal operations. NCHRP Synthesis 251: Lead-based Paint Removal for Steel Highway Bridges and NCHRP 257: Maintenance Issues and Alternate Corrosion Protection Methods for Exposed Bridge Steel are earlier publications that remain valuable resources. Society for Protective Coatings (SSPC)

Guide 6 (Containment design) and SSPC Guide 7 (Environmental monitoring) contain state-of-the-art guidance.

Metallizing

As a result of life cycle cost analyses, a few states have begun to explore metallizing as a coating option. Metallizing is a term used to describe thermal sprayed metal coatings. For corrosion control coatings on steel structures, metallizing refers to the thermal spraying of zinc or aluminum alloys as a coating directly onto steel surfaces. The coatings are created by using a heat source (either flame or electric-arc) to melt the metal which is supplied as a wire or in powder form. An airstream sprays the molten metal onto the steel surface in a thin film. Once the metal strikes the steel it resolidifies to become a solid coating. Metallized coatings provide corrosion protection to steel by sacrificial and barrier protection. The coating itself provides a barrier between the environment and the steel surface, especially when applied in combination with conventional sealers as topcoats. Due to the electrochemical reaction between steel and zinc or aluminum in an aqueous and salt-contaminated environment, these coatings tend to "sacrifice" themselves to protect the steel at the site of any damage in the coating. This sacrificial protection is similar to the protection provided by zinc-rich primers or galvanizing. According to the Turner Fairbank Research Ccenter, metallizing has been reported to be highly effective in numerous research projects and in observation of historical applications.*890* Many reports have proclaimed that a metallized structure will last 25 to 40 years with no need for maintenance touch-up. This greater life expectancy and higher effectiveness brings a higher initial cost, but a potentially lower long term cost. A project recently completed by the Illinois Department of Transportation (IDOT) incorporated metallizing technology as an experimental feature. For this project, the structural steel was metallized in the shop then transported and erected in the field. There have been several bridge rehabilitation projects around the country which have had metallizing done in the field on existing steel, but only a few have been completely metallized in the shop. The production rates, cost concerns, logistics, handling and construction issues were examined in this study in order to assist in determining the feasibility of and issues involved in using metallizing in shop applications. The project was considered successful and equipment advances enabled metallizing to be done much faster than in the past. The project illustrated that under life-cycle costing, metallizing can be advantageous despite its cost, on this project, of $9.18 per square foot versus $2.00-$2.50 per square foot for painting.(*891*)

Overcoating

As an alternative to removal, some toxic based paint is in a condition that permits an overcoating of paint to effectively contain the toxic material and protect the steel. Critical variables which determine the success or failure of an overcoating job include: the condition of the existing paint, the extent of corrosion on the substrate, the level of surface cleanliness achieved, and the environment of exposure. A recently completed FHWA-sponsored study of various overcoating materials applied to bridge structures in various parts of the country resulted in the following general results: (*892*)

- Multicoat systems, overall, performed better than single coat systems, with three coat systems showing generally better performance than two coat systems. This result is thought to be directly related to the occurrence of pinholes during brush application of maintenance coating materials; however, it shows a measurable benefit of the application of multiple coats in a realistic scenario. Other studies have shown similar results.

- Coating materials performing well in the study were three-coat moisture-cured urethane systems, and three-coat epoxy based systems using a penetrating low-viscosity sealer as a primer. In addition, two separate three-coat low-VOC alkyd systems performed well. Of the single coat systems, the coatings based on calcium-sulfonate alkyd resins did best. Similar generic results have been found by other investigators.
- In general, coatings that did well at any one test site did well at all four, diverse test sites (indicating some measure of surface tolerance, or "overcoating acceptability" for specific paint materials). Those materials that failed badly and early at any one site generally failed at more than one site. This would lend support to the use of patch tests as screening for acceptability of a particular overcoating material on a particular structure.
- In the subject testing, failures were of two varieties, 1) early coating disbondment due to incompatibility of the overcoating material with the existing paint, and 2) rust through of the newly applied overcoating material at areas where the coating is over bare steel or existing rust.

The performance of a newly applied overcoating is highly dependent upon the condition of the existing coating over which it is applied. Overcoating over existing aged paints that are often brittle and loosely adherent can pose risks of early failure and large scale disbondment. The applied overcoat applies added stress by adding physical weight to the existing coating, shrinkage during drying, different expansion and contraction rates between two different paint systems with ambient temperature cycles, and softening of the existing coating due to solvents in the overcoat. The following steps can minimize this risk: (*893*)

1. Prior to deciding to overcoat a particular structure, assess the condition of the existing steel and paint system. Condition can include extent and distribution of rusting, and adhesion. The extent of metal loss due to corrosion and the extent and distribution of paint breakdown are important in determining the scope of the work required to clean and overcoat the structure. Paint failure confined to specific definable areas is easier to clean and overcoat than general paint failure over the entire structure. Adhesion should be assessed using either standard test methods (ASTM D4541 or D3359) or by attempting to cut and lift the coating with a knife blade. If the coating lifts easily or crumbles at the tip of the knife blade, then application of overcoating paints should be considered high risk.
2. Conduct a representative patch test of the new material over the existing material using representative maintenance painting practices. Allow this patch to weather several seasons and assess the compatibility of the systems. Research has shown that reasonably good performance is achievable with various different overcoating materials. A patch test will help eliminate coatings grossly incompatible with the existing paint on the structure.
3. Where possible, consider using coatings similar to those currently on the bridge. Some investigators have seen good results from the application of newer, but generically similar alkyd coatings over older existing alkyd coatings. Some of the older technology coatings may present a compromise in overall durability when compared to newer coating materials, but in a maintenance mode, the compatibility of these materials is a definite advantage.

After the existing paint has been sampled and a plan of action developed for an appropriate paint system, spot painting can be performed by maintenance staff using the following guidelines: (*894*)

- If the paint has not been proven to be lead/chromium/cadmium free, treat it as if it were hazardous and brief personnel accordingly (refer to OSHA pamphlet 3126).
- Personnel removing the paint should wear coveralls, gloves, goggles, and a certified, properly fitting respirator for protection.
- Ensure a containment system is arranged to catch and retain all the paint removed.
- Apply an approved chemical paint remover on the desired area and allow it to stand.
- Remove the paint with hand tools or scrapers that do no not cause the paint particles to become airborne.
- Dispose of hazardous paint at the nearest district headquarters yard at the hazardous waste site in the area marked for toxic paint. Inform district personnel.
- Prepare and clean the now paint-free surface and repaint the area with an approved paint.
- Ensure that personnel do not eat, drink or smoke until they are finished and have washed and properly disposed of all contaminated tools and clothing.
- Cracks in any bridge component should be evaluated and corrective action taken. A crack in any steel component must be promptly reported to the Bridge Engineer and corrected per recommendation. Cracks in wood or concrete should be evaluated first and then cleaned and sealed with an appropriate crack sealant. Larger cracks in concrete should be sealed with polymer or epoxy based sealants. Small shrinkage cracks and all concrete surfaces where the concrete is not a specialized or high density concrete such as latex modified or silica fume concrete should be treated with a silane based sealant.

Painting operations generate dust, solvent fumes, and noise. Every effort should be made to minimize the impact of these operations on the surrounding community.

Inspecting the Structure and Preparing Equipment

- Inspect the structure paying particular attention to areas of localized rust because these are the areas that have shown to be prone to premature coating failure. Extra effort should be made to ensure that both the proper degree of surface preparation and the proper coating thickness are achieved in these areas. The presence of mill scale under the existing paint indicates a potential need for additional surface preparation. If mill scale is observed and abrasive blasting is not specified, the project Engineer should be notified since abrasive blasting may be required.
- Inventory, inspect, and calibrate the equipment.

Surface Preparation

Proper surface preparation and proper paint application are the two most important factors needed in a high quality job that will avoid peeling paint and future environmental contamination. It has been estimated that 75 percent to 80 percent of all premature coating failures are caused, partially or completely, by deficient surface preparation and/or coating application.(*895*) Cleanliness is essential since the presence of oil, grease, dust, or soil prevent the paint from bonding. Mill scale, rust, and the existing paint may increase the chance of failure of the new coating. Clean surfaces must have an appropriate anchor pattern (surface roughness). This roughness helps the new paint to mechanically bond to the surface, promoting adhesion.

The Society for Protective Coatings (SSPC) has developed a nomenclature for the different types of surface preparation methods. Best practices for each are noted in a bulleted list following description of the SP level practice. FHWA has two studies that speak to this issue.(*896*)(*897*)

Hand Cleaning

SP-1 - SP-1 denotes "solvent" cleaning and can refer to solvent wiping, water washing, or steam cleaning. The surface is cleaned to remove oil, grease, etc. This must be done prior to ALL other cleaning operations as some final surface preparation methods will actually force the contaminants into the steel, which can lead to poor bonding and premature failure.

- Clean, lint-free rags and clean solvent should be used to avoid the spreading of contaminants.
- Once the contaminants have been visibly removed, a final wiping should be done with clean rags and solvent.
- Workers should wear goggles, protective clothing, rubber gloves, and petroleum jelly on exposed body parts and should be equipped with appropriate respirators to avoid hazardous fumes.
- Benzene and carbon tetrachloride are poisonous and should not be used as solvents and neither should materials with low flash points such as gasoline, methyl-ethyl ketone (MEK), and acetone. Consult the Materials Safety Data Sheet to determine the specific hazards and protection procedures to be followed for the solvent being used.

SP-2 - SP-2 denotes hand tool cleaning. Hand tools are used to remove loose mill scale, loose rust, loose or otherwise defective paint, weld flux, slag, and spatter. This is done by brushing, sanding, chipping, or scraping the surface. Tools used include wire, fiber, or bristle brushes, sandpaper, steel wool, hand scrapers, chisels, or chipping hammers. Tightly adhering rust, mill scale, and paint are allowed to remain. This method is generally confined to small areas.

- Verify that the level of cleanliness noted in SP-1 has been achieved. Pay particular attention to the problem areas such as the top side of bottom flanges, the backside of nuts and bolts, the interior of box beams, and those areas where climbing is difficult and access is limited.

SP-3 - SP-3 denotes power tool cleaning. This is very similar to SP-2 except that power tools are used instead, thus making this a more viable and efficient cleaning method for larger areas.

- Check that the power tools have not placed any oil or grease back onto the surface. If they did, the surface should be re-cleaned per SP-1.
- Paint, rust, or millscale that can be removed with a hand scraper should not remain after a proper SP-3 surface preparation. A "dull putty knife" can be used to assess the acceptability of the surface.

SP-11 - SP-11 denotes power tool cleaning to bare metal. This method uses power tools to remove ALL paint, rust, and millscale and to roughen the surface to promote paint adhesion. SP-11 offers performance advantages over SP-2 and SP-3, which result in an irregular surface of bare steel, rusted steel, mill scale, and paint but it tends to be quite expensive because of the labor involved.

Blast Cleaning

Blast cleaning is the most effective method for surface preparation is blast cleaning. Blast cleaning is broken down into four levels according to the desired condition of the base metal. Blast cleaning does not get rid of oil and grease, which is done by solvent cleaning.

There are many types of abrasive on the market. Recyclable abrasives have gained popularity in recent years because their use can reduce waste handling and disposal by 90 percent.

Blasting Using Recyclable Abrasive

In this system the abrasive is accumulated after usage, cleaned, and reused more than one time. Recyclable abrasives must be hard and durable. Thus metallic material is typically used, and typically requires special equipment to collect, classify, separate, and convey collected waste residue. Also, since the abrasive is harder, contractors must pay close attention to abrasive gradation to keep a cleaned surface profile within acceptable ranges. A contractor must closely monitor the separation process. It is important to completely remove all fine material from abrasives. If the abrasive is improperly or incompletely cleaned, dust concentrations within the containment can be adversely affected.

Several methods are available in the industry to filter discharged air from the system. Often systems using water for blasting or water filters to remove particulates are not acceptable as the water then becomes another different waste for disposal; however, MDSHA uses a pressurized filter system to remove particles from bridge cleaning waste water. The Golden Gate Bridge Authority in the San Francisco Bay area uses filters to remove particles from bridge painting waste water.

As with all open blasting operations, the recycled abrasive method must be fully contained. Costs associated with recyclable abrasive include additional equipment and increased initial abrasive costs. This is offset by increased cleaned surface area per unit of abrasive (some times up to 100 cycles) and reduced volume of waste produced.

The Missouri DOT has developed a model recycling program for abrasive lead blast. MoDOT no longer does abrasive blasting with Department forces; the agency has tried to create incentives for contractors to develop cost saving techniques and technologies for recycling its abrasives. All MoDOT bridge painting waste containing lead collected by Department crews is taken to lead smelter for recycling.

Closed Abrasive (Vacuum) Blasting

Closed abrasive blasting or vacuum blasting allows dust, abrasive, and paint debris to be vacuumed simultaneously with the blasting operation. Debris is separated for disposal and the abrasive is returned for reuse. Typically, hard metallic abrasives are used for this system.

Vacuum blasting equipment is expensive; however, both worker exposure to dust and environmental emissions can be minimized if operations are conducted properly. Special Provisions may allow vacuum blasting to be conducted without requiring full containment. Once again, systems that uses water or water filters cannot be used. Vacuum blasting is limited by its reduced production rate and operational problems cleaning edges and irregular surfaces. To be completely effective, the whole nozzle assembly must be sealed against a surface to maintain proper suction for the vacuum operation.

Shrouded power tool technology has proven an effective engineering control that effectively prepares structural steel for new coatings, while simultaneously controlling all emissions in excess of 99.5 percent. On the Woodrow Wilson Bridge outside of the District of Columbia, this eliminated the need for containment and respirators and reduced the potential for lead poisoning to the environment or workers in the first place. These DOE, EPA, OSHA, and HUD-tested and approved tools utilize a mechanical, air-driven process that cleans surfaces to a bare substrate, while a High Efficiency Particulate Air (HEPA) filtered vacuum collection unit, the VAC-PAC, simultaneously captures dust and debris and transports it into an on-board 55-gallon drum. The Pentek system offers a fully integrated deleading system that removes, collects, drums, and seals the waste in a single step process for safe disposal. The shrouded power tools allow the workers to prepare the structural steel to a bare metal finish comparable to a Steel Structures Painting Council SP 6 specification, Commercial Blast Cleaning. Pneumatic-powered rotary scalers and needle guns are being operated simultaneously--the former for the rapid deleading of large, flat surfaces and the latter with adjustable shrouds and pivoting head for access to hard-to-reach areas, such as around bolts and angles, or in corners. Fifty-foot vacuum hoses attached to the tools convey all removed dust and debris down to the HEPA-filtered vacuum and waste collection unit, which is stationed on the deck of a barge below. The 100 percent mechanical coatings removal system minimizes the amount of waste for disposal, as well as the degree of the owner's liability and disposal costs, by adding nothing to the waste stream and collecting only the dust and debris of the coating itself. A typical lead abatement project employing Pentek's system deposits 2,500 square feet of surface in a single waste drum. An independent company conducted air quality monitoring for the project with personal sampling and high volume environmental monitors, which were placed strategically at the site. Two separate air readings with the high volume environmental monitors were conducted six weeks apart, one on land and one on the barge. The efficiency of the dustless power tool system was verified by air sampling results of two to three micrograms per cubic meter, far below both OSHA's Permissible Exposure Limit of 50 micrograms per cubic meter and the action level of 30 micrograms per cubic meter per eight-hour exposure limits.(*898*)

Figure 15: Shrouded Power Tools

SP Levels of Blast Cleaning and Associated Practices to Avoid Current and Future Environmental Impacts

The following methods are presented in order of ascending cleanliness (i.e., SP-5 is most clean):

SP-5 - SP-5 denotes white metal blast cleaning. This level of cleaning is costly and is rarely specified for use on bridges.

- The resulting surface should be free of oil, grease, dirt, rust, mill scale, all paint, and foreign matter leaving only a uniform grey-white color.

SP-6 - SP-6 denotes commercial blast cleaning.

- The resulting surface should be free of oil, grease, dirt, all rust, mill scale, paint, and foreign matter (except for slight shadows, streaks, or discolorations caused by rust stains, mill scale stains, and tight residue of previous coatings).
- At least two-thirds of each 150-cm² (9 in²) area must be free of all visible residue and the remainder limited to those discolorations just mentioned.

SP-7 - SP-7 denotes brush off blast cleaning.

- The resulting surface should be free of oil, grease, dirt, loose mill scale, loose rust, and loose coatings, retaining only tightly bonded mill scale, sound rust, and previous coatings.

SP-10 - SP-10 denotes near-white blast cleaning.

- The resulting surface should be free of oil, grease, dirt, rust, mill scale, paint, and any foreign matter (leaving only slight stains from rust and mill scale).
- At least 95 percent of each 150-cm² (9 in²) area should be free of all visible residue with the remainder limited to slight discoloration.

SP-12 – SP-12 is the standard for pressurized water blasting.

The most common surface preparation specified for bridge use is SP-6, which requires SP-1. When repainting an existing structure, the Specifications may call for SP-2 or SP-3 in areas of limited accessibility. Recent research indicates SP-10 may be more cost effective than SP-6, particularly in more corrosive environments. Inspection should verify that both the proper level of cleanliness and the proper anchor pattern have been achieved.

Blasting operations require that several additional checks occur. The contractor's equipment and material must be checked along with the resulting anchor pattern.

- **Inspection of the Abrasive** - The contractor will select the abrasive to be used based on the specified anchor pattern. The chosen abrasive should be free of toxic heavy metals such as lead, chromium, and cadmium and should not contain any free silica (sand) either. A sieve analysis from the abrasive supplier should be requested prior to delivery of the first load of abrasive.

  Once the abrasive is on site, obtain a sample of the stored abrasive material. It should be stored in a dry environment and should be clean, uniform, and free of any sign of moisture. To check, drop some of it into deionized water and shake. Watch for a film of grease or oil indicating the presence of contaminants. Keep a small sample of abrasive from each subsequent delivery. This will allow for a future analysis in the event that changes occur in the anchor pattern.
- **Inspection of the Air Supply** - This is necessary to ensure that the air supply is not introducing neither contaminants that will be embedded in the steel nor oil or water into the system. Inspect the air compressor for contaminants. The compressor should have moisture and oil traps on all lines. Shut off the flow of abrasive. Place a white blotter cloth in the air flow. It should be placed approximately 0.6m (24 inches) from an outlet downstream from the oil separator and moisture traps. Let free air flow for two minutes. Check for visible contaminants in the air flow; if there are any, corrective action is needed. This test should be repeated every four hours or more frequently when the humidity is high.

- **Blasting Pressure** - The blasting pressure should be at least 620 kPa (90 psi); any less than this can result in a lower anchor pattern and in slower production. However, jobs that use recyclable steel grit often use higher pressures. All high pressure air supplies and devices should be gauged for easy reading. For blasting, the critical pressure is located at the end of the blast nozzle. This pressure will be lower than that measured at the air supply due to loss in the hose. Hence, limiting the length of air hose is often a critical factor in the efficiency of a blasting operation. A pressure needle gage may be used at the nozzle to measure the true blast pressure.
- **Inspection of SP-6 and SP-10** - Once again, verify that the level of cleanliness noted above has been achieved including the referenced problem areas. The individual DOT Specification may provide a set of visual standards from either the National Association of Corrosion Engineers (NACE) or the Society for Protective Coatings (SSPC) to aid in this effort. Interpretation of the visual standards can take some discretion as well as some practice. Both SP-6 and SP-10 standards require the removal of ALL paint, rust, and mill scale. The only difference is in the amount of staining allowable on the bare steel surface.
- **Inspection of the Anchor Pattern** - The anchor pattern needs to be checked to ensure that proper paint adhesion will occur. Profile inspection requires the use of a micrometer and replica impression tape. Comparison coupons can be used for a qualitative visual comparison of the profile.

Monitoring

Air and soil monitoring are becoming more common on lead removal jobs. Monitoring protocols differ, and there is no current consensus on what should be done in this area. FHWA's study tour on Bridge Maintenance Coatings Environmental and Worker Protection Practices reportedly uncovered no requirement or specification for environmental air monitoring for sources other than stationary sources, and bridges are not considered stationary sources; environmental air monitoring requirements for abrasive blasting of lead-containing paint from bridges and other structures were not encountered in the U.S. or Europe, despite increasing ambient monitoring for total lead in dust and particulate size (PM10) in the U.S. Nevertheless, many state DOTs, as well as numerous city and local authorities require environmental air quality monitoring for abrasive blasting operations as part of their specifications and policies.*899* FHWA's study notes that current FHWA research could lead to "more reasonable and applicable protocols for environmental monitoring during bridge-painting operations."(*900*)

FHWA's study found that soil lead level monitoring before, during, and after the project is usually required. The Swiss have noted that as much as 70 micrograms of lead per m^2 per day may be deposited during movement and teardown of containment systems. Allowable levels of total lead in soils were found to be as low as 50 ppm. In the U.S., some states are requiring pre- and post-job soil monitoring for lead contamination, but the requirement is not universal. Characterizing the contamination level of soils surrounding bridge job sites and especially the specific source of lead in any one location is difficult at best. Field monitoring and research is currently underway to attempt to better define appropriate soil-sampling protocols.(*901*)

- Soil sampling near and under containments is generally a good idea from a liability standpoint. Check for signs of surrounding ground or water contamination.
- Air monitoring becomes more important if sensitive public access is nearby.

Paint Selection, Storage, Handling, and Mixing

- **Use paints with maximum useful lifetimes**, where toxicity is acceptable, not lowest cost, to maximize the time between repainting.
- **Verify that the paint has not exceeded its shelf life**. Shelf life is the length of time, from date of manufacture, that a paint will remain usable when stored in its can. Consequences of exceeding the shelf life include: gelling, odor, changes in viscosity, formation of lumps, pigment settling, and color and liquid separation.
  - Check the date printed on the can with the shelf life to make sure the paint has not "expired." Some suppliers use a special code on the can which contains the date of manufacture. It may be necessary to call the supplier to read the code and assure that paint is fresh. Two-component paint systems often have a different shelf life for each component.
  - If the contractor desires to use this material that has exceeded its shelf life, he/she may submit a sample to the manufacturer's laboratory for analysis and possible re-certification. The contractor should not be allowed to use the material in question until written certification is received from the manufacturer.
- **Follow good storage practices and verify that the paint is not stored in areas subject to temperatures beyond the recommended limits.** Going beyond the acceptable temperature range can cause changes in viscosity and shelf life. Water-based paint will spoil when stored below freezing. Solvent-based paint, on the other hand, may gel or become flammable or explosive when stored at high temperatures.
  - The contractor's storage site should be monitored with a high/low thermometer. Contractors often like to store the paint on site in a trailer. This is generally not a good idea because these trailers tend to get very hot during the summer and have limited ventilation. Paint should be stored in a climate-controlled environment.
  - Each lot of paint should be stored together.
  - Two-component systems should be stored close to each other, but be distinguishable from one another.
  - If the paint will be stored over several months, the cans should be inverted at monthly intervals to avoid excessive settlement and ease future mixing.
  - When opening the paint, the oldest paint should be used first. Look for signs of aging listed under shelf life.
  - Note the required temperature range for proper storage. Adherence to the temperature requirements noted on the Product Data Sheet is essential.
- **Verify that pot life has not been exceeded.** Pot life refers to the length of time a paint is useful after its original package has been opened or, for two-component systems, the length of time after it has been mixed. Pot life is temperature dependent. The pot life on the Product Data Sheet is generally for 21 C (70°F). Contact the manufacturer for additional pot life information if the paint has been stored in temperatures outside of this general range. Exceeding the pot life can result in sagging of the fresh paint along with poor performance attributable to film porosity and/or poor paint adhesion. Two-component paints tend to become unworkable at or beyond their pot life.

- **Ensure proper mixing and use of thinner.** Different paints have different mixing requirements. The instructions on the Product Data Sheet should be strictly followed. Thinner is a liquid added to the paint at the time of application to modify its viscosity. The Product Data Sheet will indicate the specific type and maximum amount of thinner to be used.
    - Upon opening the can, check the surface of the paint for "skinning over" of the paint. Any skin should be removed prior to mixing.
    - All paint must be thoroughly mixed in a clean container.
    - Check the bottom of the original can for evidence of unmixed pigment.
    - For two-component paints, verify that they are mixed in the proper proportion. The mixing operation should be witnessed and documented.
    - Unused paint that will be used the next day should not be left in buckets or spray pots. It should be placed in a container and re-mixed prior to use.
    - Thinner should be used only to achieve optimum viscosity for proper application and is not always necessary. Do not exceed recommended maximum use.
    - Witness and document each and any addition of thinner. Adding too much thinner can prevent proper application thickness and cure of the paint and may result in the mixture exceeding acceptable limits for volatile organic compounds (VOCs).
- **Verify drying and curing times.** Drying time refers to the length of time a coating is sensitive to local damage. Curing time refers to the length of time it takes for a paint to reach structural integrity and be ready for service. The drying schedule on the Product Data Sheet will show how long it takes until the paint is dry to the touch, dry to tack free, and dry to recoat. Dry to the touch implies the paint won't collect dust; tack-free implies the paint does not feel sticky and can be handled without damage; dry to recoat implies the time needed to dry until the next coat of paint can be applied. Drying times vary significantly with temperature. This is particularly important in determining when the next coat of paint can be applied. Recoating before enough time has passed can seriously affect the curing and integrity of the layer being overcoated. Some paints, particularly two-component paints, have a maximum time to re-coat as well. Exceeding this could jeopardize the adherence of the top coat.
    - After painting, inform the contractor of the estimated time that should be allowed for the paint to cure. Do not allow another coat to be put on until the appropriate amount of time has elapsed per the existing weather conditions.
- **Carry out storing, mixing and cleaning operations on land.**
- **Transport paint and materials to and from job sites in containers with secure lids** and tied down to the transport vehicle.
- **Do not transfer or load paint near storm drain inlets or watercourses.**
- **Test and inspect spray equipment prior to starting to paint.** Tighten all hoses and connections and do not overfill paint container.
- **Plug nearby storm drain inlets prior to starting painting** where there is significant risk of a spill reaching storm drains. Remove plugs when job is completed.

- **Cover nearby storm drain inlets prior to starting work** if sand blasting is used to remove paint.
- **Perform work on a maintenance traveler or platform, or use suspended netting or tarps to capture paint, rust, paint removing agents, or other materials**, to prevent discharge of materials to surface waters if the bridge crosses a watercourse. If sanding, use a sander with a vacuum filter bag.
- **Capture all clean-up water, and dispose of properly.**
- **Recycle paint when possible (e.g. paint may be used for graffiti removal activities).** Dispose of unused paint at an appropriate household hazardous waste facility.
- **Keep all materials securely locked up, to avoid vandalism and accidental spills into the watercourse.**(*902*)
- **Hold a pre-painting meeting with the contractor**, addressing the following issues. Minutes should be kept and a copy should be given to all meeting participants, documenting understandings and any agreements reached.(*903*)
    - The nature of the work and its effects on the surroundings, including possible mitigation measures.
    - Contractor's method of operation, including equipment and personnel.
    - Contractor's schedule. Discuss weather-related concerns.
    - Contractor's job-specific worker health and safety plan (if lead paint is present).
    - Proper storage of material and equipment.
    - Location of recycling and dust collection and storage equipment.
    - Inspector safety, including provision of safe access and safety from lead contamination.
    - Inspection and measurement procedures, including control points.
    - Identification and treatment of inaccessible areas.
    - Product Data Sheets and Materials Safety Data Sheets for all relevant materials.
    - Visual standards to be met. Discuss contractor's preparation of field reference sections.

Containment and Use of Enclosures

Lead was a common component of industrial paints until the 1980s, and many of the steel bridges in the highway system are still coated with paint that contains up to 50 percent lead by weight. High lead-containing primers can often be identified by their red or bright orange color. However, not all red and orange paints contain lead, and some paints of different colors can contain a significant amount of lead. Lead is hazardous to humans if it is inhaled or ingested and a relatively small amount of ingested or inhaled lead dust can elevate a person's blood lead level. Proper respiratory protection should be worn to protect against lead hazards. "Proper" protection consists of either air-fed, positive pressure respirator hoods (as worn by abrasive blasters), or negative pressure, filter-cartridge respirators. Filters should be color-coded bright pink for fine dust particulate (i.e., HEPA filters). The required level of respiratory protection depends on the concentration of lead in the breathing air, and on the amount of time the worker is exposed. For most short-term inspections of jobsites without ongoing blasting, or outside of containments, a half-mask with appropriate HEPA cartridge is enough. However, while inside of containments during or immediately after abrasive blasting, an air supplied hood is likely to be required.

A containment system, or enclosure, is needed to prevent both lead and other debris generated during surface preparation activities from entering the environment and to facilitate its gathering and disposal. Enclosures are generally made up of combinations of cover panels, scaffolds, supports, screens, and tarps. The complexity of any given enclosure will vary depending on the method of paint removal being employed and the degree of surface preparation that is specified. For a simple scraping operation ground-covering tarps may be sufficient while for a blasting operation, the enclosure could be a designed structure with a negative pressure ventilation system.

Containments for abrasive blast (and other paint removal) operations are designed to protect the surrounding environment and the public from debris (flying abrasive) and potentially hazardous material (lead-containing dust) during a paint removal operation. In addition, these containment structures are intended to help contain and collect the lead-containing debris for proper treatment and disposal.

As the use of containments for paint removal jobs has become more common over the past several years, the design of containment structures has evolved. Currently, there are standard features of each containment method, but in large part, containments are custom-designed for each bridge job. The standard features are described in detail in the "SSPC Guide 6 - Containment." This guide is not all inclusive, but it is the industry standard for description and classification of paint removal containments. In addition, several States have their own classification systems, but most of them are somewhat similar to those in the SSPC Guide 6.

It is important to remember that the purpose of a containment is to do a conscientious, "state-of-the-practice" job in containing and collecting debris. With appropriate specifications, and designs, and a cooperative effort between the owner and contractor, very near 100 percent containment and collection of debris can be approached.

Containment of abrasive blast jobs involving lead are mandatory because the law requires collection of the hazardous waste. While there is no specific rule governing the "fugitive emissions" of lead-containing dust, this dust can be controlled by designing and maintaining the containment and ventilation system properly.

Bridge maintenance involves the installation of safety nets, tarps, enclosures, barges or other means to catch paint chips and removed debris, water and abrasive blasting to remove old paint, rust, grease etc., application of rust inhibitors, primer paint (zinc, aluminum or lead), mid-coat paint (epoxy, vinyl or lead) and final coat (epoxy, polyurethane, vinyl or lead). All of these activities and products are detrimental to aquatic life in the stream below and need to be prevented from reaching the stream.

Components of a Containment System

Containment System Structure - Containments can be scaffolded from the ground or rigged to hang from the bridge structure. The key issues to consider are structural integrity under wind load, abrasive waster load, and dynamic loads on the bridge. Access, air movement, and visibility should also be considered.

- Use custom built enclosures to confine and capture the abrasives, old paint chips and paint where possible.
- Erect shrouds around working areas and suspending nets and tarps below bridges to catch debris from abrasive removal of old paint and over-spray from painting, where wind conditions permit. The work area should be clearly distinguishable from the surroundings.
- Anchor tarps to barges below and enclosing the bridge above to confine debris, where the bridge deck is not too far above water level. Using barges and booms to capture fugitive floating paint chips and debris netting is not adequate.
- Tarps should be overlapped with seams fastened and should be in good condition and free of holes.
- During blasting operations with negative pressure, the tarps should have a concave inward appearance. They should never appear to bulge during blasting.
- The containment should be tightly sealed to prevent any dust from escaping. Continually evaluate and/or perform field checks on the effectiveness of any containment. Watch for signs of dust escaping the containment and/or dust being discharged from exhaust system. Check the ground around the containment.
- The containment must also be able to support workers, construction loads, spent abrasive loads and wind load without placing undue stress on the bridge.
- The containment should be constructed in accordance with the approved plan.
- Use vacuum or suction shrouds on blast heads to capture grit and old paint where possible.

Ventilation - For work inside an enclosure air movement is necessary to avoid a build-up of dust. High dust concentrations impair visibility and increase hazardous exposure levels to workers. Without ventilation, workers and inspectors will not be able to see within minutes of blasting commencing. Ventilation also reduces the concentration of lead-dust in the work environment and makes clean up operations prior to painting easier.

Check for air movement with an anemometer, or get a rough idea of the amount of airflow by using a smoke bomb. Air movement is dependent upon the capacity of dust collectors, the volume of air input by makeup fans and blast nozzles, and interferences to airflow caused by the bridge structure itself. Ventilation ducting efficiency depends on the duct diameter and length, and on minimizing the number of sharp bends in the duct.

Location of dust collectors - Airborne emissions are often highest adjacent to dust collectors. While emissions should be minimized, they are unavoidable.

- Dust collectors should be located in areas where emissions will have minimal effect on sensitive surrounding environmental or public areas.
- Dust collectors should be operated at the rated capacity or at a capacity consistent with the ventilation design of the containment system.

Lighting - Proper lighting is often neglected. Inadequate lighting poses obvious safety concerns as it makes proper surface preparation and painting almost impossible.

The potential for escaped lead-contaminated air emissions during blasting operations also warrants the usage by abatement workers of full facepiece respirators operating in positive-pressure mode. Shrouded power tool technology has proven an effective engineering control that effectively prepares structural steel for new coatings, while simultaneously controlling all emissions in excess of 99.5 percent. In other words, the need for containment and respirators is eliminated or drastically reduced by preventing the potential for lead poisoning to the environment or workers in the first place.

Paint Application and Spraying Practices

Once the proper level of surface preparation has been achieved and the quality of the coating system has been verified, the contractor is ready to paint. To prevent "rust-back" of the cleaned surface, the first coat of paint (primer) should be applied as soon as possible (within a few hours) after blast cleaning. Painting should begin at a practical time to avoid weather changes that could cause significant changes in the surface condition of the steel, i.e. nightfall.

Painting just before the onset of poor weather is not advisable. The current and expected weather, along with the curing time of the paint being used, should be considered prior to beginning the application process. To ensure that the paint is applied and allowed to dry and cure under reasonable environmental conditions, the following environmental conditions should be followed every four hours:

- *Temperature* - The Specification will place limits on the ambient temperature to ensure proper curing. Most Specifications will require the temperature to be between 4 C or 10 C and 38 C (40 or 50°F and 100°F).
- *Relative Humidity* - Again, due to of curing requirements, the Specification will limit the maximum permissible relative humidity, which is commonly limited to 85 percent.
- *Dew Point* - Using the relative humidity, determine the dew point. The temperature of the steel should be at least 3 C (5°F) higher than the dew point. This "dew point spread" is used to ensure that no moisture is present on the steel prior to paint application.
- *Surface Temperature* - The surface temperature of the steel should not exceed 52°C (125°F) during the painting process, and, again, it should be at least 3°C (5°F) higher than the dew point.
- *Wind* - Heavy winds can cause problems. Airborne overspray, for example, may be carried onto adjacent houses, cars, etc. and can result in premature drying of the paint. If heavy winds are present, it may be best to delay the painting operation or to restrict spray application.

Debris Storage

The disposal of equipment and materials used to remove existing paint is also expensive. The waste must be placed in storage containers approved by the EPA. The contractor had two options for removing and handling the existing paint. Each option is designed to either make the removed material nonhazardous or reduce the amount of hazardous material generated; depending on the removal technology used, the waste is used as a recycled material or placed in a hazardous-waste landfill after being treated.(*904*)

DOTs should and generally do require all waste generated during removal operations to be sampled and analyzed by the contractor and submitted to a laboratory for Toxic Characteristic Leaching Procedure Testing (TCLP) for eight environmentally regulated heavy metals typically found in paint and abrasive wastes. Paint debris is classified as hazardous due to the characteristic of toxicity, if after testing by TCLP, the leachate contains any of the elements in the concentrations equal to or greater listed levels. Other elements, chemicals, and characteristics can also cause a material to be hazardous as defined in 40 CFR 261, so best practice requires that: (*905*)

- No other waste be mixed with paint waste generated during the cleaning process.
- Accumulated wastes shall not be removed from the temporary storage area without proper documentation.
- For all projects involving the removal of paint wastes, some form of manifesting is required.
- Recycling (off-site) or proper disposal of hazardous abrasive-blast media and use of approved haulers to transfer the contained waste to authorized treatment and/or disposal facilities
- The production of hazardous paint-removal waste should be minimized by the use of recyclable abrasive and the waste generated should be treated by effective methods to ensure its stability in waste containment sites.(*906*)

Lead-contaminated paint waste can be classified as hazardous material. As such, it is subject to strict disposal requirements. The contractor may wish to temporarily store barrels containing this waste on site prior to hauling them to an approved disposal site.

- If the barrels are stored on site, regulations restrict such storage to 90 days. Some entities, such as New York City Transit, voluntarily limit temporary storage of hazardous wastes to 45 days, instead of the allowable 90 days.(907)
- Barrels should be clearly marked as containing hazardous waste.
- The barrels should be stored in a location inaccessible to the public, and they should also be in a location where they are not at risk of being hit by traffic.

The SSPC publication, SSPC 96-06, ISBN 1-889060-02-X, *Guidelines for Cost-Effective Lead Paint Removal-Final* Report includes information about waste testing and disposal. Also, it describes how Kansas DOT has placed bridge painting waste in concrete blocks.

Quality Assurance and Public Outreach Programs

In 2001, Illinois' Department of Transportation (IDOT) revised its overall painting policy along with its environmental and containment specifications for all repainting maintenance. The most significant change in the specifications was related to quality control and quality assurance responsibilities.(*908*) The Kentucky Transportation Cabinet has also been a national leader in the development of a quality assurance for bridge painting and maintenance.

As a proactive quality assurance measure, the Indiana Department of Transportation outline for bridge painting pre-bid meetings, *Specification & Pre-Bid Conference Content Review,* is used by the Indiana DOT environmental and safety professionals to make pre-bid conference presentations. The outline helps InDOT staff ensure that important environmental and safety topics are always presented at these conferences.

Public outreach programs have become a part of bridge painting and lead removal projects. The Port Authority of New York City provides a good example program.

CHAPTER 8: WINTER OPERATIONS AND SALT, SAND, AND CHEMICAL MANAGEMENT

Currently about ten million tons of road salt is used each winter in the United States.(*909*) A 1994 NCHRP report estimated that North Americans spend $20 billion annually on snow and ice control.(*910*) A more recent report by the New England Transportation Consortium estimated that winter ice control chemical application alone, in the U.S. totaled $500 million per year, accounting for one-third of highway winter maintenance expenditures in the United States.(*911*) More effective use of deicer chemical could result in significant economical and environmental benefits.

Much of managing the environmental effects of winter operations comes down to management of salt. Salt contamination has become a growing issue for some state DOTs, which have had to purchase contaminated wells and properties and have had to extend pipes to municipal water systems. In Canada, salt has become more heavily regulated by the federal environmental agency; the Canadian Ministers of the Environment and of Health therefore recommended adding road salts to Schedule 1 of Canada's Environmental Protection Act of 1999. In response, Environment Canada proposed management measures to minimize the impacts of road salt on the environment in late 2003.(*912*)

The Transportation Association of Canada and many US DOTs have begun to develop best practices to minimize salt usage and salt entry into the environment surrounding roads and maintenance facilities. Along with reduced salt usage and the shift to more proactive anti-icing methods, sand usage, water and air quality problems, and roadside vegetation inundation decrease as well. The stewardship practices are compiled to help transportation agencies implement a winter operations program with reduced impacts to the environment from salt, sand, and other chemicals.

The transition to reduced salt usage has been facilitated by great improvements in snowfighting equipment and technology in recent years. Equipment is available to facilitate precise, controlled applications of material, at reduced rates established as a result of extensive research and testing. While much of this new equipment is more sophisticated, durable, and easier to use, the potential benefits can be best realized if maintenance staff are thoroughly trained, material use is closely monitored, and feedback systems are in place. Increasingly, application rates are being tied into sensor based information systems including real time data, weather forecasts, road friction measurements, road surface temperature measurements, and global positioning equipment. As the use of this technology evolves, considerable planning, organization, and evaluation are required to ensure the best use of existing technology.

This chapter on environmental stewardship practices in winter operations will first identify recommended practices for strategic planning for reduced salt usage, and then look at initiatives by leading DOTs, and practices and accomplishments in specific program areas to achieve such reductions and improve environmental outcomes.

8.1. Selecting Snow and Ice Control Materials to Mitigate Environmental Impacts

NCHRP and AASHTO are producing NCHRP 6-16, Guidelines for the Selection of Snow and Ice Control Materials To Mitigate Environmental Impacts, which will be available in 2005. The objective of the project is to develop guidelines for selection of snow and ice control chemicals and abrasives, based on their constituents, performance, environmental impacts, cost, and site-specific conditions. The project will identify and justify methods for measuring the constituents and properties that determine the environmental impacts of the current range of snow and ice control materials, and present this information on available materials and significant properties in matrix format, with purchase specification and quality assurance test protocol for the evaluation of existing and future materials. Environmental impacts to be studied include effects on human health; aquatic life; flora and fauna; surface water and groundwater quality; air quality; vehicles; and physical infrastructure including bridges, pavements, railway electronic signaling systems, and power distribution lines. Guidelines will be developed that incorporate: (*913*)

- A decision-making process for the selection of snow and ice control chemicals and abrasives, based on their composition, performance, environmental impacts, cost and site-specific conditions.
- The matrix of currently available products and their properties.
- The purchase specification.
- The quality assurance protocol.

For the purposes of this report, NCHRP 25-25(04), impacts of various snow and ice control materials and the background for use of recommended environmental stewardship practices are summarized below.

Impacts of Salt and Chloride-Based Deicers on the Environment

Road-salt use in the United States ranges from 8 million to 12 million tons of NaCl per year according to the National Research Council (NRC); Massachusetts, New Hampshire, and New York report the highest annual road-salt loadings, with Massachusetts the highest at 19.94 tons/lane-mile./yr.(*914*) Salt usage and impacts on the roadside habitat, water sources, fish and wildlife, and pavement are growing concerns in North America and abroad. Such concerns in Canada prompted the federal environmental agency, Environment Canada (EC), to conduct a comprehensive assessment of road-salt application to determine whether conventional deicers should be considered toxic substances under the Canadian Environmental Protection Act.(*915*) EC conducted a five-year, comprehensive scientific assessment of the environmental impacts of road salts that contain inorganic chlorides, such as sodium chloride, calcium chloride, potassium chloride, and magnesium chloride. The study found that high concentrations of road salts commonly enter the environment through roadway melt water and through seepage from mismanaged salt storage facilities and snow disposal sites.(*916*) Although not directly harmful to humans, the road salts can have harmful effects on the aquatic environment, plants, and animals.(*917*)

Much of the salt that is placed on a road during snow and ice control operations eventually runs off with the roadway drainage. While sodium may bond to negatively charged soil particles or be taken up in biological processes, chloride ions are less reactive and can be transported to surface waters through soil and groundwater. Road salts applied to roadways can enter air, soil, groundwater, and surface water from direct or snowmelt runoff, release from surface soils, and/or wind-borne spray.(*918*) Deicing salt reaches the natural environment in a number of ways:(*919*)

- Through salting practices in which some of the spread salt lands directly on or bounces onto roadside verges of footways.
- Through salt being thrown to the edge of the road by the action of passing vehicles or by the wind.
- Through dissolved salt running off roads and into drainage systems, which eventually discharge into natural waters.
- Through dissolved salt being splashed or sprayed onto roadside soil, vegetation, and surface waters by passing traffic.
- Through salted snow being blown or plowed onto the roadside by snow blowers or snowplows.

These salts remain in solution in surface waters and are not subject to any significant natural removal mechanisms. Their accumulation and persistence in watersheds pose risks to aquatic ecosystems and to water quality. Approximately 55 percent of road-salt chlorides are transported in surface runoff with the remaining 45 percent infiltrating through soils and into groundwater aquifers.(*920*) In the past, salt storage has led to contamination of local soils and watercourses. According to Hogbin, 0.125 to 02.5 percent of the initial weight of an uncovered stockpile is lost per year by leaching for each inch of rainfall on that stock pile.(*921*)

While wind deposition has received less attention than other areas of salt impact, study results have shown that roadside exposure to airborne salt was related strongly to the wind direction.(*922*) Bulk deposition was collected in a field adjacent to highway E4 in SE Sweden and related to wind characteristics and deicing activities on the road; chloride was shown to be transported several hundreds of meters away from the road and the amount of air-borne chloride deposited in the roadside environment was well correlated to the road-salting intensity.(*923*)

Salinity and chlorine-impaired streams are present in a number of Midwestern and Western states.(*924*) A Nevada DOT-Caltrans study in 1990 concluded that 15 percent of the trees observed along the Lake Tahoe Basin highways within both Nevada and California, were salt-affected, showing evidence of disease, bark beetle infestation, and the effects of four years of drought.(*925*) Roadside trees and other vegetation are affected by salt primarily through two mechanisms: 1) increased concentrations of salt in soil and soil water leading to greater root absorption; and 2) salt accumulation by foliage and branches due to vehicle splash and spray and windblown dry salt. Although deciduous trees have no leaves in winter, they can still be affected by salt spray as dormant twigs intercept the salt, which may reach living tissue by entering twigs through leave scars. In contrast to salt taken up by roots, salt spray rarely causes tree death outright, but annually recurring damage tends to keep the crowns narrow, stems thin, and plants short. Trees close to roads are generally the worst affected. Damage is most severe within five meters of the road but there is frequently a distinct injury gradient with distance; damage is minimal about 30 meters from the road. Trees on the downhill side of a road suffer more damage than those on the uphill side. On high-speed roads where salt spray instead of runoff is the major cause of injury, trees on the downwind side of the carriageway have the greatest injury. (*926*)

CDOT research on the environmental effects of chloride-based deicers found that aodium chloride, magnesium chloride, and calcium chloride may contribute to the mobilization of trace metals from the soil to surface and groundwater, though field evidence is limited. The chloride-based deicers have the potential to increase the salinity of the rivers, streams, and lakes. Since the dilution of deicers from the roadways to nearby streams is estimated to range from 100 to 500-fold, salinity increases are only likely to occur in slow-flowing streams and small ponds. Increased salinity was reported in groundwater at a distance of more than 300 feet from roadways. Damage to vegetation from deicing salts was reported to a distance of 100-650 feet. (*927*)

Sodium chloride crystals attract birds and mammals, which can contribute to road kills. Sodium-deficient wildlife sometimes travel great distances to ingest road salt. Many animals tend to overshoot their salt deficit and then drink salty snow melt to relieve thirst, which increases salt toxicity in blood and tissues.(*928*)

In contrast, magnesium chloride and calcium chloride deicers do not attract wildlife since the main chemical attractant is sodium. Acute toxicity tests show that there is slight oral toxicity of the chloride deicers to small animals.(*929*)

Further study of magnesium chloride deicer by the Colorado DOT and the University of Colorado concluded that application of Mag chloride at current rates is highly unlikely to cause or contribute to environmental damage at distances greater than 20 yards from the roadway. Even very close to the roadway, the study found that the potential of magnesium chloride deicer to cause environmental damage is likely much smaller than that of other factors related to road use and maintenance, including pollution of highway surfaces by vehicles and use of salt and sand mixtures to promote traction in winter.(*930*)

Caltrans found that Magnesium chloride, being a liquid, can be applied in a more uniform manner than granular salt, but must be kept in storage tanks.(*931*) Depending on service conditions experienced by automobile components, $MgCl_2$ is more corrosive than NaCl under humid environments, and NaCl is more corrosive under immersion and arid environments.(*932*)

Colorado DOT's study concluded with the following practice recommendations for Mag chloride: (*933*)

- Mag chloride may offer net environmental benefits if its use leads to a reduction in the quantity of salt and sand applied to roadways as long as concentrations of contaminants remain low and rust inhibitors containing phosphorus are avoided.
- Appropriate specifications for vendors and routine testing can ensure the continued environmental acceptability of magnesium chloride deicers.
- Deicers provided by vendors should be monitored independently by DOTs for chemical characteristics. Any significant changes in processing or source material should be disclosed by the vendor. Independent specifications should probably be developed depending on elevation in the state.

Impacts of Acetate Based Deicers on the Environment

Acetate-based deicers are organic and have different kinds of effects on the environment than the chloride-based deicers. The acetate ions are broken down by soil microorganisms and may result in oxygen depletion of the soil, which can impact vegetation. The acetate deicers also have the potential to cause oxygen depletion in rivers, streams and lakes. Since the dilution of deicers from roadways to nearby streams is estimated to range from 100 to 500-fold, oxygen depletion has been considered likely to occur only in slow flowing streams and small ponds.(934) The aquatic toxicity of Calcium Magnesium Acetate (CMA) to fish and invertebrates is low.935 However, the depletion of dissolved oxygen (DO) from the degradation of the acetate component of CMA has been a water quality concern, and studies have shown that CMA decomposition exerted a significant biochemical oxygen demand on receiving waters.(936)(937)

The acetate deicers Potassium Acetate, Sodium Acetate (NAAC), and CMAK have higher toxicity to aquatic organisms. The use of the acetate deicers results in the decrease of air pollution from the reduction in sand use. However, the solid acetate deicers CMA and NAAC may contribute fine particulates to the air and increase air pollution. The acetate deicers CMA and Potassium Acetate are not harmful to terrestrial vegetation at the concentrations typically used on the roadways. However, NAAC may potentially have an adverse effect on vegetation because of the presence of the sodium ion, which decreases the stability and permeability of the soil. The depletion of oxygen in the soil from the breakdown of the acetate ion can have a negative effect on plant growth. Slight acute oral toxicity to mammals has been reported for the acetate deicers. No studies have been conducted on whether the acetate deicers attract wildlife to roadways.(*938*)

Oregon DOT has decided to tightly control and potentially avoid the use of calcium magnesium acetate (CMA) and potassium acetate (KA) in the following areas:

- Those where receiving waters will not provide 100:1 dilution during the runoff season, or if the runoff occurs in the late season when the receiving waters may have warmed and protected aquatic species are present;
- Those where a larger highway runoff volume can directly reach a small, shallow pond, lake, or wetland, particularly if the receptor is ice covered. A 30-foot vegetation buffer may be adequate;
- Those where there is no vegetation buffer between the road and receiving waters, and the waters should be protected from oxygen depletion. Present DOT standards for vegetative buffers are adequate;
- Those known to have heavy metal concentrations, coarse soils overlying sensitive aquifers, or percolation devices such as French drains and drywells: when CMA or KA is used in any of the above situations due to over riding concerns for highway safety, water quality should be carefully monitored for possible problems.

Caltrans tests of CMA found the compound less effective than salt for deeper snow packs, resulting in a delay in the melting of ice and snow pack, particularly at temperature below 24 degrees F though the consistency of the snow pack was changed such that it was easier to plow.(*939*) CMA can cause respiratory distress and eye irritation for personnel required to handle it, thereby necessitating the use of protective gear. CMA costs over 10 times more than salt and typically requires an application rate 50 percent over that of salt for CMA to be effective.(*940*)

The National Research Council conducted a study to examine the full economic costs of using salt and CMA for highway deicing. The report, TRB Special Report 235, Comparing Salt And Calcium Magnesium Acetate, defines the true cost of salt; estimates of monetary costs involved in mitigating environmental damage from road salt; and summarizes field performance, infrastructure and environmental impacts, production technologies and costs of CMA.(*941*) Other studies have investigated the effects of different deicers on concrete deterioration.(*942*)

Impacts of Sand/Abrasives on the Environment

Sand is not a deicer, but has been used for snow and ice control since the early 20th Century. Agencies tend to spread sand many times throughout the winter months, an expensive process that can create large debris deposits on roadways and require road sweeping and subsequent disposal as solid waste. Sweeping picks up only a small percent of the total sand applied during a typical winter. An Oregon DOT study found that 50 to 90 percent of sand applied to pavements remains in the environment after cleanup.(*943*) The rest remains in the environment, much of it in catch basins or on or around roadways. Much of the sand not retained in catch basins stays in drainage pipes, decreasing their capacity. Abrasives can clog stormwater inlets and sewers, requiring cleanup in urban areas, on bridge decks, in ditches, and where aquatic environments are at risk. The materials may wash downstream and end up in streams and lakes.

Resource agencies have determined that roadway sand contributes to sedimentation in streams and impacts fish and other aquatic resources. Sand has a negative effect on water quality as a result of the increased turbidity caused by the presence of sand particles in water. Sediment impairment is the most widespread cause for waters of the state to fail to meet water quality standards.(*944*) The increased water turbidity can result in mortality of fish and bottom-dwelling invertebrates that may be covered by the sand. The increased turbidity will also reduce or inhibit photosynthesis in aquatic plants.

Air pollution from particles less than 10 microns in size (PM_{10}) has been documented from winter abrasive use. Vehicle grinding of sand allows fine particulate matter, PM_{10} (or $PM_{2.5}$), to become airborne when dry, and causes river silting during snow melt via surface drainage. Sand used for snow and ice control increases air pollution and has been estimated to contribute approximately 45 percent of the small particulates present in air.(*945*) A 1995 study documented "The Contribution of Road Sanding and Salting Material on Ambient PM_{10} Concentrations" in Albany, NY; Denver, CO; and Reno, NV, the impacts of wintertime road sanding and/or salting on ambient particulate loadings and found the following: (*946*)

- **Albany.** In 21 6-hour sampling periods, sanding contributed more than 44 percent of the total PM_{10} particulate loading, with a high of 75 percent. Motor vehicle emissions contributed approximately 22 percent and deicing salt was as low as 1 percent, averaging 24 percent.
- **Denver**. In 24 samples analyzed in the study, the sand loading contributed over 59 percent to the ambient PM_{10} levels, with a high greater than 89 percent. Motor vehicles contributed 19 percent and deicing salt just over 1 percent. Shortly after the study was completed, the U.S. EPA approved the State of Colorado's air quality improvement plan including a new section dedicated to "Improved Street Sweeping" which requires "that any entity responsible for applying street sanding material within the Denver Central Business District shall clean all streets using vacuum sweepers or a more effective technology within four days of each sanding episode."

- **Reno**. In 20 samples analyzed, sand contributed an average of 57 percent to PM_{10}, similar to Denver, with a high of 80 percent. Motor vehicles contributed 22 percent and highway salt approximately 1 percent.

Last but not least, recent studies have shown sand to be of limited value on icy roads. The Iowa DOT and the Iowa Highway Research Board completed a study on "The Use of Abrasives in Winter Maintenance" and concluded that "… applying abrasives dry is of limited value in providing lasting friction enhancement. This represents a substantial change in current practice. Nonetheless, the results of a variety of studies are unequivocal in finding that abrasives applied to roads where significant traffic travels at high speeds are swept off the road rapidly, remaining in place (and providing friction enhancement) for somewhere between 10 and 100 vehicle passages, at most." The effects of sanding are temporary, whether spread dry or prewetted. Abrasives do little to improve driving conditions on roads with high traffic volume. When dry sand is spread, 30 percent of it immediately scatters. Over time, cars usually displace most of the remaining sand. As few as 8 to 12 vehicles can sweep it from snow covered highway surfaces. Even with light traffic, friction gained from dry sand is quickly diminished. University of Iowa (UI) researchers have drawn similar conclusions about methods to prewet abrasives with a chemical deicing brine.(*947*)

Responding to Public Concerns/Complaints Regarding Contamination

If a complaint suggests that a DOT may be responsible or involved in the alleged contamination NYSDOT has recommended the following steps or practices to respond to public concern and address the environmental issue:

- *Site Location.* Locate the contaminated property or area on a map and observe if transportation facilities or major roads or highways are located near the affected site. Sometimes, we observe salt contamination in aquifer areas adjacent to salt storage (including former or temporary) facilities or more rarely, along major highways such as highly traveled State roads or interstates. Salting of smaller or low traffic volume roads generally does not cause significant groundwater contamination.
- *Interview.* Discuss with Regional Transportation Maintenance staff whether salt (or salt/sand mixtures) is or has been stored at or near the affected site. If so, find out if the salt pile is or was uncovered, and for how long. If stored salt is in contact (even occasionally) with rain or surface water, then recommend or perform actions (i.e., cover the pile with tarpaulins when not in use) to avoid such contact. Inadequate salt storage often results in aquifer salt-contamination.
- *Photo, Map, and Background Water Quality Review.* If possible, review historical aerial photos, soil/geological maps, and area background water quality data. Aerial photos may show previous salt piles. Soil/geological maps may suggest the location/orientation of potential geological conduits for the contaminants to migrate in the subsurface. Background water quality data from nearby wells will help in interpreting and deciding whether the water quality results received with the complaint could relate to salt-contaminated groundwater from DOT activities.
- *Inspection.* Inspect affected residences and ask residents for well data (well type and depth, soil/rock type, etc.). Look for water treatment system connections, if any, and identify where the system effluent goes. Typically the effluent discharges to the septic

system. Also, inspect any nearby DOT facilities and evaluate past or current salt storage practices or conditions. If uncovered salt-, salt/sand mix- piles, or significant amounts of spilled salt are observed, recommend that regional transportation maintenance staff immediately cover or relocate the piles or remove the spilled salt.(*948*)

8.2. Reducing Sand Usage

Stewardship practice requires the careful review of use of sand in areas with the following issues: (*949*)

- PM10 (dust) related air quality problems;
- Potential for in spawning streams, shallow lakes or ponds;
- Sensitive, rare plants near the roadside; and,
- Sand is considered to have a negative impact on aesthetics.

The Montana Department of Transportation (MDT) and the Western Transportation Institute are developing "Recommendations for Winter Traction Materials Management on Roadways Adjacent to Bodies of Water," results of which are due in 2005. The main goal of the project is to develop a comprehensive document for the management of winter road traction materials on highways, to minimize impacts on adjacent aquatic resources. The project will 1) identify the design features and management practices that are the most successful in minimizing the impacts of road sanding materials on adjacent water bodies and identify the conditions under which they are the most effective; 2) address the issues associated with each design feature, including the applicability, site criteria, sizing criteria, engineering characteristics, safety concerns, maintenance issues, costs, effectiveness in the presence of snow, and sediment removal efficiency; 3) identify the effects of road sand particle size on aquatic habitat and summarize the practices regarding gradation of aggregates, friability factors and aggregate types; 4) examine the level of chloride and associated cations allowable in streams and compare their impact with the impact of road sand; 5) review current technologies that allow snowplows to change from sand to chemical deicer on selected road segments; 6) identify sediment delivery factors of road sand to adjacent streams, such as distance, slope, and vegetation; and 7) make recommendations for the management of winter traction materials, in terms of structural BMPs and non-structural BMPs, respectively, considering the needs and constraints related to climate, budget and affected roadways.(*950*)

Since 1989 Caltrans has substantially reduced the amount of traction sand applied to the highways in the Lake Tahoe Basin through a combination of deploying state-of-the-art sanding equipment, operator training, and the employment of anti-icing strategies.(*951*) Caltrans has significantly increased the amount of sand recovery, mainly due to the deployment and use of state-of-the-art vactor and sweeper equipment.(*952*)

The Iowa Department of Transportation and the Iowa Highway Research Board study on "The Use of Abrasives in Winter Maintenance" recommends the following stewardship practices for effective and minimal use of abrasives on the following categories of roadways: (*953*)

- **High Speed Urban Roads.** For urban streets with posted speed limits above 30 mph, there is no significant value in placing abrasives. Research recommends plowing and applying chemicals to achieve bare pavement.

- **Low Speed Urban Roads.** For urban streets with posted speed limits less than 30 mph, there is less abrasive dispersion. Abrasives should be limited to parts of the road where motorists must brake, accelerate, or maneuver. Even then, abrasives should be applied only when it will likely take a long time to provide bare pavement.
- **Urban Intersections.** Urban intersections are relatively low-speed traffic locations. Abrasives could be placed if needed. However, they should be used only when an intersection might be snow or ice-covered beyond a normal period.
- **Rural Roads.** Both paved and gravel roads can expect to see high-speed traffic. Abrasives will not stay on the road for any reasonable amount of time. Abrasives should be applied on hills and curves only on low-speed low-volume roads. Paved rural roads should be plowed and chemical applied to achieve bare pavement. The recommended gravel rural roads approach should be simply to groom the snow pack.
- **Rural Intersections.** Again, gravel versus paved roads must be considered. An intersection should be considered "paved" only if all intersecting roads are paved. Road segments where motorists must stop or yield are low-speed traffic locations. Abrasives could be placed if needed. The preferred approach for paved roads is to plow and apply chemicals to achieve bare pavement. On gravel parts of intersections, abrasives may be applied over that part of the road where speeds of less than 30 mph are expected.

8.3. Strategic Planning for Reduced Salt Usage

Several state DOTs have undertaken strategic planning efforts to reduce salt usage; examples are provided below.

Caltrans Salt Reduction Policy and Implementation

Caltrans implemented a reduced salt-use policy starting in October 1989 that required transportation districts to develop specific route-by-route plans. That policy mandated that "Snow removal and ice control should be performed as necessary in order to facilitate the movement and safety of public traffic and should be done in accordance with the best management practices outlined herein with particular emphasis given to environmentally sensitive areas."(*954*) During the first winter, Caltrans reduced salt usage by 62 percent statewide as compared to the previous winter, helped by improved control of the application frequency of deicing salt.(*955*)

NYSDOT's Salt Reduction Strategy

NYSDOT's salt reduction strategy has revolved around "right application at the right time with the right chemical." NYSDOT has employed thorough management controls, keeping track of amount of salt delivered to sheds and the salt used on each beat, and doing calculations afterward to see if the agency is within established guidelines. If not, the first thing they check is the truck; if calibrations are on target, a supervisor has a discussion with the operator. With this system, NYSDOT does not have a problem with operator over-application. Computerized on-board systems allow application at any rate and take into account weather information.(*956*)

PENNDOT District 10 Salt Management "After Action Reviews" and Annual Update of Salt Management Plan

PENNDOT is among the DOTs that have taken the lead in the U.S. in reducing salt usage. PENNDOT District 1 relies on precise application rates to minimize contamination in runoff from anti-icing and deicing operations. All trucks are equipped with thermometers for informed decisions on application rates; equipment operators can make informed decisions on when to spread material because each truck has a thermometer that displays both air and road surface temperature. After every snow event and every shift, PENNDOT operators complete tracking forms and turn those in to the foreman; such "after action reviews" utilize automatic data downloads from spreaders. The foreman and the operator check the application rate and discuss any variances. Summaries are prepared with regard to stockpiles. PENNDOT's universal database from each snow event allows them to evaluate and compare application rates by district and by truck. Information from spreader controllers can be downloaded to a computer or output directly to a printer through a data port on the controller at the end of each shift. This information includes:

- Types and amount of material spread
- Miles spread

Each operator keeps a written log of:

- Routes spread at what time
- Air and road temperatures
- Type of storm

From this database, many different reports can be run. The district has established application rate goals for different types of storms and different temperature ranges. PENNDOT's District 10's Strategic Environmental Management Program Manual details the process and the roles of various stakeholders. (*957*) Listed in the Appendix is PENNDOT's Post-Storm Salt Management Tracking.

PENNDOT District 10 updates their Salt Management Plan annually, including the following activities: (*958*)

- Analysis of previous year's winter data.
- Revision of materials application charts and tracking sheets to improve application rates.
- Update of target application rates by snow lane miles by truck and charts to collect actual results.
- Equipment evaluation, calibration, repair. and purchasing plan.
- Update of winter training plan.
- Training of Equipment Operators on application rates.

Ohio DOT Pretreatment, Weather, Decisionmaking, and Routing System

Ohio DOT has a statewide initiative to reduce the amount of salt used to treat snow and ice conditions expanding anti-icing pre-treatment to a statewide level starting in 2002. Storm tracking with the aid of pavement sensors and mini weather stations placed strategically around the state give vital information to the counties to maximize their resources of time and materials.

Advances in equipment monitors enable the snowplow truck drivers to be more effective in treating the roads. Optimizing truck routing can save time and money for districts through reduction in the "dead-head time" where a truck must return empty to a yard to refill. The initiative has received high level leadership in the department, from ODOT's Assistant Director and Deputy Director, and affecting District Highway Management, Equipment, and Facilities areas. To date, the initiative has: (*959*)

- Implemented a material matrix expressing the relationship between pavement temperature and precipitation.
- Determined critical information for operational decision including: surface condition, material freeze point, precipitation type/amount, wind direction/speed, and air temperature.
- Developed a plan to deploy pavement sensors along the interstate system and weather systems at county garages not along interstate system.
- Drafted a plan to display information from weather and pavement sensor on statewide maps.
- Performed research to determine most appropriate pavement sensors to measure freeze point.
- Evaluated computer truck routing software for route optimization. Software modification needed to handle multiple salt locations.
- Established base line parameters for application rates, travel speed, and cycle time for evaluation.
- Developed draft process for long-range planning from the computer truck routing parameters.
- Snow and ice procedures will be included in the new Maintenance Manual being developed.
- Developed equipment evaluation forms and process.
- Developed an equipment matrix listing basic units and auxiliary equipment.
- Testing friction device to monitor surface conditions.
- Purchasing a salinity device to mount on truck to determine surface freeze conditions.
- Evaluating Automated Vehicle Location (AVL) device to track vehicle location, monitor material application, and record operational information.

Remaining goals of the initiative are to:

- Validate material matrix and pre-treatment plan including research for pre-treatment effectiveness.
- Deploy pavement sensors and weather devices statewide.
- Develop enhanced application to display pavement and weather information.
- Coordinate snow and ice operations through Central Radio Center for weather bulletins and condition alerts.

- Implement computer truck routing process and resource planning procedure for equipment and facility location, and staffing.

Transportation Association of Canada Recommended Practices for Developing Salt Management Plans

Given the increased emphasis on salt discharges to the environment in Canada, the Transportation Association of Canada has identified best practices in planning for salt management.(*960*) Good plans for reducing salt usage and associated environmental impacts should include: (*961*)

- **Current baseline/metrics for salt management practice and progress**. A situational analysis may include the following to allow the DOT to measure and track progress in managing the amount of road salt being placed into the environment:

  Examination of On-Road Salt Use:
  - Type and amount of chloride freeze point depressant used (all sources including solids, liquids, and abrasive mixes).
  - Type and amount of non-chloride freeze point depressant used (all sources including solids, liquids, and abrasive mixes).
  - Current application rate for each type of material.
  - Percentage of fleet with pre-wetting.
  - Percentage of fleet with liquid only applications.
  - Percentage of fleet with electronic spreader controls.
  - Number of road weather information systems (RWIS) installations.
  - Number of other surface temperature measuring devices (hand-held or vehicle mounted).
  - Use of dedicated pavement and/or atmospheric forecasting

  Identification of Salt Vulnerable Areas:
  - Locations of salt vulnerable areas
  - Description of winter maintenance practices in the vicinity of salt vulnerable areas (e.g. alternate treatment). Examples of possible salt vulnerable areas include:
    - Groundwater recharge areas
    - Areas with exposed or shallow water tables with medium to high permeability soils
    - Sources of drinking water
    - Salt-sensitive vegetative communities
    - Salt-sensitive wetlands
    - Small ponds and lakes
    - Rivers with low flows
    - Salt-sensitive agricultural areas
    - Salt-sensitive habitats for species at risk

Evaluation of Sand and Salt Storage Sites:

- Number and capacity of storage sites
- Percentage of sand/salt piles covered and type of cover
- Percentage of indoor loading
- Management of drainage from sand/salt mix piles
- Levels of environmental indicators (e.g. chloride levels)
- Percentage of salt in winter sand
- Percentage of sites with washwater treatment
- Existence of a good housekeeping policy, and adherence to the policy

Snow Disposal Sites: (only necessary in the most snowy regions of the U.S.

- Number and capacity of disposal sites (permanent and/or temporary)
- Levels of environmental indicators (e.g. chloride levels)
- Percentage of disposal sites with water management systems
- Conformance with existing environmental standards for snow disposal sites
- Existence of a good housekeeping policy and adherence to the policy

Training:

- Training includes such on-the-job elements as preseason "dry runs." Drainage facilities, wildlife crossing structures and other facilities requiring delineation or special treatment in plowing operations should be noted by foremen and equipment operators during dry runs of routes in the fall along with possible obstructions.
- Percentage and frequency of staff receiving training in best salt management practices broken down into categories (e.g. managers, supervisors and operators)

- **Comparison of current practices to best management practices and document the gaps.** The salt management plan should then focus on closing these gaps. The plan should include preseason, **in-season, and post-season actions** to be taken to reduce the adverse impacts of road salts. It should also include **consideration of equipment, labor, materials, and the local climate**.
- **How general road use of salt, salt use in salt vulnerable areas, and salt storage will be addressed**. Snow storage and disposal sites should be dealt with in regions where this is an issue.
- **Clear tasks, schedules with milestones, budget considerations, and assigned responsibilities** for implementing best salt management practices. The plan will involve prioritizing in many cases. For example, spreaders on the highest salt routes or in proximity to vulnerable areas can be targeted first for replacement, and the most versatile mechanical removal equipment can be stationed where it will help lessen salt loadings.
- **Documented policies, procedures, and guidelines in the following areas,** aimed at introducing best salt management practices with both in-house and outsourced operations.

- Level of service for each roadway type
- Salt and sand application rates
- Managed sand and salt storage
- Good housekeeping practices for maintenance yards consistent with TAC's Design and Operation of Road Maintenance Yards Synthesis of Best Practices
- Equipment calibration & re-calibration
- Training
- Snow disposal
- Incorporation of salt management consideration into road design and construction
- Salt vulnerable areas

- **Monitoring, Record Keeping, Reporting & Analysis**
  - Progress on implementation of the salt management plan can only be confirmed by tracking specific indicators and comparing these to the baseline that was benchmarked at the outset of the program.
  - Each salt management plan should assign responsibility for monitoring and reporting on implementation of the plan. These results should be reported annually to the senior executive responsible for the salt management plan.
  - The monitoring and record keeping system should document and assess the indicators identified in the situational analysis. Where there are new issues or activities being implemented as part of the salt management plan, new monitoring initiatives may be required.
  - Any changes from the baseline established in the situational analysis need to be analyzed to assess the degree of progress being made. The analysis should also take into account the type of winter experienced to ensure that realistic conclusions are being drawn. For example, an increase in salt use may be due to an unusually severe winter rather than the failure of a plan.
  - Similarly, a reduction in salt use may be due to a milder than normal winter rather than the successful implementation of a plan. Therefore the analysis must be sufficiently in-depth to account for these variances. Where there are known releases to the environment being monitored (e.g. stormwater outfalls, water intakes, water treatment plants, monitoring wells, material storage sites or snow disposal sites), then these data should be included in the annual progress report.
- **Management Review**
  - Each year, senior management within each administration should review the results of the previous year's salt management actions to confirm that the plan is achieving the desired results and to adjust the next year's salt management plan to respond to shortcomings and new opportunities. Policies and procedures should be updated prior to the next snow and ice control season and communicated to management and operational personnel.
  - This review should be integrated into the budgetary process to permit timely acquisitions of new equipment and to identify other funding needs, including:

- Personnel commitments.
- Review of organizational equipment needs and fleet management strategy, staying current with changes in the business.
- A transition strategy to shift from the existing fleet to a new fleet that incorporates available technology. To gain experience in new methodology, new equipment may be assigned to preferred "champions" in the organization for demonstrated use on less significant roadways until there is confidence in the new practices.

8.4. STEWARDSHIP PRACTICES FOR REDUCING SALT AND OTHER CHEMICAL USAGE

The minimization of salt related impacts should be one objective of any management strategy formulated for roadway drainage systems. Efficient employment of anti-icing programs and other management systems minimizes the introduction of salt alternatives into the environment.

The Transportation Association of Canada (*962*), Oregon DOT (*963*), and NYSDOT (*964*) make the following overarching stewardship practice recommendations for reducing salt usage, included below in addition to practices suggested by recent research. A number of these practices are expanded upon in subsequent sections.

- **Practice anti-icing by promoting a timely response to snow and ice events in order to prevent a bond** from forming between the frozen precipitation and the pavement. (This strategy consumes much less material than a de-icing strategy.) **Evaluate road and weather conditions and trends** to ensure that the proper type and timing of treatment is made.
- **Snow and ice control decision-making should be based on ongoing monitoring of pavement temperatures rather than air temperatures.** Pavement surface temperatures can fluctuate significantly depending upon the time of day, degree of cloud cover, sub-surface conditions (i.e. frost penetration, moisture presence, thermal retention properties, etc.) and type of pavement. Therefore ongoing monitoring of pavement temperatures is important to good decision-making.
- **Plow off snow or slush prior to applying materials to decrease dilution and increase effectiveness of the materials.**
- **Do not overload the material spreader, to avoid spillage.**
- **Control spreading speeds to reduce bounce and scatter.**
- **Control spread patterns to concentrate material where it is most effective** on the road. Solid road salt is usually placed on the crown or high side of the driving surface where a good crossfall and traffic will distribute the resulting brine over the road. When re-applying material, consider the possibility of partial vs. full and spot vs. blanket treatments where appropriate. Wider spread patterns are called for when spreading on deteriorated pavements where an undulating surface or poor crossfall will not ensure adequate chemical migration across the entire road, or when rapid distribution is required to address frost or black ice conditions.

- **Consider alternative treatments** (e.g., plow only, use of snow fencing) which do not involve materials usage where applicable. Non-chemical deicers have the potential to introduce less salt and environmental contamination. Innovative techniques in debonding were explored in SHRP Report H-644, Ice-Pavement Bond Disbonding—Surface Modification and Disbonding, including noncontact and contact methods, additives to alter surface texture, electromagnetic radiation, and abrasive air and liquid jets applied directly to ice pavement interface.(*965*) In terms of contact debonding technology, SHRP Report H-673, An Improved Displacement Snowplow, describes the research on improving the design of snowplows, as well as design, fabrication, and testing of plows incorporating improvements, toward the effort of decreasing energy consumption during plowing by twenty percent.(*966*) Improved Cutting Edges for Ice Removal presents an evaluation of snow plow blade geometry and its effects on the force required to remove ice from a highway pavement surface including prototypes and testing of three different cutting edges.(*967*)
- **Alter application methods and rates in sensitive areas**: (*968*)
    - Use CMA on bridges and roads where permitted and during freezing fog in lieu of sanding, when optimum conditions exist, where adjacent water bodies support a 100:1 dilution factor or there is a vegetative buffer between the road and water body and where there is no standing, shallow water.
    - Place barriers in site specific locations where appropriate and practical, along streams or direct drainages to route sanding/anti-icing material away from watercourses.
    - Reduce plowing speed in sensitive areas.
    - Stop sidecast sweeping within 50 feet of structures over water, where structurally possible.
    - Identify and creating facilities to capture sanding material where appropriate.
    - Reduce quantity of sand applied where appropriate.
    - Clean inlets prior to first rain as feasible.
    - Modify blade angles or blower hoppers in sensitive areas.
    - Educate DOT maintenance staff on water quality and fishery resource issues.
- **Return unused materials to stockpiles and avoid heavy "end of beat" applications** that empty the load
- **Keep accurate records of materials usage to allow monitoring and improvement of operations.** While it is not practical to monitor all runoff from roadways for chloride levels, transportation agencies should consider monitoring salt vulnerable areas. One municipality worked with their local conservation authority to add chloride monitors to their stream monitoring network.

Shifting to Anti-Icing

Anti-icing is the proactive use of any melting agent to assist melting and resist the formation of a bond between snow and ice and the pavement surface. Highway anti-icing is the snow and ice control practice of preventing the formation or development of bonded snow and ice by timely applications of a chemical freezing-point depressant. It provides a maintenance manager with two major capabilities: the capability for maintaining roads in the best conditions possible during a winter storm, and the capability to do so in an efficient manner with the fewest chemicals and environmental impacts possible.

Anti-icing can involve application to the roadway of liquids, pre-wetted solid granular materials or dry granular material. Thus, anti-icing is not confined to using liquids. Direct liquid applications are efficient since they provide melt action immediately and do not take time to dissolve and form brine. Furthermore, liquids do not depend on the presence of heat from the ground, sunlight or traffic to dissolve (endothermic reaction). The timing of the application is not as critical as with granular materials; the principle is that traffic will help the liquid migrate across the road cross-section and yet not develop into road spray. Liquids can be applied in advance of the start of a storm. If the application is earlier than the onset of a storm, a NaCl brine will evaporate leaving a salt crystal residue in the surface pores/texture of the pavement (and which will redissolve and reform a brine with precipitation); conversely, hygroscopic brines (such as CaCl2 and MgCl2) will attract moisture and continually wet the road until they are dissipated. The approach to resisting the bond is not to wet the road, but simply to provide enough chemical to enhance early-storm safety with an application of chemical that stays on the road. The intention is not to "wash" or even fully wet the road with an equivalent chemical loading as that of a granular application. Generally, an equivalent weight of salt applied as a liquid (e.g. dissolved in water) performs better than the same weight of dry granular salt because the liquid is fully retained on the road surface. The cost on a dollar-per-gram basis may be greater for liquid only applications (depending on the liquid used), however the offsetting safety benefits have to be considered.(*969*)

European and Scandinavian experience has shown that as little as 5 to 10 g/m^2 (65 to 130 lb/lane-mile) of salt is needed for preventing salting treatment for frost, black ice, and light snow. There appears to be no consensus among European countries regarding the rate of salt spreading during continuous snowfalls. Estimates of application rates under these conditions range from 10 to 60 g/m^2 (130 to 780 lb/lane-mile). Highway agencies in the United States have found that reducing the conventional application rate to quantities on the order of 4 or 5 g/m^2 (42 or 65 lb/lane-mile) is not generally possible with current equipment that is designed for deicing application rates of 23 to 38 g/m^2 (300 to 500 lb/lane-mile) and higher. Liquid freezing-point depressants offer the advantage of precise and uniform application over a wide range of rates.(*970*)

Environmental Benefits and Cost Savings of Shifting to Anti-Icing

According to a study by the Strategic Highway Research Program, experiments at nine state highway agencies, anti-icing treatment requires less chemical use than most deicing procedures and makes it easier to achieve bare pavement conditions.(*971*) As a result, anti-icing can provide cost savings as well as environmental benefits. For example, the Iowa, Missouri, Oregon, and Washington DOTs realized cost savings and the following benefits in test programs: (*972*)(*973*)(*974*)(*975*)

- Fewer snowplow trips were made. The anti-icing truck only had to make one trip for every three trips made by the larger conventional snow-removal truck.
- Crews experienced less wear on equipment due to fewer snowplow runs.

- When required, plowing was easier and faster. Less time was spent clearing roads. Crews were able to complete snow removal on roads that received anti-icing treatment up to three hours sooner than on conventionally treated roads.
- Fewer chemicals were needed by applying the treatment prior to snowfall. With fewer chemical applications needed, the anti-icing method was better for the environment.
- With reduced costs for labor and chemical use.

Since Boulder began using a liquid solution comprising 29 percent magnesium chloride and 71 percent water in 1993, sand use has decreased by 55 percent. When all costs are considered, using the liquid chemical costs $2,500 per lane mile, as compared to $5,200 for deicing and sanding operations.(*976*) The Center for Geotechnical Engineering Science (CGES) at the University of Colorado at Denver completed a CDOT-sponsored study on ”Environmentally Sensitive Sanding and Deicing Practices” in 1994. The study recommended the formulation of an optimal practice that minimizes the use of sand and increases the use of environmentally friendly chemicals for the purpose of enhancing winter highway traction and maintaining both environmental health and human respiratory health. Implemented since 1994, the shift has had a direct beneficial impact on all issues related to safety, cost, environment, and human health and has improved the Colorado air quality, allowing Colorado to avoid exceedance of the EPA PM_{10} standard over subsequent winters.(*977*) The Idaho Department of Transportation (IDT)'s anti-icing retrofits showed reductions in annual averages of abrasive quantities, labor hours, and winter crashes over five years.(*978*)

Stewardship Practices to Minimize Anti-Icing Materials Application

Stewardship practices to minimize materials application and release to the environment include the following:

- **Since anti-icing is preventive in nature it is desirable to have the first application completed two hours prior to the anticipated event, or at a minimum prior to bond forming on the road surface.** The anti-icing chemical solution concentration will decrease as it is diluted with water from either the melting of the snow/ice or falling rain/freezing rain and becomes less effective.
- **Pavement should be cleared of as much snow, ice, or slush as possible before reapplying a liquid anti-icing material.** Application rates for liquid anti-icing operations are based on local experience as documented through logs.

FHWA's Manual of Practice for an Effective Anti-Icing Program: A Guide For Highway Winter Maintenance Personnel describes program factors, practice recommendations, and guidance for conducting anti-icing operations during specific precipitation and weather events.(*979*) Recognizing that the development of the program must be based on the specific needs of the site or region within its reach, FHWA provides the caveat that no short discussion or list of recommendations can completely cover the range of conditions facing agencies continent wide; instead the guide is to be used as a starting point for developing its own anti-icing program, and to modify the recommendations when necessary in order to accommodate local experience, specific site concerns, and agency objectives. The report does present specific recommendations for anti-icing operations for five weather events, from light snow storms to heavy ones, frost, freezing rain, and sleet. Guidance on maintenance actions for each event is provided for several pavement temperature ranges and for initial and subsequent operations.

Temperature trend, an important factor, is also indicated. Solid, liquid, and prewetted solid chemical application rates are suggested where appropriate—rates not to be considered as fixed values but rather the middle of a range to be selected by an agency according to its local conditions and experience. Traffic volumes were not found to have a consistent or dominant influence on pavement condition or traction to suggest varying chemical application rates except in the case of frost and black ice, and that category is the only one incorporating traffic as an operational consideration. The guidance presented was based upon the results of four years of anti-icing field testing conducted by 15 State highway agencies and supported by the Strategic Highway Research Program (SHRP) and FHWA, and then was augmented with practices developed outside the U.S., where necessary, for completeness. Steps in initial operation of an effective anti-icing program include: (*980*)

- **Information assembly** upon first notice that a winter storm or frost/black ice event may affect the maintenance area, including weather forecasts, weather radar data, satellite data, local road condition and RWIS data, pavement temperature forecasts, and any RWIS data from areas outside the immediate maintenance jurisdiction that might have already have been affected by the approaching storm. The information must be reviewed to estimate when and where the event will begin, its extent, and severity.
- **Decision** on whether or not to initiate a treatment, when to start it and what type of treatment to apply can be made after the review is made of the information assembled. The decision is based on when precipitation is expected to start, what form it will be, the probable air and pavement temperatures, the anticipated trend of the temperatures, the expected sky conditions, the wind speed and direction, and the intended timing of the treatment.
- **Chemical application.** Either dry solid chemicals, liquid chemicals, or prewetted solid chemicals can be used as an initial anti-icing treatment. Whichever is used, the timing of the application should be consistent with the underlying objective of preventing the formation or development of bonded snow or ice, and should reflect an underlying readiness consistent with a preventive strategy. That is, it should be made in anticipation of or in prompt response to worsening pavement conditions. Applications in advance of snowfall are not necessary for preventing bonded snowpack, but early applications when the pavement condition is no worse than wet, slushy, or lightly snow covered are for the most part necessary for anti-icing success. As this may not always be possible, for example because of a limited fleet or heavy traffic, pretreating the road before a snowstorm may be the only way to ensure that all areas are treated before conditions deteriorate. Chemical application at the right time can reduce chemical usage and environmental effects.

  For snowstorms, initial liquid applications can be made either as a "pretreatment" in advance of the storm or as an "early-storm treatment," i.e., soon after snowfall has begun and/or when the pavement temperature is dropping toward freezing. A pretreatment can be made well ahead of a storm as long as the storm does not start out with above freezing temperatures and rain, washing the chemical away. In the case of early-storm treatment, the application may be made onto dry, wet, light slush, or lightly snow covered pavement. Late applications onto pavements with more than a light covering of slush or snow can result in excessive dilution of the chemical, and risks failure. These should always be coordinated with plowing. Recommendations for **use of solid and prewetted** solid chemicals, **plowing**, and time when **doing nothing** are most appropriate are also discussed.

Direct liquid applications can be applied over multiple lanes by trucks traveling at higher speeds (than conventional salt spreading) with due regard for traffic. Trucks used for straight liquid applications can range in size, to accommodate frame-mounted or slide-in tanks. Truck configurations may include small trucks with tanks ranging from those used as patrol vehicles (pickups to two-tons) to vehicles used for vegetation spraying or bridge washing in the off-season; larger trucks used for water applications or calcium dust suppression applications in the off-season; and/or full-size, larger capacity tractor trailer tanker units used for long distance hauling in the off season. The application of liquids can be triggered by sensors and sprayed on a road or, more commonly, a bridge deck surface via Fixed Automated Spray Technology (FAST).

A Guide to Selecting Anti-Icing Chemicals and Considering Environmental Impact is available on-line.(*981*) The purpose of the guide is to specify the key performance measures that are required from an anti-icing chemical, and suggest ways of grading chemicals according to those performance measures. It also provides a method whereby an agency can weight these measures according to the specific needs of that agency, including Freezing Point Depression, Consistency, Environmental Impact, Stability, Corrosion, Handling, and Documentation. SHRP Report H-683, Anti-Icing Study: Controlled Chemical Treatments, developed correlations between meteorologic parameters and chemical effectiveness that can indicate the optimum conditions for a particular anti-icing chemical application.(*982*)

Road Weather Information Systems (RWIS)

An anti-icing program is only as good as an agency's ability to predict the onset of winter weather events accurately. Understanding and interpreting weather information can be critical to the success of any winter snow and ice removal operation. Knowing when, where and what type of deicing material to use for a particular winter weather event can be a challenge. Knowing where to find the weather information needed to make decisions and what information to use can be difficult.

National Weather Service forecasts are not sufficiently site-specific and do not include all the data necessary to provide the accurate, real-time storm prediction and road temperatures that make anti-icing strategies effective. Thus, Road Weather Information Systems (RWIS) are an essential tool in a successful anti-icing program. Using pavement and atmospheric sensors and communication systems, RWIS collect and deliver roadway and weather condition data to decision maters in the maintenance garage and even behind the wheel of the snowplow. The data from a system of RWIS sensors along a highway network—especially along trouble spots—help maintenance personnel know when and how fast a winter weather event is approaching. The RWIS data indicate the kind of precipitation likely, where the precipitation will freeze on the roadway, and other information that will help Maintenance forces decide when to apply the minimum amount of chemicals to be effective.(*983*)

Recent research has found that the use of an incentive-based compensation model built on RWIS results in reduced use of salt compared with a compensation model based on measures to such an extent that the Swedish National Road Association is making preparations for changing the whole compensation system before the next winter season 2004–2005.984

What Are Road Weather Information Systems (RWIS)?

Road weather information systems (RWIS) are networks of weather data-gathering and road condition monitoring systems and their associated communications, processing, and display facilities which provide decision information to maintenance managers. The most visible components of RWIS are the roadside installations of system components. A single site, which may have many sensors, is referred to as a remote processing unit (RPU) station, typically consisting of atmospheric sensors mounted on a tower, sensors embedded in the pavement surface and beneath the surface, and an enclosure which contains data processing capability and communications equipment. Data from the sensors are formatted at the RPU and transmitted to a central processing unit (CPU) where they may be stored, retransmitted to other workstations or locations, or accessed directly. The CPU can be a separate computer or a workstation.

Another component of a RWIS is the data processing and display capability used by the maintenance personnel. The actual system configuration depends on the management structure of the maintenance organization. This component can be a computer workstation in a maintenance facility or at a District or Area headquarters. It can also be a portable computer a manager, supervisor or foreman takes home.

- For made from a central office, one workstation with the CPU may suffice.
- If decision making is decentralized, workstations and/or portable computers should be available to the local decision makers for them to access data.

Benefits of RWIS

Data from RWIS are used to determine when and where to apply salt and other materials-commonly called deicing chemicals-that either prevent ice from bonding to the pavement or break the ice-to-pavement bond. The technology helps maintain ice-free roadways, cuts down on labor costs, and reduces chemical use.(*985*)

Sensor-based RWIS has been in use for over 25 years by road and airport authorities around the world. Beyond giving road information and trends, RWIS sites and networks provide information required to develop specific forecasts as well as some service documentation. RWIS supports winter road operations in the following ways: (*986*)

- An understanding of pavement temperature forecasts and trends can improve the accuracy of decision- making.
- Sensors embedded flush in the pavement, as well as sub-surface, generate data that can be sent back to central locations allowing trends and forecasts to be developed.
- Pavement sensors can monitor pavement temperature, wet/dry status, freeze point of the solution on the road, presence of chemical and concentration (for some chemicals), as well as subsurface temperature.
- Tower-based sensors can also provide real-time information of typical atmospheric conditions such as precipitation, relative humidity, dew point, air temperature, and wind speed and direction.
- Weather forecasting services can use road-based information to provide “road weather” forecasts to help the road maintainer make better decisions regarding snow and ice control.

- Salt use optimization is achieved by more accurate deployment of equipment and application of chemicals.
- Other types of sensors and systems can be added to RWIS to further support road maintainers (e.g. road-imbedded device to measure road friction and snow cover, automated liquid deicer application system—Fixed Automated Spray Technology (FAST), etc.).
- The RWIS can be equipped to perform other beneficial functions. A camera can be attached to provide real-time weather information. A laser device can measure visibility. The intensity and accumulation rate of snow can be measured. And the station can activate changeable message signs to warn drivers of snow, high winds, and other hazardous conditions.

By doing a better job of predicting where and when crews and materials will be needed, agencies are able to reduce usage and expenditures while maintaining level of service. Pilot tests have indicated the potential for wider scale reductions; for example Mass Highway estimated that a complete RWIS could yield savings of $150,000 to $250,000 during a typical Boston winter.(*987*) NJDOT is equipping all crew supervisors with portable computers so that they can access RWIS and other data at any time and winter maintenance decisions are made by the people most familiar with the roads and weather in a particular area, estimating that the resulting savings in chemical, labor, and equipment costs could reduce snow and ice control expenses by 10 to 20 percent statewide. A fully implemented system was estimated to eliminate at least one chemical application pass per storm.(*988*) NYSDOT is stressing pavement temperature not air temperature and in-pavement sensors are beginning to provide this information. At NYSDOT, 10 percent of trucks have units, plus supervisors have hand-held units to estimate pavement temperature.

Strategically placed RWIS stations provide forecasts that are 90 to 95 percent accurate, a rate which is improving with addition of further stations and better technology. In sum, (*989*)

- Crew chiefs have a better idea of how much deicing chemicals to apply to the pavements and when, cutting costs and minimizing any environmental impacts.
- Maintenance activities can be better planned and executed. Labor, material, and energy costs are reduced. DOT operations have become more efficient, giving the agency a return on investment of 200 percent to 1,300 percent.(*990*)
- Road safety is enhanced and the public benefits from faster response to weather-related emergencies.

RWIS Selection, Siting, Use, and Maintenance, Connection to Snow and Ice Control Materials and Methods and Use of Friction Indicators to Minimize Chemical Usage

Additional information about RWIS, their selection, procurement, siting, use, maintenance, and calibration can be obtained in the two-volume SHRP report Road Weather Information Systems Volume 1: Research Report and Road Weather Information Systems Volume 2: Implementation Guide (SHRP-H-351).(*991*)(*992*) The National Cooperative Highway Research Program (NCHRP) recently completed Project 6-13, Guidelines for Snow and Ice Control Materials and Methods, to help maintenance managers select appropriate strategies and tactics for specific winter storm conditions. NCHRP has distributed the report to state departments of transportation. In combination with the results of NCHRP Project 6-16, Guidelines for the

Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts—now in progress—the report will provide a complete winter maintenance handbook for managers. Supplementing RWIS data with real-time friction measurements may be useful for managers allocating resources for snow removal as a storm is occurring, and NCHRP Web Document 53, Feasibility of Using Friction Indicators to Improve Winter Maintenance Operations and Mobility, provides practical insights. NCHRP Project 6-15, Testing and Calibration Methods for RWIS Sensors, in progress, will assemble best practices and produce practical guidelines to ensure the reliable operation of RWIS sensors in the field.(*993*) Together, these resources and the RWIS tools below can help maintenance managers optimize road safety and minimize chemical usage.

Road Information and Temperature Assessment

Maintenance decisions should not be based on a rigid, automatic basis but rather on the assessment of a need. In contrast to prescribing that chemicals be applied, or plow runs be made every hour or two or other fixed interval, decision on treatment need can be based on a number of information sources, including the visual observations of precipitation/weather and pavement conditions from patrols and from operators, an indication or the measurement of chemical concentration on the pavement, and the measurement of frictional resistance to sliding.(*994*)

Real-time knowledge of the pavement surface state is necessary for making an informed decision on treatment: the pavement temperature, whether it is wet or dry, and some indication of the concentration of a freezing-point depressant. The most important is pavement temperature, as the solubility of all chemicals varies with temperature. Lower temperatures bring about less solubility. An ice-control chemical must form a solution in water in order to depress the freezing-point. The pavement temperature will determine if it will form an ice-melting interface at the pavement surface. Air temperature is less important at the critical time of application and immediately following since there is usually a lag between air temperature change and the response of the pavement surface. Nonetheless, the air temperature trend is important to track because pavement temperature will usually follow the air temperature within a few hours depending on the difference in the air temperatures, the amount of solar radiation, wind, and the characteristics of the road. Remote measurement of amount and type of precipitation will guide the maintenance manager in deploying available resources most effectively. It is not unusual for part of a region to be receiving freezing rain, another part snow, and still another no precipitation. Using the most appropriate chemical and application rate for the condition, scheduling only plowing, or choosing to do nothing can all be informed decisions based on road and weather information.

Pavement Sensors and Thermal Mapping

Pavement sensors accomplish this monitoring and warning function. In addition to their real-time monitoring function, pavement temperature sensors can be used to generate a forecast of pavement temperature trend and warn when it will drop below freezing. This warning can occur several hours before the event, providing sufficient time to plan operations and avoid unnecessary costs.

In addition to measuring temperature most pavement sensors give a relative value of the chemical concentration on the sensor surface based on conductivity measurement. It will serve as a guide to whether some chemical remains on the road and help in making the decision whether or not to retreat. Another capability is available on some of the newest types of pavement sensors: measurement of the freezing-point of the solution on the detector. Its value lies in warning of the refreeze of a chemical treatment which has been diluted by melted snow or ice.

Thermal mapping, or thermography, is the process of determining thermal profiles of road surfaces using infrared sensors. Thermal mapping profiles can be used to infer pavement temperatures between sensor locations where the temperatures are known. An extension of this process is to forecast temperatures along the roadway based on the forecasts of temperatures at known points. The measurements are typically made in the early morning hours, when there is the least change in the pavement temperature during the measurement process. They are also made under different atmospheric conditions, since the radiation balance at the surface is related to the atmospheric conditions, including cloud cover, wind speed, and precipitation. A variation of thermal mapping is called road climatology. Additional data are acquired when measuring pavement temperature, including air temperature, relative humidity, and climatological characteristics of the pavement environment. The additional data are input to a short-range (up to 4 hour) forecasting model for pavement temperature.

Thermal mapping of highway segments has been conducted in several States, including Washington, Nevada, and Minnesota. The data from thermal mapping have assisted in siting RPU stations, forecasting pavement temperatures for locations where no RWIS sensors exist, and for developing snow- and ice-control strategies. Other potential locations for thermal mapping include those areas where anti-icing operations are used, where reduced chemical areas exist, or where a significant number of different microclimates exist in a given area. Thermal mapping may also point to representative RPU locations that can eliminate the need for one or more sites. Better routing or allocation of maintenance resources and personnel is possible based on thermal mapping. The data can allow staging of responses to only those road segments expected to be below freezing. It can also indicate certain areas or locations that may not need attention. Research has indicated that thermal information from the road environment can be obtained using relatively inexpensive hand-held radiometers. Vehicle-mounted instruments for measuring pavement temperatures are already used by some State highway agencies.

There is some thought that thermal mapping should be considered when variations of pavement temperature greater than 5 degrees C (9 degrees F) are possible, or when the road elevation changes more than about 200 m (650 ft) over the segment length of interest. These “rules of thumb” are for general guidance and have not been validated by research data.

Infrared Thermometers (IRTs)

Decisions about material application are improved when information about the current road surface temperature is available and the temperature trend is known. Infrared thermometers (IRTs) are portable devices that can be used to determine the current road surface temperatures while mobile along the road network. Both hand-held and truck-mounted versions are available; with the mounted versions measuring ambient air temperature as well. Truck-mounted versions allow continuous monitoring of the road surface while the vehicle is moving down the road. The data can be recorded and transmitted as part of the data stream of a GPS/AVL system (see Operational Support Equipment later in this document). IRTs need to be checked and calibrated to confirm their accuracy and to be confident in the reading.

Road Surface Traction/Friction Measurement

Decision about material application can be improved by having better information about the current friction level of the road surface. Devices that measure the degree of friction on the road surface have the potential to eliminate the unnecessary use of salt on roads with adequate traction. In some cases friction sensors are mounted on the spreader vehicles and used in conjunction with on-board mounted pavement temperature measurement equipment to automatically control the application rate of snow and ice control chemicals. Several DOTs and suppliers are conducting research on affordable and convenient measurement methods.

Measurement of friction was used successfully in the SHRP and FHWA anti-icing projects. An agency may find it reasonable to establish this as a technique used during patrols. There are many devices for measuring friction. Skid trailers are commonly used for the measurement of the coefficient of friction, but for various reasons related to safety and equipment deterioration, they are not normally used on snow-covered pavements. Specialized vehicles incorporating a fifth wheel, which measures the increase in force when braked at a controlled slip rate, are available, but high cost has limited their use mainly to airports. A low-cost device was used in both the SHRP and FHWA test programs because it can be installed in most any vehicle and can produce reliable measurements. It gives a direct readout of friction coefficient when the vehicle is hard-braked from 65 km/h (40 mph). Its repeatability is acceptable for treatment analysis and decision support purposes, provided the device is calibrated and operated in accordance with the manufacturer's specifications. Because it requires hard braking, however, it is not suitable for use in heavy traffic.

A 2004 TRB paper on the Feasibility of Using Friction Indicators to Improve Winter Maintenance Operations and Mobility presented the results of NCHRP Project 6-14, which evaluated the feasibility of using friction indicators as tools for improving winter maintenance operations and mobility. As part of the project, information was collected and reviewed regarding the use of friction indicators for winter maintenance operations decision-making, operations performance evaluation, and motorist information. In addition, short-term and long-term implementation scenarios were developed in which friction measurements could be used to improve winter maintenance safety, operation, and mobility. The study also found that analyzing information collected from low-cost and reliable friction measuring devices and other data, such as pavement temperature, traffic, and weather conditions, could be useful for allocating snow-fighting resources in real-time. The information gathered suggested that a traction-control system is the most promising technology for practically and safely measuring friction in winter conditions, followed closely by deceleration and slip devices. Forecasting surface friction based on models that relate data such as temperature and traffic was also identified as a promising technique for improving winter maintenance operations, but further research is needed in this area.(*995*)

Residual Chemical Measurement

The availability of chemical concentration indicators appears to enhance the timing of subsequent applications by providing indications of the dilution of the chemical. After a storm event has passed and the road has become bare and dry, there often is a residue of chemical on the road surface which can be activated with the next precipitation event. The concentration of salt contained in roadway slush is the determinant of the freeze point temperature of the slush. It is helpful for decision-makers to know the residual salt concentration on the road. An RWIS road sensor will provide this information, enabling a manager to time the reapplication of chemicals so that the operation is complete before the freezing-point of the brine on the pavement surface starts to climb and, especially, before it reaches $0^{o}C$ ($32^{o}F$). Where decision makers have confidence in these data, they can be used as a basis for establishing cycle times of the repeat applications for different conditions.

Portable salinity sensors are available, although their high cost makes widespread use unlikely. Existing salt concentration meters permit only point-to-point measurement and are, therefore, not suitable for road management that relies on longitudinally continuous concentration measurement. These existing methods of measurement require that field personnel stop the vehicle and manually take measurements on the pavement. Consequently, this method is not convenient and is also dangerous for field personnel. The New England Transportation Consortium has been working on development of a method and prototype for the continuous measure of deicer concentration.(*996*) Another tool on the horizon is a "chemical presence" sensor that can measure the chloride concentration of road spray in a vehicle's wheel well.

Nowcasting

Nowcasting refers to the use of real-time data for short-term forecasting. It relies on the rapid transmittal of data from RWIS installations, radar, patrols, and any other information source for making a judgment of the probable weather and pavement condition/temperature over the next hour or two. Nowcasting is one important tool for making the decision of when to call in personnel. Mobilization timing may vary among sites, therefore the frequency of weather information updating required for a nowcast will also vary with the site. Nowcasts can be provided by a weather service or performed by the maintenance manager. Specially trained maintenance managers in some highway agencies already perform this duty using the necessary information available from a variety of sources.

Traffic Information

Vehicles can affect the pavement surface in several ways: tires compact snow, abrade it, displace or disperse it; heat from tire friction, engine, and the exhaust system can add measurable heat to the pavement surface. Vehicle tires also bounce a proportion of applied chemicals off the pavement. These positive and negative impacts on the effectiveness of anti-icing treatments should be considered in the decision-making process. The traffic information most important for making operational decisions is the variation of traffic rate throughout a 24 hour period.

Patrols

There is no substitute for visual observation of weather conditions and conditions of the pavement surface. Observations remain an important tool for making operational decisions even when an agency has access to and experience with new technology such as RWIS. Use of patrols for this purpose can be highly effective. Though the State or local highway patrol can fulfill this role, trained maintenance personnel are better prepared to judge the severity of conditions and to make or recommend corrective action.

ITS Standards for RWIS

An Introduction to Standards for Road Weather Information Systems (RWIS) describes three categories of standards (here as guidelines, recommended procedures, protocols, and other practices) that formalize some of the processes involved in deploying and maintaining RWIS sensors: siting standards, calibration standards, and communication standards. While the standards are not mandated, agencies are encouraged to use the introduction as a starting point to learn about RWIS standards and to consider how they might use these standards to reinforce their own RWIS operations.

The ITS standards program has produced a number of weather-related standards, including the Environmental Sensor Station standard for road weather information systems (RWIS), weather elements in the Advanced Traveler Information Systems standards, as well as a number of other standards.(*997*) There are many examples of the use of ITS to improve transportation system operation under adverse weather conditions, including closed-circuit television (CCTV), RWIS, 511 (the national traveler information number), road closure notification/diversion coordination, dynamic message sign (DMS) advisories, variable speed limit (VSL) technologies and enforcement, in-vehicle devices, sensor/detection systems and other field devices, signal control systems, land closure/ direction change systems, smart work zones, and highway advisory radio (HAR). Recommended practices for ITS deployment include the following: (*998*)

- Make sure that area jurisdictions have compatible equipment, can share data, and have similar operating standards and procedures.
- Use technology to make sure the right equipment and the right people are at the right place at the right time and for the right reasons.
- Deploy systems so that they can prove their benefit in specific, quantifiable ways.
- Evaluate their effectiveness – from both a cost and benefit perspective – to demonstrate value to the traveling public and to relevant stakeholders, including elected/appointed officials.
- Seek both short- and long-term wins from technology deployment.

Future projects, including the Vehicle Infrastructure Integration (VII) initiative, the Infostructure, and the Integrated Network of Transportation Information (INTI), hold great promise in providing better weather information via ITS applications in the not too distant future.(*999*)

Road Weather Management Decision Support

As identified by the FHWA Road Weather Management Program two problems stand out in RWIS: 1) There are consistent complaints that weather information, and the road-condition predictions dependent on it, remains insufficiently timely, accurate, and relevant, and 2) RWIS remains a profusion of disparate environmental information sources, incompatible in communications protocols, and information formatting.(*1000*) In 1999, FHWA sponsored the Surface Transportation Weather Decision Support Requirements (STWDSR) project, which defined the decision maker, not the information sources, as central.

More than 100 types of operational information needed for winter road maintenance decisions (at the fourth or lower level of a taxonomy) were defined, which could in turn be divided broadly into four types: Resource status, weather, weather-related road condition, and other road information. The "environmental" information on weather is just part of what is needed. For road-maintenance purposes, weather is usually a predictor of the road conditions that are the immediate interest, and there is a large inferential gap between the two, is primarily due to the fine-scale climactic differences of road versus atmosphere and to the different dynamics and time constants of the atmosphere versus road heat-energy and mass transfers.(*1001*)

The basic decision problem is to choose an alternative with the best, but uncertain, impact on the goals. The uncertainty comes in part from the uncertain causal relationship between a control action that is chosen and its execution by resources in the transportation systems. The true transportation outcomes under winter weather threats are almost always the result of joint decisions among maintenance agencies, other road operating agencies (e.g., traffic management), and road users. All decision-support information acts causally on a decision at the central time, and all uncertainty comes from flawed observation of data in the past and flawed translation to the central time. As all decisions have risk, or uncertainty in the outcome measures of the alternatives, maintenance managers request reliability indicators or “worst case” values for their information.(*1002*)

The development of a prototype winter Maintenance Decision Support System (MDSS) is part of FHWA’s Office of Transportation Operations (HOTO) Surface Transportation Weather Decision Support Requirements (STWDSR) initiative. The objective of the MDSS effort is to produce a prototype tool for decision support to winter road maintenance managers. The MDSS is based on leading diagnostic and prognostic weather research capabilities and road condition algorithms, which are being developed at national research centers. Several candidate road weather technologies currently exist at national laboratories, but the new technologies needed to be integrated, refined, and tailored to address road maintenance weather issues. The project will also identify new and focused research that must be conducted to address specific winter maintenance decision support needs not addressed by current technologies. The project began in 2001, with work with state DOTs on the development of a prototype MDSS, which is moving into demonstration and evaluation of selected prototype components in an operational environment. The MDSS project goal is to develop a prototype capability that: (*1003*)

- Capitalizes on existing road and weather data sources.
- Augments data sources where they are weak or where improved accuracy could significantly improve the decision-making task.
- Fuses data to make an open, integrated and understandable presentation of current environmental and road conditions.
- Processes data to generate diagnostic and prognostic maps of road conditions along road corridors, with emphasis on the 1- to 48-hour horizon (historical information from the previous 48 hours will also be available).
- Provides a display capability on the state of the roadway.
- Provides a decision support tool, which provides recommendations on road maintenance courses of action.
- Provides all of the above on a single platform, with simple and intuitive operating requirements, and does so in a readily comprehensible display of results and recommended courses of action, together with anticipated consequences of action or inaction.

Precision Application to Manage and Reduce Chemical Applications

Acquisition of precision application equipment is a large cost center for winter maintenance operations, and often requires a business case or justification for the purchases. Thus, the objectives of applying new technology to winter maintenance operations are: (*1004*)

- Reduction in accidents
- Return on investment
- Reduced chemical usage and improved environmental stewardship

Benefit-cost analysis performed by Iowa researchers demonstrated that integration of the newer emerging technologies in the concept vehicle met the business case, reducing accidents, increasing mobility, reducing adverse environmental impacts, and generating positive economic effects. (1005)

Mechanical removal of ice and snow can be facilitated by preventively treating roadways with road salts. Such pre- or early-storm applications will often minimize the overall amount of road salts required to achieve the desired surface friction level. Reacting to a snow and ice event and applying road salts after a bond has formed requires additional salt to be used; proactively treating the road surface just prior to the event, or just as it commences, can prevent a bond, simplify the mechanical removal and expedite the achievement of bare pavement.

Some transportation agencies choose to leave a small amount of snow on the road before salt is applied in order to keep the salt from bouncing or being blown off the road surface by passing traffic or wind. This can increase the amount of salt required to "de-ice" or melt the snow packed on the road, and is not as efficient in retaining salt on the road as other methods (e.g. slower spreading speeds, pre-wetting, "zero-velocity" spreading, etc.)

General overviews of technology available and disadvantages and advantages of their use are summarized below from the Transportation Association of Canada and a TRB Report on Snow Removal and Ice Control Technology. (*1006*)(*1007*)

Spreaders, Spread Patterns, and Spreader Controls

The total amount of salt used for winter maintenance is significantly influenced by the characteristics of the spreader equipment.

- Spreader controls should be capable of delivering several precise application rates.
- The application rate should be consistent whether the spreader is full or nearly empty, regardless of material variations, or temperature changes.
- When purchasing new equipment, transportation agencies should require test results from suppliers to confirm that the equipment will achieve precise application rates under all conditions.
- Spreaders must operate in a severe environment of low temperatures, high moisture, poor visibility, and corrosion, often with limited maintenance. Controllers must be easy to load, and simple to operate.
- Ideally, a spreader should be adaptable for other tasks, or the hopper should be easily removed so the trucks can be used for other operations during the summer.
- Hoppers must be constructed so that all sand and salt can be easily removed from the body.
- Spreaders should be fitted with screens to ensure that frozen clumps of material or other contaminating material that would jam the chain/conveyor mechanism are not loaded into the spreaders.

- Cab shields should be fitted to assist in loading the spreaders to ensure that all loaded salt enters the box, and material is not spilled over the truck.
- Spreaders should be manufactured from a material that will resist corrosion. Special chlorinated rubber primers and epoxy-based primers will increase coating life. Stainless and galvanized steel, and fiberglass bodies are available but can be relatively expensive. High strength, low alloy self-coating steel, used with good surface preparation and special primers has been proven to provide a cost effective body life of up to fifteen years. Manufacturers also supply spreader bodies constructed of fiberglass. These bodies are lighter and thus provide increased payload possibilities, but are also more expensive than steel.
- Electrical wiring for controls and lighting, and hydraulic components must be enclosed in vapor proof, or sealed systems.
- Neoprene spinners are frequently used to improve durability and spreading efficiency.

Spread Patterns

Salt and sand application methods can be modified to meet differing requirements.

- Salt use sometimes can be reduced by applying the salt in concentrated locations (e.g. windrowed on the crown), rather than being spread uniformly or broadcast across the entire road surface.
- In most cases solid or pre-wetted salt should be applied in a continuous narrow windrow along the centerline of the road. The concentrated mass of material minimizes the tendency of the material to bounce or be blown off the road by passing traffic. Salt going into solution drains down the crossfall of the road, and can migrate under packed ice and snow; a uniform section of road is then bared off initially along the center of the road to provide two-wheel stability for traffic. Application in a windrow is achieved without using the spinner, by dropping the material from a chute. Windrowing on the centerline will not work if the crown of the road is not consistently on the centerline, or the road surface is badly deteriorated which could cause the salt brine to pond in some areas. Centerline application is also not appropriate if the entire road surface is slippery and immediate de-icing is required. In these situations, higher salt application rates may be needed across all traffic lanes.
- Application ahead of the drive wheels can provide improved traction under the drive wheels of the spreader vehicle. Application close to the driver's cab also enables the driver to monitor the application to ensure that material flow has not been impeded.
- Hopper Spreaders

Conventional hopper spreaders provide good control of material application and dependable service. However, they are the least versatile for other operations during the off-season. New hopper designs, including rear-discharge, slide-in units with a longitudinal agitator bar and belt conveyor, are gaining popularity, particularly for pre-wetted applications.

Tailgate Spreaders and Reverse Dumping of Dual Dump Spreaders

The primary limitation of tailgate spreaders is the inconvenience of raising the dump box and the possibility that the box will not be raised high enough to ensure that sufficient material is dumped in the hopper to provide consistent delivery. The rear discharge restricts the operator view of the operation and ability to ensure that the material is being discharged at the right location. The vertical clearance and the upward and rearward shift of the center of gravity when the box is raised can cause instability and is a safety concern in some areas.

Dual dump spreaders were developed to overcome problems identified for tailgate spreaders while still providing a multi-purpose spreader that could be used year round. They function as regular rear dumping bodies when not being used to apply winter maintenance materials. Disadvantages of this spreader are the high weight compared to a regular dump truck, and the need to raise the body while driving to move the material to the front of the truck. This reduces the truck's stability and care is required by the operator to ensure that sufficient material covers the cross conveyor at the front to maintain a precise application rate. The pivots have been a source of failure and replacement is expensive.

Multipurpose Spreaders

Multipurpose spreaders incorporate most benefits of the other spreaders. A recent design makes use of a U-shaped box to ensure that no material hangs up in the box and that all material can be easily removed from the box at the end of the shift. Material is either discharged in a windrow using a chute for concentrated action, or spun across the lane using spinners. The spreader provides precise application rates and all the advantages of distribution in front of the rear wheels. Cross conveyors are easily removable during the summer so that there is no tare weight penalty. The units are lightweight and provide year round use, and the body can be easily switched to carrying construction materials (simply by installing a pan or tray across the floor conveyor). As these units can carry substantial loads, care must be exercised to ensure that adequate truck components, axles, springs, and wheels are specified to carry the load. This is particularly important on combination units that are also equipped with snow plows.

Rear-Discharge Spreaders

Based on the premise that no salt particle should be placed dry onto the road surface, and that fine salt is the gradation of choice for prompt dissolving and melting, certain spreader design characteristics cater better to liquid and fine salt use in prewetted applications. The salt must be of a fine gradation in order for it to retain the brine moisture content and fine salt does not travel as easily on certain chain-type conveyor systems. These spreaders allow a "high-ratio" salt application rates up to 255 liters per ton of salt, or at a ratio of 30:70 liquid-to-solid by weight. This requires a large capacity of liquid onboard and adequate pumping capability that may not be possible or practical on a conventional retro-fitted unit. They are either frame-mounted or slide-in, rear-discharge v-hoppers can stand on self-contained stilt legs in the maintenance yard, and remain tarped until needed. Pre-wetting liquid can be applied directly on the spinner, that is designed to spread the material across a given area of the road cross section. Areas that only have access to coarser salt may find that the liquid component must be reduced since saturation can be achieved with less liquid.

Electronic Spreader Controls

All spreaders require an accurate electronic controller to ensure that the appropriate application rate is achieved. Simple hydraulic circuits, used to maintain a steady application rate, are still in use in many transportation agencies. This equipment starts to exceed the desired application rate as soon as the truck speed drops below the design speed and an excessive salt application is then dumped on the road. Early models of the electronic controllers were not dependable and required extensive maintenance. The new models are improved but can still require patience.

Modern spreaders use electronic groundspeed spreader controls to provide consistent, accurate application rates. The truck speed is monitored from the truck's speedometer drive, and the spreader output is adjusted to maintain a steady output at the set rate per kilometer. Both open loop and closed loop systems are available to monitor material flow and provide increased accuracy of the spread rate (closed loop systems provide confirmation of the actual application rate). Electronic controllers automatically increase the output rate if a second spinner is actuated (if so equipped) to treat truck climbing and turning lanes. With some electronic units, calibration settings can be applied electronically using infrared controls.

Manufacturers can now provide units that record, for printing, information about the amount of salt used, the time it was used, and the associated application rate, for analysis and control by the transportation agency. Information that is captured and logged can include: amount and type of material applied, gate position, run time, blast information, average speed, spread width/symmetry, etc. Units are also available that incorporate global positioning systems (GPS) for automated vehicle location (AVL) and to identify where the material was discharged (either generating a passive history or a live transmission). There is currently no industry standard format in place for this information reporting; it is difficult to compare and combine the information from the units supplied by the various manufacturers.

Rearward Casting Spreaders (*including Ground-Speed and Zero-Velocity Spreaders*)

With normal spreaders, a high percentage of the dry salt applied to the road bounces off the road due to the combination of the impact of the granules hitting the pavement, and the speed of the spreading vehicle. Most transportation agencies now theoretically constrain their spreading speed to avoid wasting salt due to the scatter effect at higher speeds. In practice however, speeds of 40 km/hr and more are not uncommon. If salt could be applied at higher speeds, combination units would be much more productive as the unit could apply salt at plowing speeds. This would allow for safer operating condition since trucks could move at the speed of traffic. Casting material rearward has shown potential for salt use reduction by increasing the percentage of applied salt that is retained on the road, and in the required location on the road. This is a concept by which the salt is discharged rearward at exactly the same speed as the spreading vehicle is traveling forward. The two velocity components cancel each other causing the salt to drop on the road as if the spreading vehicle was standing still.

To-date, the available equipment has experienced some operational problems such as material caking, uneven discharge and mechanical complications (fan/blower) under certain conditions. One manufacturer makes use of a shielded-spinner at the mid-chassis discharge location, discharging at a point just beyond the width of the rear wheels where the material is "flung" rearward. Another manufacturer used a high-speed blower to discharge the salt rearward. This results in a large cloud of salt that can be hard to control and may be affected by side winds. Also, the spreader units may not suitably handle pre-wetted material or finer sands. Though useful for salt applications, there is no good way to spread sand with these spreaders. Modifications are being developed and it is anticipated that further refinements will enable transportation agencies to reduce application rates and increase application speeds using this concept.

Ground-speed spreaders and prewetting are recommended to permit high-speed spreading of salt in a windrow patter on bare pavement. Equipment manufacturers and material suppliers have attempted to overcome these problems by using spreaders designed to place the material on the road at zero velocity or in a controlled location, and through the application of small quantities of deicing liquids to the dry material before it is applied. The specialized spreading equipment is referred to generically as ground-speed spreaders, and the application of liquid deicer is referred to as prewetting. Prewetting did not significantly improve material placement over dry salt at a spreader speed of 34km/h and is therefore not recommended as a means of reducing material loss during spreading at current operating speeds. At 60km/h, prewetting made a small but significant improvement over dry rock salt in material placement using a centerline chute and a ground-speed spreader, and it is therefore recommended as a means of reducing material loss during salt spreading at high speeds.(*1008*)

Zero Velocity Spreaders can optimize the use of deicing material through the controlled distribution of the material. The material is dispensed at the same velocity of the forward motion of the equipment. This helps reduce bounce and whip off allowing more of the material to remain on the pavement, saving up to 40 percent in de-icing material and reducing salt runoff to the surrounding environment. The zero-velocity spreader applies material in such a way that the material lands at a velocity that is zero relative to the road surface. The spreaders, which mix and spread liquid and solid deicers, use technology that enables plow trucks to apply chemicals at speeds as fast as 35 miles per hour, which increases efficiency and safety in terms of the speed differential between plows and traffic. In 1994 and 1995, Iowa was the FHWA test site for the zero velocity spreader, at that time a new concept in roadway chemical spreaders. Mn/DOT tested eight zero-velocity spreaders that same season and discovered savings of 30 percent or more. Even in 1995 when the spreader was priced at around $10,900 compared to $2,000 to $2,500 for a common spreader, tests indicated that material savings compensated for the increased cost.(*1009*)

At PENNDOT, during the 1995-1996 winter season, the use of 4 trucks equipped with the system resulted in average material savings of about 50 percent and a cost savings of about $2 per mile per truck. In 1997-1998, PENNDOT purchased 95 additional ZVS units and another 150 units in 1998-1999, equipping all of Pennsylvania's Interstates and limited access highways with ZVS. The systems were expected to pay for themselves in about 1½ years. PENNDOT also equipped every new dump truck with a ground speed control salt spreader system known as the AS2 system, an on-board computer adjusts the discharge rate of salt and anti-skid material according to the speed of the truck. The truck's operator inputs how wide the material needs to be spread and the desired tons of salt and anti-skid material to be used per lane mile. At intersections or other areas that may require a heavier application of salt, the operator may use a "blast button" for a preset number of seconds.(*1010*)

Pre-Wetting Solid Materials to Minimize Bounce

Applying liquid melting agents or pre-wetted salt can prevent or clear frost more quickly than solid salt. Pre-wetting is a commonly used practice to improve retention and keep salt on the road by reducing the effects of bouncing, blowing and sliding of the salt or sand particles. This technique uses salt brine, liquid calcium chloride or other liquid chemical to wet the salt or salt as it is spread on the road. Pre-wetting also enhances the melt action of the chemical present by speeding the dissolving of salt and the formation of brine.

Spraying stockpiles and truck loads has also been termed pre-wetting or "pre-treating", but this practice is not as practical since the granules are not uniformly coated, the liquid may drain out of the solid material and the performance on the road is not consistent throughout the route. Therefore, pre-wetting should be done by spraying the salt as it is discharged from the chute, or at the spinner. A straight liquid will avoid the endothermic cooling effect that solid salt can have on pavements. Practical considerations relate to the gradation of the salt being wetted, the maximum liquid to solid ratio that can be mixed, the amount of mixing action, caking/clumping concerns, etc.

Pre-wetting is commonly considered to have the following benefits:

- The deicing effect of the salt spread onto the highway surface is achieved more quickly, with time lag significantly reduced or even eliminated.
- A significant proportion of the salt spread by dry spreading techniques ends up o the channels of the highway or on the highway verge because of particle bound and the action of traffic. It is also claimed that this may well increase the longevity of the salt action on the highway surface, with a direct result of possible reductions in salting frequency.
- It is claimed that significant reductions (on average one-quarter, but up to one-third) in the overall amount of salt use can be realized.
- Because less salt can be used, and more of it stays o the road surface, pre-wetting techniques can lead to significant environmental benefits compared with traditional dry salting techniques.
- Damage to concrete structures is likely to decrease with high-purity prewetted salt although a calcium chloride wetting agent may cause more damage than a sodium chloride one.

While pre-wetting may provide significant potential for reductions in salt use, it can increase the complexity of the required equipment and controller. Pre-wetting requires additional equipment. Storage tanks for the liquid(s), or brine making equipment are required, along with pumps to load the spreaders. The on-board liquid capacity and loading time are factors to consider. Additional maintenance is required such as ensuring that the liquid filters, lines and nozzles are purged and the equipment cleaned at the end of the storm to prevent clogged lines and seized equipment. Pprewetting is not universally acclaimed. A University of Iowa study found that prewetting at the stockpile had little effect on the ability of the abrasives to remain on the pavement surface when delivered and that prewetting while loading or final prewetting at the truck spinner was found to help keep salt and other chemicals on the road surface when first delivered but may do little to help material stay on the road.(*1011*) Brine is a method that has mixed reviews. While brine has uses les salt, melts faster, and dries road surfaces faster than prewetted salt, maintenance areas must have equipment for spreading prewetted salt, as brine is not suitable for use during heavy snowfalls. If the road surface is very wet or precipitation is ongoing, there is a risk that the brine will be excessively diluted and the liquid will refreeze.(*1012*)

The Transportation Association of Canada outlines the following recommended practices for pre-wetting: (*1013*)

- Adjustment of the spray nozzles is critical. Tests by one state department of transportation showed that they never achieved more than 60 percent coverage of the salt.

The remaining 40 percent of the pre-wetting liquid was effectively being applied directly on the road. Also, as the wetting agents are corrosive, it is important that corrosion resistant nozzles and non-contact pumps are used to ensure dependable performance.

- Utilize the latest research on optimum liquid application rates; extensive testing is currently being performed.
- The application pumps on the spreaders should be regulated by ground speed controllers to ensure the correct liquid application rate is maintained under all conditions.

A recent study on the possibility of decreasing the use of salt by changing the spreading method found that saturated brine (20 percent) is spread more evenly across the road than prewet salt, and more salt from the brine is still present on the road 2 hours after spreading as compared with prewet salt. Several statistical analyses were carried out, giving a useful picture of the amount of residual salt on the roadway and indicating that more salt from brine than from prewet salt is active on the roadway and that degradation of residual salt is crucially affected by high traffic intensity.(*1014*)

Fixed Automated Spray Technology (FAST)

Areas that experience a high number of frosting or black ice events each winter season have traditionally required a significant amount of labor and road salt to manage properly. Maintaining material on the road to deal with frosting events can be difficult and expensive on roads with higher traffic volumes. Applying the material just prior to an anticipated event is ideal. Fixed, automated liquid anti-icing spray systems, called FAST systems, have been developed to help organizations better manage these demands and place the right material, in the right amount, in the right place and at the right time. Fully automated FAST systems have been developed that use sensors embedded in the roadway and mounted on bridge towers, elevated ramps, or intersection approaches. Site mounted computer hardware and software and nozzles embedded in the roadway or the parapet wall automatically apply liquid anti-icing chemical to the road surface just prior to a forecasted icing event.

The information in the remainder of this section has been previously profiled by AASHTO, FHWA, and TRB in relation to "Smart Bridges."(*1015*)

Brooklyn Bridge Anti-Icing/Deicing System Paves the Way for Others

The New York City Department of Transportation developed a fixed anti-icing system that is comprised of a control system, a chemical storage tank containing liquid potassium acetate, a pump, a network of PVC pipes installed in roadside barriers, check valves with an in-line filtration system, 50 barrier-mounted spray nozzles, and a Dynamic Message Sign (DMS). The DMS displays warnings to alert motorists during spray operations. A Closed Circuit Television (CCTV) camera allows operators to visually monitor the anti-icing system. Each self-cleaning nozzle delivers up to three gallons (11.4 liters) of chemical per minute at a 15-degree spray angle. This angle minimizes misting that could reduce visibility. Two nozzle configurations were implemented to investigate different spray characteristics. On both sides of one bridge section, nozzles were installed 20 feet (6.1 meters) apart for simultaneous spraying. On another section, sequential spray nozzles were mounted on only one side of the bridge. Due to concerns about bridge deck integrity, nozzles were barrier-mounted rather than embedded in the road surface.

System operators consult television and radio weather forecasts to make road treatment decisions. When anti-icing is deemed necessary, “ANTIICING SPRAY IN PROGRESS” is posted on the DMS and the system is manually activated to spray potassium acetate on the pavement for two to three seconds, delivering a half-gallon per 1,000 square feet (1.9 liters per 92.9 square meters). Operators then review forecasts and view CCTV video images to monitor weather and pavement conditions. If there is a 60 percent or greater chance of precipitation and pavement temperatures are predicted to be lower than the air temperature, maintenance crews are mobilized to supplement anti-icing operations with plowing to remove snow and ice.

An analysis of maintenance operations found that bridge sections treated with the anti-icing system had a higher level of service than segments treated by snowplows and truck-mounted chemical sprayers. Road segments treated by the anti-icing system have less snow accumulation than sections treated conventionally, improving roadway mobility and safety in inclement weather. The system was most effective when chemical applications were initiated at the beginning of weather events. If potassium acetate was sprayed more than an hour before a storm, vehicle tires dispersed the chemical necessitating subsequent applications. The system also improves productivity by extending the life of bridges and minimizing treatment costs associated with mobilizing maintenance crews, preparing equipment, and traveling to treatment sites on congested roads, in addition to minimizing salt runoff to the environment. The DOT would like to expand the anti-icing system by integrating a Road Weather Information System (RWIS) with the control system, the CCTV camera, and the DMS to improve treatment decision-making. A wireless or fiber optic cable communication network is envisioned for connectivity of these elements. Deployment of the system on the entire Brooklyn Bridge and on other local bridges is also anticipated.(*1016*)

Guidelines for Prioritizing Bridge Deck Anti-Icing System Installations

A 2003 report for the Mid-America Transportation Center and the Nebraska Department of Roads (NDOR) developed guidelines for prioritizing bridge deck anti-icing system installations. This research was undertaken with the objective of developing a decision-support tool that can aid NDOR with the prioritization of bridges for installation of automatic anti-icing systems. Based on a literature review on automatic bridge anti-icing systems was conducted, factors considered important in the installation of automatic anti-icing systems included accident history, bridge alignment, weather, traffic, and bridge distance from maintenance yard. The factors were included in a database and decision-support tool that assisted NDOR in narrowing the list of candidate bridges for NDOR. Some of the sources and GIS layers included were: NDOR bridge inventory, NDOR accident database, archived weather data from the High Plains Regional Climate Center and the National Weather Service, Nebraska streets database, Nebraska rivers and streams database, and NDOR maintenance yard data.(1017)

Calibration

Regardless of the spreader or Fixed Automated Spray Technology chosen, the service provider must have faith that the application rate settings are indeed accurate. Spreaders should be calibrated to avoid the over-application of de-icing agents or abrasives and use no more than is necessary for snow and ice control.

- A calibration policy should be established to assure the material settings are correct. Preferably, if application is by weight, then calibration should also be by weight. Calibration checks or recalibration should take place several times during the season:
    - Calibration should occur after repairs.
    - Calibration should occur when distribution calculations show a discrepancy between theoretical and actual.
    - Calibration spot-checks on units in the fleet should be scheduled throughout the season.
- Operators should be able to easily track fuel and material usage.
- In order to apply the proper amounts of anti-icing, de-icing and/or traction enhancing materials, spreading equipment should be calibrated for both solid (typically salt) and liquid (typically salt brine, calcium chloride, magnesium chloride or IceBan/MAGic) applications.
- To ensure proper placement of materials, equipment affecting the spread pattern should be adjusted to match the required use. Critical system components include the automatic ground speed controller, the flight chain or belt, the gate opening, the chute, the liquid nozzles (if applicable), the spinner and the deflectors.
- Maintenance districts should calibrate their equipment regularly and train their operators so they understand the reasons behind pre-treating application practices and quantity of materials to be applied under specified conditions. Training presentations should be available at each District. Presentations should be showing the exact details on how calibration is performed and should be reviewed each year before beginning calibration.
- Because of the adverse conditions under which snow and ice equipment operates, periodic checks should be made to confirm proper settings. Calibration is necessary to find out how much salt and/or abrasives are discharged at each auger setting.
- All truck and spreader combinations, both Department owned and rented, should be calibrated every year. Calibration should be completed prior to the snow season. Calibration can be done using sand or other abrasive materials if the truck is used on routes where salt is not spread. Department personnel should calibrate non-municipal rental trucks equipped with spreaders.
- Those servicing state roads under lump sum agreements typically are responsible to calibrate their own equipment. Department personnel may assist with their calibration programs if requested.
- As part of calibration all Department trucks should have their augers and spinners mechanically restricted. Augers are to be restricted to spread no more than the maximum amount of material approved for the route or routes to which that the truck is assigned.
- Spinner speeds should be restricted so that no spinner will spread more than a ten-foot width of material when the truck is stationary.
- Records should be kept for each piece of equipment. Calibration information for each spreader is stored electronically on a laptop computer. If any controller is replaced, calibration information can be downloaded to the new controller as a starting point to recalibrate.

Operational Support Equipment

Accurate records should be maintained of the locations of de-icing agents and abrasives application and the quantities of de-icing agents and abrasives used. Various types of equipment support the winter maintenance program either by helping manage the operations by generating useful data or by supporting the service delivery itself.

Equipment is available to assist with meeting the following necessary functions for environmental stewardship and effective minimization of materials application:

Material Usage Monitoring

Loader Mounted Electronic Weighing Equipment

Loading extra material onto a spreader can lead to overloading or the temptation to over apply the salt. In the past, operators tended to load a little extra salt as there was no exact method of determining the amount of material loaded, and they did not want to run out without completing the route. Overloaded trucks also contribute to contamination in the area of the salt storage facilities. Salt heaped above the side boards is thrown off the trucks as they negotiate curves to exit the yards.

- With electronic scale control systems operators can more precisely load the right amount of salt. This device is a relatively inexpensive, durable, and accurate weighing device consisting of a transducer load cell mounted to the loader bucket arm. These devices can measure a predetermined load size for the scheduled route (length of route X application rate + a limited contingency amount for bridge decks, intersections, etc.). Models are available that will record with the loader in motion so that the loader operation is not impeded.
- The units will record the amount loaded for future printing and analysis. Though the equipment can be overridden, it provides the operators with a mechanism to accurately measure and control the amount of material loaded on the spreaders.

Truck Scales

Weighing the trucks as they enter and leave the maintenance yard is one way of determining the material loaded and the resulting spread rate for the serviced route. This function can be automated with a weigh-in-motion pad that tracks the equipment movement and can serve to reconcile the data from the spreader controller and other documentation.

Liquid Meters

Pump meters will likely be used to measure delivered brine, but not likely be on each pre-wet unit.

- A meter should be in place at the brine supply facility, whether the source is hauled brine or manufactured brine, in order to track loading times and quantities.
- A cross reference should be incorporated in the electronic log to identify the truck loaded for future reference.

Automated Vehicle Location (AVL)

- Tracking equipment movements along with the services provided is possible via proven GPS receivers/ transmitters and software.
- This electronic record can be actively followed realtime or can be passively recorded for later analysis.
- AVL can support a route optimization exercise, to rationalize the number of trucks required and thus the expected salt to be used on the roads serviced.
- This equipment can provide operational support to greatly enhance the monitoring of salt usage, to demonstrate prudent usage and to correlate with the achievement of the required level of service.

Material Loading and Handling

Sand and chemicals should be stored and handled in a manner to minimize any contamination of surface or ground water. Care should be taken to prevent runoff from chemical tanks or chemical treated stockpiles. Covered storage for dry chemicals is preferred.

Avoiding Contaminants to Materials

- As noted by Oregon DOT, chemicals and sanding materials should be free of contaminants known to cause water quality problems. Some of these include: Arsenic Barium Cadmium Chromium Fluoride Lead Mercury Nitrate Selenium Other heavy metals Hydrocarbons.

Bulk Salt Handling by Loaders

- Extensive environmental contamination has been identified in the area of salt storage yards. Much of this contamination results from poor salt handling practices.
- Conveyors are available which are designed to allow salt trailers to dump directly into the conveyor for movement into the storage facility.
- Loaders used to fill spreader vehicles are often fitted with buckets that are too large for the spreader hopper bodies, resulting in spillage. Though they have a slower production rate, smaller buckets are available for most loaders. Side dumping bucket attachments can also be used to provide quick precise loading.

Bulk Material Conveyors

- Whatever equipment is used for moving salt, it should provide a way of tracking the flow so the quantities can be reconciled.
  - Pre-loaded drop-hopper loaders meter salt into spreader trucks.
  - Overhead silos can be pre-filled with salt to similarly meter salt into spreader trucks.
  - Pneumatic handling equipment can handle fine material that is used for either direct application onto the road or for blending with sand.

Sand/Salt Blend Mixers

- Ideally, blended winter sand stockpile are put up in favorable, dry conditions. Relatively dry sand stored indoors should not require more than 1-2 percent salt by weight; more moisture in the sand may require more blended salt (up to 5 percent), but the purpose still is to keep the sand free-flowing, and not to support melt action.
- Traditionally, blending took place on the apron to the storage shed, with several buckets of sand spread level, followed by one bucket of salt trickled on the surface; the resulting blend was loaded in the dome, and the process was repeated. Though highly inefficient, it was also highly inaccurate, and produced sporadic result on the pavement surface. Equipment to support high-production stacking and uniform, light blends now involves a form of dual-auger pugmill or a twin conveyor feed. In either case, two supply lines are metered to an accurate ratio and the final conveyor stacks the completed mixture.

Brine Production Equipment

- The concentration should be checked with a hygrometer to measure the specific gravity of the solution. The percent of saturation is determined by reference to specific gravity charts for the specific solution temperature.
- Water supply flow rates are a critical factor. Production sites may require cisterns to ensure adequate water supply where well production rates are poor.
- Manufactured salt brine can be pumped directly into tanks mounted on the spreaders or transferred to holding tanks at the maintenance yards.
- Stored brine will normally stay in solution as long as there is not evaporation or a drop in temperature below eutectic.
- Corrosion inhibition requirements can complicate the brine manufacturing process.
- Additives such as rust inhibitors may complicate long-term storage, in which case agitation or recirculation could be considered.

Brine Delivery Equipment

- Sampling containers and a refractometer or hygrometer should be available for sampling and testing the concentration.

WisDOT's Winter Maintenance Concept Vehicle (*Wiscplow*)

The Wisconsin Department of Transportation (DOT), in cooperation with eight Wisconsin counties, embarked on a 4- to 5-year effort to implement advanced technologies in winter maintenance vehicles. The effort equipped winter maintenance vehicles are equipped with differential Global Positioning System (DGPS) receivers and numerous additional sensors that collect environmental data (e.g., pavement and air temperature), equipment status data (e.g., plow up/plow down), and material usage data (e.g., salt application rate). These data are telemetered to a dispatch center and recorded on magnetic media for later downloading. Data are transmitted and recorded as often as every 2 seconds. A geographic information system (GIS) application, dubbed "Wiscplow," was developed and initially deployed for testing within participating counties, combining vehicle data with manually entered data (e.g., storm durations, vehicle configurations, and labor and equipment cost rates) and with spatial data representing roadway centerlines attributed with functional class, number of lanes, patrol sections, and route systems. Outputs include reports on computed performance measures (e.g., cycle time and hourly average salt application rate by patrol section and storm) and decision management tools (charts, graphs, and maps) showing relationships among performance measures (e.g., salt application rate versus pavement temperature by patrol section and storm).(*1018*)

Winter operations performance measures and decision management tools were identified, defined, developed, and refined in an iterative process, with state and county transportation decision makers, that included a series of meetings, communications, and two workshops.(*1019*) Concerning material usage, Wiscplow can generate up to 19 performance measures and chart relationships among them. Sample performance measures include average pounds of salt per lane mile for each operator and event, hourly average for each patrol section of gallons per lane mile of anti-ice liquid, tons of salt used for each event and patrol section, and cubic yards of sand used for all events for each patrol section. Sample charts include average pavement temperature, salt, and sand application rates by patrol section for a winter storm event and seasonal cumulative salt use on each patrol section. Concerning equipment usage, Wiscplow can generate performance measures such as cost for each attachment unit for each event and patrol section, cycle time for each patrol section and storm, and total operating distance, season-to-date, for each attachment unit. Charts of relationships among these measures include production rates for equipment units by roadway class and cumulative operating hours for units of an attachment class. Concerning labor, Wiscplow can generate labor hours per lane mile for each patrol section and storm and percentage of labor costs attributed to clean-up for each storm. The map display can be queried and attributes displayed for roadways, patrol sections, and each data point in a vehicle track, including operator name, time, air temperature, pavement temperature, vehicle speed, front plow status, right-wing status, left-wing status, and scraper status. The user can scroll down to see material application rates, on which patrol section and route the vehicle is traveling, and the route measure of the vehicle's location. Ultimately, Wiscplow is intended to help transportation agencies at multiple levels (i.e., central office, districts, and counties) to measure performance of winter operations. (*1020*)

Monitoring, Recordkeeping, and Decision Support in Maintenance Management Systems

Evaluating Treatment Effectiveness

In addition to evaluations of chemical residue, friction, and changing temperatures during a storm, it is beneficial for the personnel of each maintenance area to conduct a post-storm evaluation of the treatment effectiveness. This can help identify areas needing improvement and changes that can be made in the treatment strategy. A post-season review of treatment effectiveness is likewise helpful. It can help identify where changes are needed in equipment, material, and route configurations, and can begin a process of engineering an anti-icing program to fit the exact needs of a site or agency. It can also help identify where changes in personnel procedures and training are needed to improve the effectiveness of the winter maintenance program.

Advanced ITS technologies are expected to automate winter operations performance measures and provide them in real-time to snow-fighting supervisors. The idea is to measure outcomes like roadway friction rather than just outputs like the time and amount of salt applied. Field studies of roadway friction measurement have been done at the NASA Wallops flight facility, and in Iowa, Minnesota and Michigan. There has also been an ongoing, coordinated study in Norway.(*1021*)

The data logging and reporting capabilities of loader scales, electronic controllers and GPS/AVL systems can assist transportation agencies in more accurately tracking their salt use. Progress in implementation of best salt management practices can be measured in improvements to the fleet. Monitoring and record keeping should include:

- Type and amount of winter materials being placed.
- Percentage of fleet equipped with electronic spreader controllers.
- Percentage of fleet equipped with pre-wetting.
- Percentage of fleet equipped with direct liquid application.
- Percentage of fleet calibrated annually.
- Percentage of staff trained in equipment use.

Decision management tools allow managers to visualize relationships among performance measures and make well-informed decisions on their business practices.

Environmental Performance Measures for Winter Operations

In 1997, Pennsylvania DOT began developing an environmental management system, to provide a comprehensive approach to integrating environmental considerations throughout the agency's complex operations. Over the last two winters, Engineering District 10 maintenance staff have developed and implemented procedures and tools to help them curtail the amount of anti-skid, anti-icing and de-icing material used while still exceeding customer expectations for safe and efficient winter travel. Preliminary survey results indicate that District 10 staff saved more than 3,000 tons of material agents using their improved procedures. By reducing their use of materials District 10 staff not only saved more than $100,000 but also significantly reduced the impact on vegetation and groundwater.(*1022*)

PENNDOT Strategic Environmental Management Program Maintenance Performance Measures pertaining to winter operations and snow removal were:

- Salt Usage per Snow Lane Mile (lbs) 250 lbs.
- Percent of Material (salt, skid) Deliveries with Penalty <10 percent

Non-Environmental Performance Measures for Winter Operations

The Wisconsin Department of Transportation sponsored a synthesis report which investigated major transportation and municipal Web sites in the U.S. and Canada for working methodologies for measuring the efficiency and effectiveness of winter operations, and found the following initiatives of interest.

The Municipal Performance Measurement Program (MPMP) is a new initiative designed to provide Ontario taxpayers with useful information on service delivery, and municipalities with a tool to improve those services over time. The program requires municipalities to measure their performance in nine core municipal service areas, including Roads. The Ministry suggests that municipalities use the following formulae to measure their performance in winter road services:

- Operating Costs for Winter Control—operating costs for winter control maintenance of roadways, divided by total lane kilometers maintained in winter, equals total cost per lane kilometer. This is a measure of "efficiency," to determine operating costs for winter control maintenance of roadways per lane kilometer. The objective is efficient winter control operation.

- Condition of Roads—number of paved lane kilometers rated as good to very good, divided by total number of paved lane kilometers tested, multiplied by 100. This is a measure of "effectiveness," to determine the percentage of paved lane kilometers where condition is rated as good to very good. The objective is to provide a paved lane system that has a pavement condition that meets municipal standards.
- Winter Event Responses—the number of winter event responses that meet or exceed municipal road maintenance standards, divided by total number of winter events, multiplied by 100. This is a measure of "effectiveness," to determine the percentage of winter event responses that meet or exceed municipal road maintenance standards. The objective is to provide appropriate winter response.

In its report to the Ministry, one of the municipalities—Middlesex—cited the following factors that can influence the results of the performance measurements: severity of the winter (amount of snowfall, incidents of icy conditions); levels of approved service; length of road system (in particular length of major arterial roads within the road system); and proximity to an urban center.

Winter Road Maintenance Ministry of Transportation Ontario (MTO) Tools for Monitoring Maintenance Activities and Performance is focusing on three categories of technology/practices for monitoring maintenance activities and performance. Information can be used to establish data on effects of material applications and rates of application. Under a partnership with Transport Canada, the device is also being tested on airport runways.

- On-board data recording systems incorporating global positioning systems (GPS) have the capability to identify where equipment is working at any time and the location where material is spread.
- Information from these systems can be used to ensure adherence to operational policies such as application rates and spreading speeds. For real-time scenarios and historical data collection, the information provided (equipment activity) is directly related to RWIS information (road conditions).
- Road surface condition monitoring equipment measures friction of driving surface during winter conditions.

The Aurora Project - Decision Support System for Winter Maintenance: Feasibility Demonstration has defined three measures of effectiveness for testing purposes:

- Elapsed time between material application and bare pavement (defined as 10 percent snow cover);
- Rate of clearing (rate of change of snow cover from time of material application until snow cover is 10 percent);
- Binary measure where effective is defined as: snow cover is reduced between t0 and tx, , where t0 is time of material application and x is 30 minutes, one hour, or two hours.

Comparisons should account for differences between test cases due to: air or surface temperature, drifting, initial snow cover, traffic, sunlight and prior applications or retention of salt on the surface between applications. Variables have been introduced to account for each of these. Two types of analysis have been used thus far: sorting of data into similar conditions, and multi-variate linear regression. Sorting analysis is a more straightforward approach but requires a large database because sorting into similar conditions for several variables results in small samples for each relevant action.

The UK Performance Audit Method for Winter Maintenance proposes verification statistics that can also be used to measure the performance of highway agencies and private consultants or whoever decides when roads should be salted, in response to a need for a simple performance audit method that measures the consequences and value of correct and incorrect decisions to salt roads. A type 1 error is defined as when roads should have been salted but were not. A type 2 error is when roads were salted when they need not have been. Up to now these checks have been applied to the forecast providers only.(*1023*)

The Federal Highway Administration is forging ahead in developing performance measures for the new National Transportation System. Among the parameters of interest to snow fighters for which measures are being developed are:

- Speed (miles per hour, transit time, ton-miles per hour, dollar-miles per hour, and passenger-miles per hour);
- Reliability (standard deviation of freight speed, percentage of "on-time" deliveries); "service quality;"
- Response times for various emergencies;
- Various measures of access such as convenience, comfort and personal security;
- Crash fatalities and injuries and property loss;
- Tons of airborne particulate matter;
- Wasted motor fuels and various measures of financial cost.

Performance-Based Assessment of Winter Maintenance Using Level of Service (LOS) can be evaluated using a wintertime pavement condition index (PCI), a set of eight road surface descriptions that can be used to help identify appropriate material application rates to be used during different snow and ice control strategy/tactic combinations for various storm types, pavement conditions, cycle times or traffic flow levels. The performance-based assessment technique allows agencies to determine not only how well they are doing relative to the LOS goals: it provides a mechanism for determining the need for additional resources or improved technology.(*1024*)

Utah made efforts to develop a measure of winter maintenance efficiency that accounts for labor, equipment, and material costs, as well as storm severity and duration, for an established number of land kilometers of given service levels. The expenditures are normalized by the lane kilometers in the maintenance facility's service area and a storm severity index.(*1025*)

In 1996, the Washington State Department of Transportation implemented a system of performance measures and service levels for highway maintenance activities known as the Maintenance Accountability Process (MAP). Initially, the MAP did not include service levels for snow- and ice-control activities based on field measurement, as it does for the majority of other maintenance activities. To gain similar benefits for snow- and ice-control activities, a pilot project that included performance measures, services levels, and field measurement protocols was developed and implemented. Two performance measures were used: the amount of roadway traction provided at the time of a field measurement, and the time taken to regain bare pavement after the end of a snowfall event.(*1026*)

Bringing It All Together: Michigan Vehicle Retrofits and Management System Partnership

Four road maintenance agencies and a regional transit authority worked together to implement a management system for maintenance vehicles in southeastern Michigan. The Southeast Michigan Snow and Ice Management (SEMSIM) partnership formed in 1998 to maintain over 15,000 road miles in the region. Partners include the City of Detroit Department of Public Works, the Road Commission for Oakland County, the Road Commission of Macomb County, the Wayne County Department of Public Services, and the Suburban Mobility Authority for Regional Transportation. The SEMSIM maintenance vehicle management system consists of snowplow systems, a communication system, and central systems. Snowplow systems include sensors on snowplows to record air temperature and pavement temperature., automated controls, and in-vehicle devices. Vehicle status sensors monitor the position of each snowplow (i.e., location, direction and speed), plow position (i.e., up/down), and material application (i.e., salt on/off, application rate). Each maintenance vehicle has automated application controls. Computerized salt spreaders automatically adjust the application rate based upon the speed of the snowplow. In-vehicle devices integrate display, text messaging, and data communication capabilities. These devices include interfaces to snowplow systems and Global Positioning System receivers, which are used for automated vehicle location. The regional transit authority's 900 MHz radio communication system transmits environmental and status data from in-vehicle devices to the transit management center. A Local Area Network, an Integrated Services Digital Network and multiple dial-up telephone lines are used to transmit data from the management center to central computers accessed by both maintenance managers and transit dispatchers.

Central computers display a map-based interface that maintenance managers view to identify weather threats, track snowplow locations, monitor treatment activities, and plan route diversions if necessary. Each maintenance vehicle appears on the map with a color-coded trace indicating where plows have been and what treatment has been applied (e.g., spreading salt, plow down). Text messages from managers, such as route assignments, may be displayed to drivers on the in-vehicle devices. With these devices, drivers can send messages to managers, as well as view temperature measurements and salt gauge. The maintenance vehicle management system can be used to plan treatment strategies, monitor real-time operations, and conduct post-event analysis. Post-event analysis provides maintenance managers with statistics (e.g., driver hours, truck miles, material applied) that can help reduce the costs of future winter maintenance operations. Environmental data from the plows also serves as decision support for transit dispatchers, who utilize this information to make scheduling and routing decisions during winter storms.

The system has helped SEMSIM improve agency productivity and has enabled managers to identify the most efficient treatment routes, reduce equipment costs, and share resources. Automated salt application controls minimize material costs. The system also improves roadway safety and mobility by allowing the partners to assess changing weather conditions and quickly respond to effectively control snow and ice. Although each agency had different types of snowplows, with dissimilar equipment, and diverse operational procedures, this project has facilitated interagency communication that benefits both the public and partners. The SEMSIM partners can collectively procure equipment and services at lower costs than individual agencies, and the partners developed specifications, issued a request for proposals, and contracted with a private vendor to furnish and install system components. Additionally, the partners have agreed to allow snowplows to cross jurisdictional lines to assist one another with road treatment activities when necessary. The transit authority allowed the partners to use excess capacity in their radio communication system. After initial testing proved the system's benefits the system was expanded to equip 290 additional vehicles after evaluation proved the system's benefits. The system hardware and software have been improved and a web-based communication system established. The University of Michigan enhanced central software by designing an application that will automate snowplow routing. As conditions change, the central software will calculate the most efficient routes and automatically notify drivers via in-vehicle devices.(*1027*)

8.5. Winter Operations Facilities Management

Materials Storage

Sand and chemicals should be stored in a manner to minimize any contamination of surface or ground water. In general:

- As previously discussed, all known runoff receptors should be inventoried and protected.
- Care should be taken to prevent runoff from chemical tanks or chemical treated stockpiles. Stockpiles of winter materials should be maintained according to best management practices.
- Covered storage for dry chemicals is preferred.
- All usage of sand and chemicals should be continuously and accurately recorded.
- Vehicle washwater should be managed as well.

Environmental stewardship practices for operation of maintenance facilities and maintenance of stockpiles are reviewed in Chapter 6 on Facilities.

Management of Snow Disposal Sites

Site Security and Environmental Controls

- The sites should be secured to avoid illegal dumping, prevent unauthorized access, by both humans and animals, for safety reasons and to permit safe efficient operation of the site. Security and environmental considerations include:
    - Delineation of the site boundary using perimeter fencing with appropriate signage and a gate with controlled access.
    - Provision of adequate lighting for operations, with the lights focused away from adjacent land uses.
    - Provision of low permeability berms (with or without trees) around the site to prevent uncontrolled offsite release of meltwater. These berms and additional landscaping can also mitigate noise, litter, and visual impacts.

Site Management

- Ensure that a single individual is assigned responsibility for the operation of the site and is accountable for its operation and environmental performance.

- Litter control:
    - With any snow removal and disposal operation a significant amount of small, lightweight debris will be collected and dumped along with the snow. This litter is blown around by the wind and can be a problem both on and offsite.
    - Staff should collect litter regularly to prevent it from blowing onto adjacent properties.
    - The installation of a net or fence around the perimeter of a snow disposal facility can help contain the litter within the site.
    - All debris in the snow storage area should be cleared from the site prior to snow storage.
    - Collect and dispose of onsite litter, debris and sediment from the meltwater settling area in accordance with local waste management legislation.
    - All debris in the snow storage area should be cleared from the site and properly disposed of no later than May 15 of each year.
- If a municipality provides locations for private contractors to deposit snow, they should require disposal according to these recommendations.
- Control emissions (drainage, noise, dust, litter, fumes) to prevent offsite environmental impacts.

Pile and Meltwater Management

- Efficient flow of meltwater to the collection area should be maintained.
- Placing snow in high, compact masses with steep sides all around minimizes the exposure of accumulating sediment on the snowfill surface to seepage and flow.
- Placing snow in a single snow mass rather than several isolated masses reduces exposure of sediment to up-gradient meltwater sources. Sites can also be operated to take advantage of aspect, with snow placed as compact masses at northernmost down-gradient locations so that a snowfill will preferentially recede from uphill to downhill.
  This practice will reduce exposure of down-gradient sediment to meltwater flows as the sediment settles to the pad surface in the final stages of melt (and becomes most vulnerable to erosion).
- Rutting caused by heavy trucks should be kept to a minimum or repaired quickly.
- Fast flowing, high volume channels of meltwater should not be allowed to develop near the piles, to avoid excessive erosion and rutting of the driving and snow pile surface. Sheet flow of meltwater under and near the piles is preferred.
- Avoid blowing, pushing or dumping snow into the watercourse.
- Place hauled snow over the full width of each swale. Sequence placement of snow starting at the downslope side and working upslope.
- Maintain snow in a compact mass with steep sides.
- Maintain setback from all containment berms and from the discharge end of V-swales.
- Maintain pad vegetative cover and re-grade only to ensure V-swale functionality.

- Restrict access and prohibit off-season traffic and on-snow storage uses.

Monitoring

All parties involved should recognizethat snow disposal sites will have an impact on the environment. Most activities should be focused on minimizing or mitigating the impacts. Monitoring aids in the determination of the extent of the impacts, the effectiveness of the mitigation measures taken, and potential adjustments that can be made.

- Baseline condition (benchmarking) of site and surrounding area for future monitoring comparisons should be completed prior to the site being commissioned. Contaminant levels recorded once the site is operational will have to be compared to levels prior to the site opening to give a true indication of any environmental impacts.
- Contamination levels may be monitored at various points around the site and surrounding area. Various factors can effect the number and location of monitoring points including - urban vs. rural location, intensity of site use, size of site, and local requirements.
- Where warranted some or all of the following locations may be monitored:
    - Beneath the site (ground water and soil).
    - Above and around the site (where air quality is an issue).
    - In the snow being dumped.
    - In the melting snow piles.
    - In the collected meltwater.
    - At the discharge site and in the discharged melt water.
    - Upstream (for comparison) and downstream of the discharge site (in the receiving area or mixing zone).
    - In the ground water downstream or downflow of the discharge site.
- There are numerous potential contaminant levels that can be monitored. Important contaminants from a salt management perspective include chlorides, sodium, pH, - metals, Total Petroleum Hydrocarbons (TPH), and suspended solids.

Site Operation

- The efficiency and remaining capacity of the meltwater collection and treatment areas need to be monitored. Over time the collection and treatment ponds will silt-up reducing their capacity and ability to handle the meltwater. Regular removal of the material that has settled out will significantly extend the life of the areas.
- The stability and condition of the snow storage and driving surface. If the surface deteriorates significantly a site may become unusable until major repairs are done.

Record Keeping

The following list includes items and issues for which records should be kept:

- General site information:
    - Number of snow disposal sites and their capacity.

- Percentage of snow disposal site with run-off collection and/or treatment system(s).
    - Percentage of snow disposal sites with a monitoring program (groundwater, surface soil, etc.).
- The volume of snow dumped and when it was dumped.
- An estimate of the melt rate. Can use estimate of volume of snow left, flow into meltwater collection and treatment system or discharge volume. A record of basic atmospheric data is useful in helping to determine the melting rates.
- Debris volume and type. Some sites have instituted a lost and found so residents and businesses can retrieve items such as mailboxes, garbage cans, signs, etc.
- Contaminant monitoring records (point data, trends, levels, etc.). Benchmark and contaminate monitoring data may need to be kept on file even after the site has been decommissioned. Monitoring records may be subject to periodic audits and third party reviews and need to be kept appropriately.
- Maintenance and operation records.
    - Regularly review site operations and look for ways to improve efficiency of dumping, pile management and melting.
    - Look for ways to reduce debris and litter by tracking type and source.

8.6. TRAINING FOR SALT MANAGEMENT AND WINTER OPERATIONS

As noted by the Transportation Association of Canada, successfully salt reduction strategy requires changes in procedures, practices, equipment, and acceptance of new approaches by managers, supervisors, and operators. For this reason, effective training programs must demonstrate the value of new procedures and ensure that personnel are competent in delivering the new program. This can be a significant shift for long-time winter snow and ice control operators, where the past standard of a job well done has been to see how much salt they can put down during their shift: "More is Better" or "When In Doubt – Put It Out."

Over applying sand and salt is as much a decision-making problem as it is a technical one; plow operators can make good decisions with old equipment and they can make terrible decisions with state-of-the art equipment.(*1028*) If an operator is using too much sand and salt, saving salt should be as simple as dialing in a lower application rate. To counteract the pressure to overuse salt, it is necessary to provide plow operators with the skills and tools to make good application rate decisions including standard application rate guidelines, based on pavement temperature, calibration, and equipping the plow trucks with infrared pavement sensors or some other means of accessing real-time pavement temperatures may enable the operators to follow these guidelines. Organizing five minute meetings and discussing application rates before and after snow and ice events may give operators the chance to learn about application rates from each other.(*1029*) MnDOT developed a performance-based program for reducing application rates called "Salt Solutions" that provided operators with tools and systems for making better application rate decisions. Application rates dropped when the entire organization actively supported the operators in making better decisions and the agency took the time to measure and reward improved performance.(*1030*)

As the Transportation Association of Canada notes, traditionally, equipment-related training focused on equipment maintenance and the safe operation of the vehicle and a plow operator could be forgiven for only plowing, just as a spreader operator might only spread. As equipment evolved, so did specific training on the differences between vehicles, which covered the spreader controller features and how to change settings, etc. These aspects of staff training are still essential to the safe and effective use of equipment. Further equipment-related training, however, should emphasize the impact of the operator's decisions made along the route, the range of settings and methodologies available to the operator, and tie these to her/his roles as a "snow and ice controller" and "decision-maker." Equipment training is integral with other winter maintenance topics such as the science of salt and record keeping. With today's understanding of best practices for snow and ice control and with the more sophisticated equipment that is available, operators need to understand that "decision-making" means choosing to spread when appropriate, and – equally important – choosing not to spread when it is not required. It is important to choose to plow the accumulated snow and slush, and important to not prematurely plow salt-laden slush before the salt has done its job. To ensure operators are confident in their duties and in using the assigned equipment, operators should have training in such equipment-related topics as: (*1031*)

- Route familiarization (preferably during daylight).
- Pre-season driver training.
- Spreader calibration.
- "circle-check" procedures.
- Spreader controller operation.
- Brine equipment operation.
- Equipment washing procedures.
- Minor equipment repair.
- Good housekeeping practices.
- Record keeping.
- Use and interpretation of pavement sensor data and forecasts.
- Infrared thermometer use.
- Agency policies.

The following equipment-related learning goals should be included in a training program:

- Understand the concept of putting out the right material, in the right amount, at the right time, and leaving it there long enough to do the job.
- Understand how the electronic controller and gate settings on each spreader must be set to achieve the specified application rate.
- Understand how to calibrate each spreader to ensure that the right amount of material is being spread.
- Understand how to recognize when re-calibration is necessary.
- Understand the importance of timely plowing.

- Understand how to efficiently plow each beat/route.
- Understand the role and effective placement of snowdrift control devices (structural snow fences, snow ridging, agricultural stubble, living snow fences).
- Understand how to fill spreaders and anti-icing units with liquid chemicals.
- Understand the health, safety and environmental precautions that need to be taken when handling liquid chemicals.
- Understand how to measure brine concentrations.
- Understand the components and purpose of RWIS installations.
- Understand how to properly mount a truck-mounted IRT so as to ensure accurate readings.
- Understand that IRTs are for measuring temperature trends not exact temperatures.
- Understand precautions about handling and using IRTs.
- Understand the importance of proper record keeping and how to complete the required documentation on equipment maintenance and salt use.

Training will necessarily include such on-the-job elements as preseason "dry runs." Drainage facilities, wildlife crossing structures and other facilities requiring delineation or special treatment in plowing operations should be noted by foremen and equipment operators during dry runs of routes in the fall along with possible obstructions.

It is not likely that all staff will need the same level of training. The amount of training and the level of detail of training that is required by specific personnel will vary. For example, managers may not need to know how to calibrate a spreader or to plow a road in order to carry out their responsibilities. They should however understand the importance of an effective calibration program and what equipment is needed to optimize salt use.

Operators that do not make salt application decisions may not have to understand much about the decision support systems. However, they need to understand salt application policies, the chemistry and application of salt, the environmental issues, good housekeeping practices at maintenance yards, record keeping, equipment operation and relevant decision-support information. Training needs vary among employees. New staff will need the full training program; determining competency among a range of staff and experience levels is more complex and often requires data gathering and testing and feedback in the course of work.

Trainers should assemble a bank of local case studies, local photos and examples to reinforce learning goals. Training opportunities should not be limited to formal classroom settings. Trainers should be aware of the workplace schedules, inclement weather policies, shift changes and shift downtime for example and take advantage of these windows of opportunity to present training modules. Depending on the regular duties of the staff there are also opportunities to provide training in informal tailgate sessions or in post storm debriefing sessions.

The Transportation Association of Canada set out the following learning goals and best practices related to winter operations and salt management training.(*1032*)

Salt Management Policy

- Understand the definition and importance of level of service and that the goal is to achieve the prescribed level of service.

- Understand the organization's Operating Policies and their application to winter operations.
- Understand the organization's Salt Management Policy.

Principles of Ice Formation

- Understand slippery road conditions are a result of water being cooled below its freezing point on the road surface.
- Understand the sources of moisture on the road include dew, rain, and snow.
- Understand dew point and what conditions will lead to dew forming on the road surface. Understand what conditions will lead to frost and black ice forming on the road surface.
- Understand the importance of pavement temperature in making snow and ice control decisions.
- Understand why bridges freeze first.

Science of Freeze Point Depressants

- Understand the concept of a freeze point depressant.
- Understand that chemicals are used to prevent or break the bond between snow and ice.
- Know the chemical composition of rock salt, and other chemicals used by the transportation agency.
- Understand that brine rather than the solid chemical melts the snow and ice.
- Understand the phase diagram for the chemicals that are used in the organization.
- Understand the implication of chemical concentrations greater than the eutectic concentration.
- Understand the criteria for the selection of de-icing chemicals.
- Understand the relationship between chemical concentrations and freeze point.
- Understand that dry chemicals and pre-wetted chemicals take time to work.
- Understand that a change from a solid to a liquid requires heat and can rapidly cool a road surface.
- Understand the testing requirements and risks associated with the introduction of new snow and ice control chemicals.
- Understand the principle of refreeze.

Material Use

- Understand the role of traffic and crossfall of the road in forming and distributing brine.
- Understand when to windrow and when to spin a pre-wetted solid.
- Understand how to treat special areas such as bridges and culverts, super-elevations, intersections, hills (crests, sags, inclines), bus stops and high wind conditions.
- Understand that chemical should not be applied to dry pavement where drifting snow is not sticking.

- Understand when to use and not use specific chemicals, taking into account pavement temperatures, forecasts, time of day, humidity, traffic volumes etc..

Brine Production and Use

- Understand the procedure for making snow and ice control liquids from solid chemicals.
- Understand the importance of quality control and chemical concentration.

Pre-Wetting

- Understand the benefits of using pre-wetting chemicals and abrasives.
- Understand the difference between proactive anti-icing and reactive de-icing.
- Understand how dry materials are pre-wetted.
- Understand that salt and sand can bounce or be blown off the road and that this product loss can be reduced by pre-wetting.

Anti-Icing

- Understand the concepts of liquid anti-icing.
- Understand the benefits of a proactive anti-icing approach.
- Understand how to fill spreaders and anti-icing units with liquid chemicals.
- Understand the health, safety and environmental precautions that need to be taken when handling liquid chemicals.
- Understand how to measure brine concentrations.

Plowing

- Understand the timing of plowing operations so that chemicals are not plowed off the road prematurely.
- Understand the importance of timely plowing.
- Understand how to efficiently plow each beat/route.

Road Salt and the Environment

- Understand that chlorides are mobile in the environment.
- Understand that road salt may attract some wildlife to the road, potentially increasing the hazard of animal/vehicle collisions.
- Understand that high salt levels can harm vegetation and agricultural crops adjacent to the roadway.
- Understand that high salt levels can harm animals including fish living in streams, wetlands and lakes.
- Understand that it is desirable to only use enough chemical to achieve the prescribed level of service.

Maintenance Yards

- Understand that all salt and sand/salt blends should be covered to minimize salt loss.

- Understand that salt spillage is wasteful and can be harmful to the environment.
- Understand the salt-handling activities that result in wasteful releases of salt to the environment.
- Understand how these salt-handling activities should be carried out to prevent the wasteful release of salt to the environment.
- Understand that timely yard maintenance and repairs are necessary to control salt loss.
- Understand maintenance yard salt cleanup procedures that must be followed.

Snow Disposal

- Understand how to manage the snow pile to facilitate melting.
- Understand the measures to be used to control nuisance effects (noise, dust, litter).
- Understand how to monitor and record chloride, metal, pH, TPH and suspended solids in meltwater discharges.
- Understand how the snow disposal system has to be managed to be cost-effective and to reduce environmental and social impacts.

Managing Snow Disposal Sites

- Understanding how to manage the snow pile to facilitate melting.
- Understanding the measures to be applied to control nuisance effects such as:
  - Noise from trucks and equipment.
  - Visual impacts such as dirty snow piles and vehicle and site lights from nighttime dumping.
  - Dust.
  - Litter and debris.
- Understanding how to monitor, and record the chloride, metals, pH, Total Petroleum Hydrocarbons (TPH) and suspended solids in the meltwater discharges.
- Understand how the snow disposal system has to be managed to be cost effective and to reduce environmental and social impacts.
- Understand the importance of proper record keeping and how to complete the required documentation on snow received and quality of meltwater being discharged.

Record Keeping

- Understand the importance of timely and accurate records.
- Understand the importance of good records for mounting a due diligence defence in the event of a lawsuit.
- Understand how to complete the organization's activity/ storm reports.
- Understand the importance of recording actions and inactions and the rationale for each.
- Understand the importance of knowing the beat/route and what it takes to properly maintain it to the prescribed LOS.

Spreaders

- Understand the concept of putting out the right material, in the right amount, at the right time, and leaving it there long enough to do the job.
- Understand how the electronic controller and gate settings on each spreader must be set to achieve the specified application rate.
- Understand how to calibrate each spreader to ensure that the right amount of material is being spread.
- Understand how to recognize when re-calibration is necessary.

Drift Control

- Understand the role and effective placement of snow drift control devices (structural snow fences, snow ridging, agricultural stubble, living snow fences).

Weather Forecasts

- Understand the kinds and sources of weather information.
- Understand how to read a weather forecast.
- Understand what can affect local weather conditions and why weather might vary from one location to another.
- Understand lake effect snowfalls.
- Understand that wind chill does not significantly affect absolute road temperatures but does affect the rate of cooling.
- Understand when a forecast could be wrong.

Wind

- Understand that a wind of 15 km/hr is needed to drift snow.
- Understand how wind changes can signal an approaching or passing storm.

Weather Tracking

- Understand how to monitor weather conditions and anticipate changes.
- Understand how to read a radar image and use the information in decision-making.

Weather and Decision-Making

- Understand how weather forecasts can be used in making snow and ice control decisions.

Pavement Temperatures

- Understand the concept of heat balance and how it can affect pavement temperatures.
- Understand how to read a pavement condition forecast.
- Understand how pavement condition forecasts and real time information can be used in making snow and ice control decisions.

RWIS and IRTS

- Understand the components and purpose of RWIS installations.
- Understand how to read and interpret RWIS data.
- Understand how to properly mount a truck-mounted IRT so as to avoid erroneous readings.
- Understand that IRT's are for measuring temperature trends, not exact temperatures.
- Understand why odd readings might be obtained (e.g. interference, out of calibration, acclimatization, buried utilities, shading etc).
- Understand precautions about handling and using IRTs.
- Understand the role of pavement crossfall in snow and ice control and when to windrow and when to broadcast chemicals.
- Understand the importance of pavement surface temperature on snow and ice control decision-making.
- Understand how to track pavement temperature trends.
- Understand what factors can affect pavement temperatures and how knowledge of these factors can be used to predict temperature changes.
- Understand how to treat different pavement conditions during different types of weather events. Also, good pavement design can help improve road salt performance, minimize usage for the same or better level of service and safety, and thus reduce environmental impact.
- Monitor pavement temperatures to assist in making decisions. This can be done when mobile using hand held or truck mounted infrared thermometers. Road Weather Information Systems can provide a surface and subsurface pavement temperature at a fixed location, and can support the generation of a pavement condition forecast as well as real-time pavement condition information.
- Record pavement temperature trends in daily logs, along with pavement conditions, weather conditions and winter treatment strategy.
- Test pavement temperature monitoring equipment at least annually to ensure that they are operating correctly. Inaccurate equipment should be recalibrated, repaired or replaced.

Trainings should be scheduled for each fall, close to the onset of the snow and ice control season and should include seasonal and contracted personnel. While this season of the year prevents the actual plowing of snow, it does not preclude training and testing on such items as; trucks, grader and loader operation, mounting and adjusting the plow, familiarity with plow and spreader control, driving skills involving turning and backing, and clearance judgment with the plow mounted. This type of training can be given by Equipment Operator Instructors.

Some transportation agencies have included testing and a minimum passing grade in their training programs. In the absence of any industry certification standards this type of internal agency certification may be advantageous to those transportation agencies wanting to provide an assurance of minimum competency levels.

PENNDOT "Smart Salting" Training and Snow Academy

PENNDOT's training program is incorporated with winter planning, which starts in April with after action reviews, equipment repairs, route identification, and route assignments. In the fall, PENNDOT conducts dry runs, marks hazards, and familiarizes operators. Foremen have to sign off that equipment operators have done this. Training for Winter Operations includes "Levels of Service," presented by the leader of the local organization. The training addresses mission, vision, customer service philosophy, priority roads, intervals of service, peak travel times, local directives and changes, alternative resources—temporary operators, etc. A "Smart Salting" module covers material testing, sampling, salt specs for current year's content and other elements, including how to read lab reports. The training program and standards are presented as putting the operator in charge of his own destiny; by adhering to internally developed procedures, PENNDOT staff attend to these issues so the state environmental agency doesn't have to. One quarter of the workforce attends a two day Snow Academy yearly. All other employees receive one day Snow Academy refresher training. Trucks are equipped with ground speed controlled spreaders, which allow precise control of material application rates at any speed or engine rpm with "electric over hydraulic" controls and load-sensing hydraulic pumps. Training occurs on this equipment as well. All spreaders are calibrated each year.

NSYDOT Salt Sensitivity Training for Stormfighters, and Snow and Ice Guidelines

NYSDOT has had to work to educate and train their workforce, the public, and even the police. The Department has implemented training to teach that "the way we've always done it" is not acceptable; the Department wants to get the most bang for the buck AND do an effective and safe job. NYSDOT found their decision to dedicate more resources to training is bearing fruit and raising consciousness among staff. One class is "Salt Sensitivity for Stormfighters." The agency teaches where all the applied salt and brine go; 55 percent goes back into surface drains, 45 percent goes into the ground and affects roadside vegetation. Liquid brine has led to salt reductions but increased mowing, as salt retards growth. NYSDOT trains designers for considering snow and ice as well; i.e. enough road to store the snow, roads built on a slight berm, for snow to blow across, road geometrics, design of living snow fences, identification of drainage features and roadside water quality receptors, and use of raised markers, roundabouts, turnabouts, and curbing.

Maintenance environmental specialists focus on erosion control and spill containment year round. NYSDOT has developed Snow & Ice Guidelines primarily for managers, with application rates, storage of materials, etc.; it is currently being revised and will be out in 2005. NYSDOT has another version for operators, NYSDOT's Snow and Ice Operators Manual, that reviews application rates, how to plow, when to use chains or not, how to put on plow wings, etc. The Department is certifying operators and one-person plowing and providing a certification for calibration. NYSDOT encourages many employees to get this training because it gives them a better appreciation for application rates. Promotional opportunities are tied to these certifications for Category 3 operators.

CHAPTER 9: ROADSIDE VEGETATION MANAGEMENT

The over 17 million acres of right of way (ROW) land managed by state DOTs include some rare ecosystems and endangered species, and involve a wide range of concerns including prevention of erosion and sedimentation control and spread of noxious weeds, in addition to transportation concerns and efficient use of resources to accomplish management objectives for the right-of-way.(*1033*)

In the name of safety, improved visibility and obstacle-free roadsides, roadside vegetation managers favor grasslands. Once established, the native grasses save maintenance dollars over time, provide a self-reliant and hardy plant community, improve wildlife habitat, and protect the local character and natural heritage of a site.(*1034*)

Integrated Vegetation Management (IVM) or the Integrated Roadside Vegetation Management (IRVM) approach encourages stable self-sustaining vegetation with limited use of mowing and herbicides. IRVM is achieved through techniques that encourage self-sustaining native plant communities to naturally discourage the establishment of unwanted plant species. IRVM starts with good soils management, planting design, and revegetation, and then recognizes proper mowing or restrictions, weeding, pruning, and thinning. Herbicide use is not ruled out, but other strategies are combined to limit its necessity. As IRVM strategies take hold over time, mature roadside plant environments lead to long-term herbicide use reductions and minimal of maintenance requirements.

9.1. THE IMPORTANCE OF VEGETATION IN THE RIGHT-OF-WAY

More than half of the United States was once covered naturally by grasslands: Palouse, prairies, Great Basin, meadows, glades, savannahs, balds, pine barrens, and others.(*1035*) Vegetation slows or prevents erosion by intercepting raindrop impacts, retaining soil with its roots, slowing runoff velocities, and decreasing runoff volumes by increasing infiltration and transpiring water to the atmosphere.

WSDOT's State Roadside Manual outlines some of the many functions vegetation contributes that add significant value to our environment, including: (*1036*)

- Traffic calming
- Stress reduction
- Buffer or shade for pedestrian or park and ride facilities
- Stream bank stabilization
- Wetland mitigation
- Water quality improvement

General Environmental Practices for Vegetation Maintenance Operations in the ROW

- After pruning, chipping, and removing vegetation, clean up your work area.
- Do not leave cuttings or chips in areas where they may be easily washed into the stormwater drainage system.
- Do not fuel or lubricate equipment, such as weed whackers or leaf blowers, next to drain inlets or watercourses.
- Consider the potential erosion problems in an area when vegetation is disturbed.
- Remember to cover your load when transporting vegetation debris.

From: Caltrans, Maintenance Stormwater Pollution Prevention Bulletin, Feb. 2000.

- Water retention and smoother flows
- Air pollution mitigation
- Noise abatement
- Wildlife habitat
- Enclose, screen, expose, or blend
- Visual quality, quality of life
- Corridor continuity

Today, ROW managers must be concerned with multiple use aspects of ROW management; multiple use concerns necessitate the development of plant communities that resist the invasion of woody plants, are aesthetically pleasing, provide food and/or cover for wildlife, and can be economically established and maintained.(*1037*)

Visual quality of the roadside is a topic of increasing interest, and several DOTs have conducted surveys to try to identify the nuances of driver preferences. The following stewardship guidelines were developed by WSDOT to maintain the visual quality of the roadside: (*1038*)

1. Identify opportunities to partner with adjacent land owners to preserve or reveal desirable views and roadside segments that enhance or maintain corridor continuity. (It is not WSDOT policy to remove vegetation to open up views toward commercial properties.) Balance desirable visual functions with the needs of roadway users and adjacent land owners. Coordinate with the regional or headquarters Landscape Architect. On Scenic Byways coordinate with the Heritage Corridors Program Office.
2. Enhance or retain vegetation to screen undesirable views and to meet the requirements of the *Roadside Classification Plan* (corridor continuity, blending with, and buffering adjacent land uses).
3. Maintain low growing vegetation or limb up trees to retain desirable views.
4. Carefully consider actions before removing vegetation to open up views. Consider whether development adjacent tot the highway is likely to eliminate the view after removing vegetation. Analyze the angle of view from the driver's perspective and minimize removal of vegetation to meet the view objective. Consider selective removal of tree limbs or removal of only the limbs on the lower one third of the tree to reveal desirable views.

NCHRP 20-5, 33-04, "Synthesis of Highway Practice: Integrated Roadside Vegetation Management" surveyed a sample of state DOTs and identified erosion control as a primary concern in management of vegetation. Indiana, Minnesota, Texas, and Washington reported that their vegetation management activities were affected by stormwater management objectives. Florida, Illinois, Indiana, Maryland, Ohio, Texas, and Washington reported control of roadside fire starts as a concern addressed by their vegetation management practices. The use of native plants in construction or restoration of roadside vegetation patterns was mandated by policy or state laws in slightly more than 40 percent of the reporting states. The dollar value assigned to benefits of "environmentally sensitive" maintenance methods (i.e., mowing of brush verses spraying of brush) have been established by four of the responding states: Florida, Illinois, South Carolina, and Texas. The same valuation in regard to construction methods was identified by only Florida and Illinois. Connecticut, Illinois, Maine, Minnesota, Nebraska, Ohio, Pennsylvania, Texas, Utah, Washington, and West Virginia said that environmental impacts from long-term sustainability were given consideration in construction of new roadside projects.(*1039*)

NCHRP 20-5, 33-04 recommended that an entity be created and funded as a depository for retention and distribution of IRVM BMPs.(*1040*) It is hoped that this document, undertaken for NCHRP 25-25(04), might provide a first step in that regard.

9.2. Integrated Roadside Vegetation Management and Methods

The Integrated Vegetation Management (IVM) or Integrated Roadside Vegetation Management (IRVM) approach encourages stable self-sustaining vegetation with limited use of mowing, herbicides, tree removal, and other methods as necessary. IVM is achieved through techniques that encourage self-sustaining native plant communities to naturally discourage the establishment of unwanted plant species. IVM starts with good soils management, planting design, and revegetation, and then recognizes proper mowing or restrictions, weeding, pruning and thinning. Manual activities, mechanical tools, and chemical applications are combined with cultural and biological methods to develop a vegetation community that requires minimal maintenance and benefits wildlife and its habitat. As IVM strategies take hold over time, mature roadside plant environments lead to long-term herbicide use reductions. According to the upcoming NCHRP 20-5, 33-04 on IRVM, on average, 58 percent of DOTs' newly planted acreage requires no significant maintenance work on a perpetual basis; 23 percent indicted that less than 20 percent of the newly planted acreage requires significant maintenance work on a perpetual basis. Around a quarter of responding state DOTs were aiming for 90 to 100 percent of planted acreage requiring no significant maintenance work on a perpetual basis.(*1041*)

Iowa DOT was an early leader in the implementation of IRVM, which the agency understood as simply using the most cost-effective and ecologically-sound method of management on a site by site basis. The approach was based on the following principles.(*1042*)

1. Nature does not allow bare soils to exist.
2. Bare soils are revegetated by successions of plant groups until a most-fit community of plants develops.
3. Disturbance of the vegetative cover reverses the succession of revegetation back to the bare soil starting point, and therefore allows more invasions.

The emphasis on weed eradication rather than weed prevention has led to increased mapping of vegetation, statewide planning, and new maintenance/construction practices.

Within IVM, various key elements of IPM systems have only recently been developed or recognized; some examples include: (*1043*)(*1044*)

- Managing a pest with integrated control measures, including prevention and an emphasis on biological control (liken to the use of low-growing plant communities to naturally control pest tree populations).
- Growing emphasis on monitoring and assessment (including refined efforts to document a pest problem).

- Decisions based on tolerance levels (of pest species/noxious weeds).
- Professional-grade prescriptions of treatments.
- Formalized efforts to determine long-term efficacy and effectiveness of treatments.

Integrated vegetation management includes the use of cultural, mechanical, biological, and chemical practices. Each location must be evaluated to determine the method to be used. One or more of the following will be used:

Cultural control methods introduce and manage desirable plants and covers to control noxious weeds and other undesirable plants. Many native plants are poor competitors in their early stages of growth, but once established they crowd out most other plants with minimum management. Many agencies are using native grasses to control noxious weeds, since their dense, deep root systems inhibit weed growth. Both Minnesota and Iowa DOTs have found success in controlling noxious weeds, and Canada thistle in particular in Minnesota, using native grass stands.(*1045*) Controlled burning is recognized as a cultural control tool for enhancing and maintaining native plant communities, but DOTs are in the early stages of exploring and defining proper burning procedures and parameters.

Mechanical methods, usually tractor mowing, can involve anything from complete tillage for reseeding to hand scythes, shovels, string trimmers, push mowers, pruning shears, etc. for weed control and desirable vegetation maintenance.

Biological methods involve the use of animals, insects, bacteria or virus to control plant growth.

Chemical Methods are typically selected for use based on agency guidance, label constraints, and residual effects on the environment. Chemicals are generally monitored to document their effectiveness and impacts upon target and non-target species. There are several new herbicides with very specific effects on specific plant species which can be valuable tools for controlling undesirable plants on a short-term basis.

9.3. Developing IVM or IRVM Plans

To achieve the multi-faceted goals described above, using all the tools available in an efficient and environmentally sound manner, a number of DOTs are developing Integrated Roadside Vegetation Management Plans (IRVM) or Integrated Vegetation Management Plans (IVM). A survey undertaken for NCHRP 20-5, 33-04, to be published in late 2004, reports that implementation of integrated roadside vegetation management (IRVM) programs by official policy has occurred in Florida, Maine, Maryland, Minnesota, New York, Pennsylvania, Texas, and West Virginia, and that roadside management plans were part of the implementation program in Florida, Illinois, Maine, Maryland, Minnesota, Montana, New Mexico, Ohio, Pennsylvania, South Carolina, Texas, Utah, and the provinces of Alberta and Quebec.(*1046*)

The IVM plan identifies environmental constraints and gives the vegetation manager flexibility in management methods. Properly executing integrated vegetation management practices using a combination of methods can result in the conversion of rights-of-way to a plant community requiring minimal maintenance activities in the future. Integrated vegetation management balances service reliability, environmental compliance, and customer service while lowering the cost of maintenance over time. (*1047*) Working with utility communities and now NYSDOT, Nowak and Ballard of the State University of New York call IVM "a sophisticated system of information gathering, planning, implementing, reviewing, and improving vegetation management treatments," which "differs from past management approaches to managing vegetation on ROWs in its greater breadth and complexity of management considerations, and in its higher level of sophistication and effort in evaluating management choices."(*1048*) As a continuous cycle of information gathering, planning, implementing, reviewing, and improving vegetation management treatments and the related actions, IVM constitutes an Environmental Management System for roadside vegetation.

New York State's 6-Step Approach to IVM Planning and Implementation

Integrated Vegetation Management (IVM) has been used on powerline corridors for over 20 years in New York State, where a focus on culturing desirable plant communities that minimize the presence of undesirable plants has reduced treatment needs, and reduced herbicide usage by over half during that period.(*1049*) Nowak and Ballard's work with the utility industry and NYSDOT has involved a six-step approach to IVM that provides a framework for communicating, organizing, and conducting an IVM program.(*1050*) The following step-wise system is summarized and adapted from Nowak and Ballard's work for the utility industry and the U.S. EPA.(*1051*)

Step 1: Understand pest and ecosystem dynamics

A first step to conducting IVM is to develop a working knowledge of the organisms in the managed system and how they interact with each other and the environment, with or without vegetation management, to produce ecosystem conditions. It is important to identify and understand:

- Species life histories (reproduction, growth and longevity), plant strategies, and responses to disturbance.
- Plant succession, changes in distribution and abundance of plants through time and space.
- How plants and communities can be manipulated to control the rate and direction of plant succession via interference, grazing, and other mechanisms.

Step 2: Set management objectives and tolerance levels

Tolerance levels are specific descriptions of vegetation condition—individual plant and plant community size, abundance, and composition—that, if exceeded, trigger a need to intervene. Undesirable species are not treated unless they exceed the critical threshold. Well-defined thresholds are a critical element of IVM (*1052*)(*1053*) that can be useful in communicating management needs to various stakeholders, e.g., thresholds and tolerance levels can be used to demonstrate the cyclic nature of vegetation dynamics, which supports a need to control vegetation on a regular basis. Stakeholders include vegetation management professionals responsible for management decisions on a particular ROW, landowners of the ROW or adjacent properties, governmental regulators responsible for administering State and Federal policies and laws, and non-governmental organizations with a general concern for the environment.

Step 3: Compile treatment options

Different treatment options may be needed to match variable environmental and site conditions, concerns and interests on a ROW. Vegetation treatments can be grouped into categories, such as: mechanical, chemical, cultural, physical, biological, and ecological; however, IVM does focus on integrating biological/ecological control into all treatment schemes. Creation of stable, low-growing plant communities is the long-term objective, and biological/ecological control produces a long-term reduction in treatment efforts, and a reduction in herbicide use.(*1054*)(*1055*)

Step 4: Account for economic and environmental effects of treatments

Economic and environmental considerations factor into choice of treatment. Cost effectiveness may be used as a measure of the success of a treatment in terms of economics, plant community dynamics, and related environmental considerations; (*1056*)(*1057*) direct costs include labor, equipment, and materials to treat ROW vegetation, while indirect costs include the loss of values or service that can result from a treatment. The latter are often associated with water quality, pollution, wildlife habitat, and aesthetics, or other ways that the environment can be degraded. Effectiveness pertains to production of desired vegetation conditions and associated benefits and values with operation and management of the transportation corridor in the public interest, taking environmental interests and values into account. Cost effectiveness timeframes may be short- or long-term, and often, efforts must be made to balance short-term savings with long-term costs. For example, it may be monetarily less costly to mow a ROW today vs. use of herbicides, but mowing may produce higher costs over the long-term because of short-term control of vegetation conditions and shorter treatment cycles than can be achieved with other treatments.(*1058*)(*1059*) IVM is used to maximize cost effectiveness of management efforts, minimizing costs while creating the desired vegetation conditions and associated positive values associated with these conditions over the long-term.

Step 5: Develop site-specific treatment plans

After developing a suite of treatment options (Steps 2, 3 and 4), and weighing the effects of those treatments on long-term production of vegetation conditions and associated benefits and values, a treatment is chosen by the professional vegetation manager. Prescriptions should not be written for whole ROWs, but are instead developed for specific sections of any one ROW and the constraints therein. It is important to base treatment choices on inventory and analysis of existing site and vegetation conditions,(*1060*) particularly because these data will be critical in monitoring outcomes of treatments, as outlined in Step 6. Prescriptions for different areas and circumstances of vegetation management should include:

- Desired future conditions of the ROW area to be treated
- Description of the treatment as a function of current vegetation conditions, and justification of treatments, considering ecological, socioeconomic, and administrative or fiscal factors. (1061)(1062) Treatment recommendations are the crucial part of the prescription.

Step 6: Monitor outcomes and revise and adapt management plans

Adaptive management incorporates learning from experience.(*1063*) Monitoring of the effects and performance of various treatments may include:

- Amount of materials used in treatment
- Treatment costs

- Vegetation conditions before and after treatment (e.g. quantification of changes in noxious weed cover)

In addition to vegetative community changes, herbicide residuals with chemical treatments, water quality, and wildlife populations can also be monitored and feed into the next round of treatment planning and decisionmaking. Vegetation conditions are compared to the desired condition set during the "Management objectives and tolerance levels" step (Step 2), and described in prescriptions during the "Site-specific implementation of treatments" step (Step 5). Any disparities between "desired" and "achieved" results are investigated, and future treatment options adjusted accordingly. Monitoring assures that treatment effects are gauged, and shortfalls corrected by improving management schemes to better accomplish management objectives.

To What Extent Are You Implementing IVM: A Self- Evaluation

Nowak and Ballard pose a series of questions, which maintenance managers may use to self-evaluate their current approach to vegetation management, and identify gaps between current systems and the integrated approach presented above. Numbers correspond to the steps presented previously. (*1064*)

1) Do you have a detailed, basic knowledge of the managed ecosystems?

2a) Do you actively involve stakeholders in vegetation management decisions?

2b) Do you consider tolerance levels when determining the need to treat vegetation (positive approach), or do you take a rote approach and treat vegetation only routinely (negative approach)?

2c) Are you proactive in vegetation management (e.g., treat vegetation in concert with tolerance levels, with decisions based on inventory and planning), or reactive (e.g., "hot spotting", where vegetation is treated after thresholds are soon-to-be, or already, exceeded)

3a) Do you maintain a broad range of vegetation treatments--mechanical, chemical, cultural, and biological--in your "toolbox", and apply a variety of treatments depending on the site and vegetation conditions?

3b) Do you foster the use of biological/ecological controls to prevent pest populations from building past economic thresholds?

4) Do you use broad considerations of cost effectiveness in selecting a treatment for a specific site?

5) Do you prescribe treatments in a site-specific manner, based on a contemporary inventory of ROW resources?

6) Do you monitor the results of treatments to compare actual conditions vs. desired future conditions, and look to improve the system based on that comparison?

Iowa DOT's Integrated Roadside Vegetation Management Approach

Iowa DOT was one of the first DOTs in the country to encourage an integrated vegetation management approach. Iowa DOT defines Integrated Roadside Vegetation Management (IRVM) as a long term approach to vegetation management that: (*1065*)

- Systematically evaluates each area to be managed.
- Determines which plant communities best fit the area.
- Develops procedures that will encourage, enhance, or reestablish desirable plant communities.
- Provides self-sustaining, diversified, visually interesting vegetation.
- Keeps safety and an improved environment as priorities.
- Utilizes the most beneficial methods to prevent or correct undesirable situations caused by disturbance or less than optimum vegetative ground cover.

Iowa DOT's IRVM plan is brief and general, allowing adaptation by counties. Iowa DOT defines the prime purpose of roadside vegetation as holding soil in place without creating hazards. At the same time, Iowa DOT hopes to address other desirable uses for roadside vegetation (aesthetic, economic, and environmental) once safety and functional requirements are met. Thus, the goals of Iowa DOT's Integrated Roadside Management Plan are to:

- Preserve and provide safe, functional and environmentally improved corridors of travel throughout the state.
- Utilize a long-term integrated management program that promotes desirable self-sustaining plant communities. Encourage those plant communities that are native to Iowa through preservation and re-establishment whenever practical.
- Bring about considerable reduction and possible elimination of the use of chemicals as a control method of undesirable plants.
- Enhance the scenic qualities of the roadsides and their value as wildlife habitat.

To achieve these goals, Iowa DOT outlines the following procedures, which follow a Plan-Do-Check-Act process as follows:

- Inventory the sites to be managed.
- List the existing areas of desirable vegetation as well as those that need improvement.
- Determine the appropriate management methods needed.
- Determine the best time to implement management procedures and see that they are accomplished at that time. Temporary procedures may be needed to preserve an area before permanent procedures can be utilized.
- Evaluate the results periodically.
- Take further measures if necessary.

Once an IRVM plan is developed, communication must occur. Iowa DOT's IRVM plan committed the DOT to:

- Develop a public awareness campaign to gain support for integrated management through media, established organizations, seminars and brochures.
- Develop educational and informational material on IRVM to be presented in seminars and distributed to adjacent landowners, the general public, consultants and contractors.

- Provide guidelines and directives for contractors and others who seed, plant and maintain roadsides.
- Prepare and distribute instructions to state, county and city personnel on preservation of desirable areas and treatment of areas that need improvement.
- Gather, develop and distribute information with other jurisdictions; seek and share information with other states.
- Encourage research in all aspects of IRVM, i.e.; road design for improving IRVM, planting methods, management practices, seed sources, seeding rates, seed mixes, planting equipment, etc.
- Encourage state production of native seeds and plant materials for use in the rights of way.

Iowa DOT and the Iowa State Legislature have supported establishment of an Integrated Roadside Vegetation Management center at the University of Northern Iowa.

Mn/DOT Process for IRVM Planning

Mn/DOT's process for IRVM planning is detailed in the Minnesota Best Practices on Roadside Vegetation Management and summarized below.(*1066*)

Preliminary Planning, Categorization and Goals

- **A local plan adapted to fit local culture, political concerns, and climate and environmental conditions is best.** Each roadway is unique, and one plan for all roads in a jurisdiction may not be appropriate. The next step in moving towards integrated roadside vegetation management is to evaluate the roadways for which an agency is responsible, and assign them to categories for which a plan can be developed.
- **Plan development should be a team effort,** with input from those people having expertise in landscape architecture, maintenance, design, construction, biology, horticulture, utilities, and public relations as well as from general citizens. A steering committee responsible for developing the plan, providing guidance on how it is run, and reviewing the annual work plan and progress may also be created.
- **Prior to plan development, the agency should identify the roadways they are responsible for maintaining and prioritize them according to the level of management they will receive.** The amount and type of vegetative maintenance done on each roadside will depend on the category to which it is assigned, whether urban or rural, or based on zoning, high or low traffic levels, or roadway type.
- **While developing the plan and considering maintenance strategies, keep the following guidelines in mind**:
    - **Timing** is an important factor for all control and maintenance methods.
    - **Flexibility**. Programs should be kept flexible to allow for changes as needed.
    - A combination of several control methods is usually more effective than any single treatment.

- Maintenance costs are lowest when programs are planned and carried out on schedule.

- **Also, identify the desired outcome for a given feature**. For example, is the objective to have low maintenance, return the roadside to prairie grasses, maintain golf course-like sod, or re-establish a wetland? Once the desired outcome has been identified, a plan can be developed to achieve it.

Assessing Existing Conditions

Assess existing conditions to assign and prioritize management strategies for an area. Three factors that will steer management techniques are soil, topography, and vegetation.

Soil

Understanding the type of soils present and their physical characteristics is important when outlining a plan for roadside vegetation management. Soil type and texture determine vegetation selection, herbicide application rates, fertilization needs, and erosion potential. Once known, management techniques should be targeted to those conditions. The ideal surface soil is composed of 5 percent organic matter, 25 percent air, 45 percent mineral material, and 25 percent water. The organic material provides fertility and water-holding capacity and supports microbial life. Oxygen is required for all root growth. Along roadsides, soil is typically stripped of its nutrients and compacted such that little air remains in the soil, leaving a very hostile environment for vegetation to flourish. When trouble-shooting to determine causes of vegetation problems, assessing the soils in an area may explain excessive weed growth or resistance to chemical control methods.

Soil Health

Healthy soil is a critical element for establishing a healthy roadside environment. Even the most appropriate and useful tools for managing roadside vegetation may not work if the soil lacks enough nutrients to support the targeted vegetation. To improve unhealthy soil, try measures such as the use of a fertilizer, compost, aeration, or deep scarification to incorporate oxygen into the soil. If improving soil health is not possible, choose appropriate vegetation (that does not need high nutrient soils to flourish) for establishment in that area.

One way to assess the health of the soil is to send a sample to your state Extension Service Office. For a small fee, the service will analyze the nutrient content of the soil sample and recommend the appropriate type and application rate for any necessary fertilizer.

Soil Considerations for Herbicide Use

- Use lower application rates for coarse-grained soils and higher rates for fine-grained soils or soils high in organic material.
- Learn the potential for herbicide runoff before using it.
- Do not spray in steep slope areas if rain is likely since steeper slopes increase runoff.

Native Vegetation

There are three main reasons for preserving native plants:

- **Environmental:** There are no substitutes for the original wild species of your state. Once lost, their genetic material can never be re-created. Also, native wildlife often depend on native vegetation for survival.
- **Economic:** Native plant communities are relatively stable and require little maintenance. Natural communities provide good erosion control and are less susceptible to weed invasions.
- **Aesthetic:** Native wildflowers and grasses provide seasonal color changes along roadsides, a natural beautification. They also screen undesirable views and objects if planted strategically.

Developing a Plan

After the steering committee or appropriate personnel have been assembled and roadside areas have been categorized, the IRVM Plan may be written. Steps to writing the long-range plan are listed below.

1. **Develop a vision or mission statement.** A vision statement is a picture of your road 10 to 20 years in the future. It includes your highest aspirations for what the roadside can become and serves as a source of motivation for all those involved in the process. A mission statement is broad and outlines the ultimate reason for the program's existence.
2. **Collect pertinent data, such as costs, vegetation (existing and desired), available personnel, and resources.** This step includes reviewing records of current maintenance operations and taking an inventory of current roadside vegetation conditions.
3. **Establish goals and objectives.** When doing so, consider the following basic principles:
    - Safety for the traveling public and maintenance staff
    - Maintenance of the infrastructure and highway integrity
    - Cost-effective use of public resources
    - Environmentally sound decision-making
    - Needs and concerns of adjacent landowners and the traveling public
4. **Analyze and prioritize goals and objectives.** Identify which goals are most important. This allows problem areas to be dealt with first, making other goals and objectives easier to reach.
5. **Assign duties and responsibilities for each program participant.** With input from those staff members who will be responsible for plan implementation, assign duties and responsibilities.
6. **Plan for budget considerations.** Identify costs connected with implementing each plan element, as well as ways to deal with budget constraints. This may include planning for equipment purchases and staff needs and increasing the efficiency of existing operations.
7. **Provide an opportunity for research and innovation.** Note research opportunities that may result in innovations for improving quality, reducing costs, and improving working conditions for maintenance staff.

8. **Provide evaluation criteria.** This may be the most important element of the IRVM plan. It is critical that some benchmark be developed to measure program success. Meet and document short-term goals and objectives. Maintain records of implementation activities over time to evaluate overall direction and accomplishments. Periodically evaluate the plan to determine if it is advancing and if it has reasonable and attainable goals and objectives. Make changes as needed.

Implementing the Plan

Take the following steps to implement the IRVM plan:

1. **Identify appropriate methods and application for control.** For each maintenance activity, identify the appropriate control method. This could include mechanical methods, such as mowing and aeration; biological or natural processes; cultural methods, such as appropriate seed selection, planting and mulching, or burning; chemical methods, such as the use of herbicides and pesticides; a hands-off approach; or preservation and conservation.
2. **Train.** Train all staff responsible for implementing each element of the IRVM Plan regarding the plan components and their responsibilities. This is especially important for those staff members who will be completing the actual maintenance activities.
3. **Keep records.** Keep records of maintenance activities. This includes information about the type of control used, conditions under which it was applied, and general management information. Information about the control method includes weather, application area limits, time of application, concentration and quantity of any chemicals applied, and other information as needed. For general management purposes, hours, personnel, equipment, and costs are needed to set priorities, evaluate cost-effectiveness, and budget time and money for future activities. A complete and continuously updated location map, indicating control activities and dates of application, is recommended. This can be integrated with a Geographic Information System (GIS) to automate the record-keeping process.
4. **Evaluate the program.** Regularly evaluate in order to measure the success of an IRVM Plan. This may include tracking the number of citizen complaints received before and after plan implementation, cost reductions for certain maintenance activities, and allocation of staff time. Evaluate the effectiveness and success of plan elements and make changes as necessary. Evaluation is an ongoing process, as are changes and improvements.

Mn/DOT's Best Practices for Convincing Stakeholders, Decisionmakers, and Staff to Undertake IRVM

Mn/DOT notes that convincing maintenance staff and decision makers to adopt an integrated approach to roadside vegetation management may be challenging, and full implementation of an agency-wide IRVM program may take time. To that end, Mn/DOT recommends the following best practices for promoting an IRVM philosophy.*1067*

Public Involvement

- Educate the public on why and how roadsides are managed. This education should include the reasons for roadside vegetation management in relation to functional roadway objectives, surrounding land use, the overall ecosystem, natural processes, and applied technologies.
- Communicate an appreciation for the beauty of self-sustaining, low-maintenance roadsides.
- Communicate the cost-savings realized through lower life cycle maintenance costs, less negative environmental impact, and efficient use of tax dollars.

Legislative Considerations

- Communicate to the legislature that IRVM is a worthwhile investment that will result in lower maintenance life cycle costs. To do so, initial costs must be presented clearly in relation to long-term savings with innovative technologies.
- Maintenance funding must be dedicated at a reasonable base level for accomplishment of all critical maintenance and some preventive maintenance activities.

Upper Management

- Communicate the role that IRVM can play as a problem-solving tool for roadsides.
- Provide the necessary links with design and construction personnel when constructing the roadway.

Maintenance Supervisors

- Recognize that these people are the primary resources for motivation, coordination, guidance, training, and follow-through on an IRVM program.
- Develop a management system that includes necessary record-keeping and cost-tracking components for measurement and evaluation.
- Require these staff members to develop and implement relevant technology and computer applications for the implementation and practice of the IRVM program.

Maintenance Staff

- Hire, train, and dedicate crews for roadside maintenance.
- Inspire crew members and motivate them to learn and continuously improve the quality of roadsides in their care.
- Recognize those individuals and crews that succeed in improving their roadside environment.

NYSDOT's Draft "Metric for Assessing Performance of Integrated Vegetation Management on Rights-of-Way"

As part of NYSDOT's evaluation of their current vegetation management program and the agency's "Alternatives to Herbicide" program, NYSDOT is developing a systematic framework and research protocol for identification, evaluation, and implementation of environmentally sensitive, lower maintenance, and cost effective vegetation management techniques that can be integrated into the overall vegetation management program. (*1068*) To assist NYSDOT in this effort the State University of New York (SUNY) developed a Draft listed in the Appendix for "Metric for Assessing Performance of Integrated Vegetation Management on Rights-of-Way," drawing on three sources: 1) U.S. Environmental Protection Agency model for Environmental Management Systems (ISO14001); 2) the Forest Stewardship Council and Smartwood's assessment standards for sustainable forest management (see www.fscoax.org, and www.smartwood.org); and 3) Nowak and Ballard's "Framework for Applying Integrated Vegetation Management on Rights-of-Way;." key elements to IVM are presented in the metric as general Principles (total=10) and sets of associated Criteria (total number of criteria=36), which constitute stewardship practices and measures.(*1069*)

Assessments include interdisciplinary field meetings and interviews with staff; visits to a representative sample of roadsides; and review of standard operating practices, vegetation conditions, field performances, site challenges, and vegetation management innovations. A report is developed that presents findings and recommendations associated with each principle and criteria. Each principle will have highlighted strengths and weaknesses, and sets of commendations for successes and recommendations for program improvement.

9.4. INVENTORY OF AND MANAGEMENT FOR RARE SPECIES AND SENSITIVE RESOURCES IN THE ROW

Maintenance and construction crews are making increasing use of environmental GIS data at DOTs. DOT staff in construction and maintenance already use GIS layers depicting topography (including Digital Elevation Model, Digital Line Graph, and other topographic layers), hydrology (Streams, Lakes, Wetlands), and Geology (Bedrock Geology, Soils, Land Use, Karst Aerial Photographs).(1070) Inventories of species in the ROW are now being used to support IRVM planning as well.

A large number of states are undertaking efforts to map stands of invasive species and noxious weeds with Geographic Positioning Systems (GPS), which can then be used to track progress of treatment. Iowa, Kansas, Maryland, Minnesota, Oregon, Oklahoma, Missouri, New Mexico, Texas, Utah, and West Virginia are among the state DOTs that have begun such efforts.(*1071*) For example, implementation of a mapping system is an element of the IRVM Plan for Mn/DOT Maintenance Area 3B. To accomplish this, CAD maps were obtained from Mn/DOT and plat books obtained from the county. The maps that were developed included established areas of noxious weed infestations, hazard trees, native seeding, and other important elements of the management plan. These maps are updated and assist in program planning, record keeping, and assessment. Paper-based map systems are widely being converted to Geographic Information Systems (GIS). NCHRP 20-5, 33-04 reports that Maryland and Utah have connected their IRVM plan to GIS and GPS.(*1072*)

A number of states are beginning to identify rare plant species in the ROW and tailor ROW management to encourage native species. California, Colorado, Delaware, Iowa, Missouri, Minnesota, and Wisconsin are among the DOTs which have begun to preserve high quality roadside remnant habitats.(*1073*) These initiatives typically have several common elements:

- Mapped information is combined from multiple agencies. Typically, the primary mapped data on known plant locations of rare species is obtained from the state Natural Heritage Program. Other potential contributing agencies may include the state DNR or Forest agency, U.S. Fish and Wildlife Service, Bureau of Land Management, U.S. Forest Service, Native Plant Societies, Department of Agriculture, knowledgeable individuals, and local counties.
- Upon completion of the initial data compilation phase, field surveys are conducted in some cases.
- Special Management Areas are set up with particular management practices.
- Maintenance forces are educated regarding the special maintenance needs of and expectations in these areas.
- Tracking of species condition and progress, in some cases.

Caltrans Biological Management Areas

Caltrans began a plant community preservation program in 1994. Working with conservation groups, they identified more than 20 quality natural heritage remnants on highway ROW. Each Biological Management Area is signed and has its own management plan.

Colorado DOT Maintenance Specs and Training for Management of Rare Species in the ROW

Roadside resource management is an important aspect of the Colorado Department of Transportation (CDOT)'s Shortgrass Prairie Initiative, a programmatic consultation and proactive avoidance, minimization, and mitigation effort covering 36 listed and non-listed species and associated habitats that could be impacted by CDOT's maintenance and construction activities on Colorado's eastern plains over the next 20 years. As part of the agreement, the U.S. Fish and Wildlife Service (USFWS), the State Division of Wildlife, and CDOT negotiated best management practices to be employed in the right-of-way (ROW) and developed geographic information systems (GIS) and hard copy resources/maps that can be used by regional environmental and maintenance staff. Field training is being developed as well.

Management practices were recommended as follows: (*1074*)

- If target plant(s) are present, mowing will be avoided until late in the season (mid-September) if possible.
- Re-seeding of disturbed areas will be with a mix of native graminoids and forbs wherever possible. Native mixes should be specified and/or approved by the CDOT landscape architect.
- Herbicide applications will be used only if the herbicide targets monocots but not dicots. If monocot targeted herbicides are used, timing of application is not an issue.

- Where road widening results in alteration of the hydrologic regime, efforts will be made to ensure that water flow is not interrupted.
- Habitat destruction for species and decimation of the original seed source population will be avoided to the maximum extent practicable during construction/widening.

Right-of-way management practices are designed with multiple, and sometimes conflicting, species needs in mind, and with attention to the maintenance and enhancement of ecosystem processes. This builds upon CDOT's ongoing efforts to map patches of invasive, noxious weeds and sensitive areas in the ROW via geographic positioning systems (GPS), and selectively manage plant species to promote natives. The effort has been extended statewide and will incorporate management prescriptions and proscriptions.

North Carolina Rare Species Management

The North Carolina Department of Transportation (NCDOT) has been protecting roadside populations of rare plants since 1989, focusing on over 90 sites with federally listed species and a number of other sites with state listed species. NCDOT's initial efforts emphasized marking these rare plant populations in order to prevent them from being mowed. NCDOT signed a Memorandum of Understanding (MOU) with the NC Department of Environment and Natural Resources in 1990 that committed NCDOT to protect populations of threatened and endangered species that occur on NCDOT ROW, and a MOU with the NC Department of Agriculture in 1996, agreeing to work cooperatively on a variety of plant conservation issues, including protecting roadside populations of federal and state-listed endangered and threatened species. For simplicity, NCDOT has established some general statewide management guidelines for areas marked for rare species as noted in the Appendix.

Oregon DOT Special Management Areas for Rare Plants

In 1994, the Oregon Department of Transportation introduced a voluntary Special Management Area (SMA) program designed to protect threatened and endangered (T&E) plant species occurring on its lands, drawing on information from the Oregon Natural Heritage Program and multiple agencies, individuals, and counties. The system helps ODOT apply the appropriate levels of protection within SMAs, and enables ODOT to maintain or increase population numbers and assist long-term conservation of these resources on public lands.

SMAs have special signs and activities are restricted. SMA signs installed at the edge of buffer areas for sensitive species are coded so maintenance forces understand which activities are and are not allowed. Maintenance personnel carry a "decoder card" that allows them to decipher the code on the sign. The code provides information that tells what type of maintenance activity is allowed (such as ditch cleaning, mowing, spraying, etc.) and when it is allowed (season). ODOT also developed an educational video and implemented training that was presented to ODOT maintenance crews and sign installation was initiated.

Field Signing has the benefit of giving ODOT maintenance crews information on correct management requirements for each SMA, defining the field limits of the SMAs, provides a clear

Figure 16: ODOT Special Management Area Maintenance Sign

optical reference so inappropriate management is not applied, and establishes continuity around the state. All SMAs in the state follow the same signing format, leading to less confusion and fewer impacts.

Thus far, 40 SMAs have been established for 14 different threatened and endangered plant species in 15 ODOT Maintenance Districts. Proactive late fall mowing has benefited two Willamette Valley species. The ODOT model is being adopted by Oregon counties and WSDOT, to manage rare species. Currently the SMA program is focused almost exclusively on flora (plants), however, other disciplines such as wetlands, fisheries, and possibly archaeology may benefit from the use of Special Management Area Signage. ODOT has noted that long-term departmental commitment and a good working relationship between Environmental Services, district maintenance crews, and state and federal regulators have been essential components in the effort's success in protecting and enhancing populations of rare plants.

WSDOT Threat-Specific Rare Plant Management

During June and July of 1998 WSDOT conducted an extensive survey within 200 feet of U.S. Highway 2 for its length of Tumwater Canyon. Biologists/botanists from WSDOT, the

Washington Department of Natural Resources' Natural Heritage Program (WDNR-NHP), and the U.S. Forest Service participated. This survey disclosed the presence of three rare plants; one of which is proposed for federal listing as endangered and the others listed as state threatened and sensitive plants. An ortho photo with GPS points of rare plant locations was prepared and a GIS map, of much larger scale showing these same points, was prepared for the WSDOT Maintenance Office in Leavenworth and the Leavenworth Ranger District.

Actual/potential threats to rare plants were identified, highlighting ones over which WSDOT had control or influence. From that list, appropriate management practices were identified.

1. Competition and shading from native trees and shrubs
2. Competition from nonnative and/or state-listed noxious plant species
3. Wildfire and fire suppression
4. Activities associated with fire suppression
5. Plant succession in the absence of fire
6. Low seedling establishment
7. Roadside vegetation control by applying herbicides
8. Spreading of roadway anti-icers/deicers during winter months
9. Mass-wasting and soil erosion on unstable slopes
10. Motor vehicle exhaust emissions
11. Human trampling and collecting
12. Poor seed development
13. Low reproductive capacity

It was determined that WSDOT could do very little to minimize Threats numbered 3, 4, 5, 6, 10, 12, and 13. Those that WSDOT can assist to minimize (1, 2, 7, 8, 9, and 11) are covered below in the next sections.(*1075*)

Minimizing competition and shading from native trees and shrubs

Rare plants can be threatened by competition and shading from native trees and shrubs. In some instances, the removal of hazard trees can help protect rare plants. At the same time, tree removal can impact rare plants if not done correctly.

WSDOT maintenance implements the following stewardship practices to reduce undesirable shading:

- Identify areas where trimming or removal of trees is desirable for maintenance.
- Contact the land manager (USFS) or regulatory oversight agency and come to agreement on the best approach, meeting on-site if needed.
- Employ identified BMPs.

Minimizing competition from non-native and/or state-listed noxious plant species

Nonnative and/or state-listed noxious plant species threaten rare plants by competition. Applying herbicides to weeds while performing roadside vegetation control can help protect rare plants. To this end, maintenance in areas with rare or endangered species involves the following stewardship practices at WSDOT:

- Inform the land manager/regulatory agency of spraying dates. Agree on best approach. Meet on site as needed. The land manager, in this case USFS, is responsible for weed control in immediately adjacent areas.
- Identify road segments where rare plants are absent and spraying can be conducted.
- Utilize selective control and hand application of herbicide when near rare plants.
- Employ BMPs for water quality, habitat, and worker protection.

Minimizing impacts to rare plants during work on ditches

To avoid adversely affecting rare plants near the highway while working on ditches, WSDOT maintenance forces employ the following stewardship practices in the vicinity of identified populations:

- Check the known locations of all rare plants.
- If rare plants occur within 2 m (6.6 ft) of the ditch and plant disturbance cannot be avoided, consult the land management/regulatory agency in advance. If another agency manages the area (such as the USFS), maintenance forces can identify work locations and ask the land manager to mark any individual rare plants on the day work will be done.
- Perform the maintenance and repair in accordance with agency procedures and stewardship practices for Water Quality and Habitat Protection.
- Remove all location markings from plants in the field.

Minimizing threats to rare plants from soil erosion on unstable slopes

To minimize rare plants being threatened by soil erosion on unstable slopes within the highway easement, WSDOT maintenance forces have committed to do the following for identified target populations:

- Check to determine if rare plants are known to exist in the unstable area.
- If within the area, mark all individual plants on the day work will be done.
- If the plant disturbance cannot be avoided, consult the land manager or regulatory agency.
- Perform the maintenance and repair in accordance with standard and agency best management practices.
- Remove all location markings from plants in the field.

Permanent solutions to chronically unstable slopes are undertaken by WSDOT's Unstable Slope Program. In those cases, construction forces:

- Identify the areas with chronically unstable slopes.
- Consult with technicians from the Unstable Slope Program.
- Check to determine if rare plants are known to exist for each of the chronically unstable areas.
- If safety measures such as "scaling," "bolting," "netting," "trim blasting," "doweling," "fencing," and/or "rock buttressing" will be performed, consult the land manager and/or the regulatory agency for concurrence.
- If possible to revegetate the exposed areas, confer with the land manager or regulatory agency about using local rare plants or suitable noninvasive native plants.

Minimizing threats from human intrusion, trampling, and unauthorized collection

Rare plants that are threatened by human intrusion, trampling and unauthorized collection will require a conscious effort, on the part of land managers and the DOT to watch for such action or implement a monitoring program. If it is determined that such threats occur, both agencies will confer with one another to establish a contingency plan for minimizing the threat. Actions the DOT can take may include blocking newly constructed maintenance pullouts during flowering of rare plants or other measures if parking and public access become significant issues.

Annual training sessions will be conducted to assure that rare native plants, in the canyon, receive the attention required for their protection and sustainability. Field staff from both Design/Construction and Maintenance Divisions will receive training that includes discussion of the importance of the rare plants in their associated ecosystems, their natural history, and the roles each agency has agreed to play in the planned rare plant management strategies. Training should include a field review to point out individual rare plants, their specific locations, and advice as to what can and cannot be done to them. Such training should be conducted annually.

Identifying new locations of rare plant species

If new or additional rare plants are found, their type (common or scientific name) and specific location should be reported to DOT biologists, land management or regulatory agency biologists, and/or the state Natural Heritage Program, depending on the state DOT's process for confirmation of plant identification. If confirmed, and depending on the location, it may be recorded as a new sighting and subsequently logged via GPS into the appropriate GIS database. The relevant state or federal agencies should be notified of the find and its location.

TxDOT Rare Plant Management Partnership

One of the major public landholders in Texas, a state with less than 10 percent public land, is the Department of Transportation (TxDOT). TxDOT manages over 750,000 acres of highway right-of-way.(1076) A 1989 survey of the Texas Biological Conservation Database revealed 150 occurrences of listed or category plants on or within the immediate vicinity of highway right-of-way. To assure protection for these species, a project was undertaken between 1990 and 1994 to identify listed and non-listed rare plants occurring on highway right-of-way, collaboratively develop management agreements to protect these species, and establish monitoring plans to assess the effectiveness of the management. Of the 150 potential sites identified in the Conservation Database as possibly occurring on highway right-of-way, 57 were relocated, 15 were either not found or not found to be on highway right-of-way, and 88 were still being verified as of 1995. The management effort for species in the ROW led to establishment of 26 management/ monitoring areas; monitoring/management agreements were maintained between TxDOT and the Texas Parks and Wildlife Department until the program ran out of money several years later. A total of 33 populations representing 26 species were monitored while the program was in effect, and data collected in that period indicated that about two-thirds of the species' populations increased or remained stable under the agreed upon management regimes. Decreases were usually assignable to drought, but occasional abnormal habitat disturbances such as fiber optic cable placement contributed as well. However no decreases in either population numbers or vigor were attributable to TxDOT management. TxDOT placed "No Mow" or "Wildflower Research Area" signs were placed around some rare plant populations. In a few areas reflector posts cordoned off populations, to help keep mowers out.

Oregon DOT GIS-Based Sensitive Resource Inventory

The Oregon Department of Transportation (ODOT) has developed a geographic information system (GIS)-based inventory of sensitive resources and erosion control problem areas along nearly 6,000 miles of state highway as part of its Salmon Resources and Sensitive Area Mapping Project. The primary purpose of the project is to provide accurate resource protection maps to roadway maintenance crews so that mowing, pesticide application, and other activities do not harm listed salmon species and other sensitive resources and so that streams and banks in poor condition might begin to be addressed.

The comprehensive resource inventory was developed by using color infrared digital imagery with 2-foot resolution. Other sensitive resource features were recorded from current knowledge bases and limited roadside surveying, and from modeling of interactions between multiple resources and data layers. After distance to water, stream and bank characteristics, known threatened and endangered species locations and the overall condition of the salmon and trout habitats were identified. ODOT compared the imagery to previous data collected from other sources, such as wetland information from the National Wetland Inventory and hydrographic data from the U.S. Geological Survey to update and validate these findings.

GIS maps were tied into ODOT's linear referencing system, which enables ODOT to identify the locations of sensitive natural resources features within a hundredth of a mile.(*1077*) From this GIS resource, ODOT's Transportation Inventory and Mapping Unit and the Information Systems Branch developed a series of detailed resource maps in 0.01-mile segments, which indicate where sensitive resources are present including which side of the road. Based on the potential for environmental harm, certain restrictions were developed for each mile of highway. This information was then placed on restricted activity zone maps. These maps were designed to alert ODOT staff to specific locations of sensitive natural resource features in order to avoid inadvertently harming wildlife or wetlands when performing routine maintenance practices, such as slope maintenance, snow removal, and vegetation management. They also served to help minimize the potential for violations of the Federal Endangered Species Act and the Clean Water Act. ODOT supplied these maps to all districts, for use by biologists, planners, and maintenance managers. Laminated Restricted Activity Zone Maps for maintenance use a simple color-coding scheme of green and red to indicate, for each major class of maintenance activity (e.g., surface and shoulder work, vegetation management, snow and ice removal, etc.), whether or not that activity should be restricted along the left or right side of a given 0.01-mile segment of highway.

For approximately the same cost as field surveys, ODOT produced better quality data that was less subject to individual interpretation, and covered over a much larger analysis area— 1,000 feet from the roadway centerline, without concern for access/trespass issues. By using remote sensing techniques to collect and map data, ODOT recognized significant savings, both in cost and time. Before turning to advanced imaging technology to help implement this project, ODOT had been sending three two-person crews into the field for three and a half months to physically capture data. Once the digital imagery provided a base map to work from, the field crews were able to focus their energies on data validation instead of data capture. It also reduced the amount of time and resources needed to one two-person crew for two months, allowing for a quicker solution to the increasing problem of deteriorating wildlife habitats. Had ODOT chosen not to use digital imagery to map these sensitive areas, the results may have been significantly less accurate and outdated within a short period of time. In fact, some natural features may not have been inventoried at all as they would have been inaccessible to the field crews or too expensive to map across the entire state. The methodology developed by this project is easily adaptable for other state projects.

The library of geographic information system (GIS) data resulting from the project has given ODOT's regional staff a detailed environmental inventory of ecological resources, facilitating consideration of sensitive natural resource features when planning and designing transportation system improvements. The maps have proven to be a reliable, desktop scoping tool. The GIS system, data layers, and existing modeling routines facilitate easy updating as new information and aerial photography becomes available. ODOT is now developing an internet-based application to enable wider desktop access to the information. Because the inventory data is digital and easily transferable between agencies, ODOT can also easily share this data and streamline communication processes with the National Marine Fisheries Service, the Oregon Department of Fish and Wildlife, the USFWS, and the U.S. Army Corps of Engineers. ODOT's Resource and Restricted Activity Zone Maps were also key to negotiation of programmatic consultation for maintenance operation activities with the National Marine Fisheries Service (now NOAA Fisheries), under the federal Endangered Species Act (ESA). Specifically, ODOT received an exemption under 4(d) of the ESA allowing crews to perform routine road maintenance without having to consult with NOAA Fisheries on individual actions. ODOT is also exploring real-time geographic positioning system (GPS) connection to maintenance vehicles, as well as herbicide application spray booms to automatically activate and deactivate applicators as needed to avoid impacting sensitive resources including streams, wetlands, or rare plant populations.

Wisconsin DOT Characterization of the Karner Blue Butterfly Habitat in the ROW

As part of Wisconsin's Statewide Habitat Conservation Plan (HCP) for the Karner blue butterfly, the Wisconsin Department of Transportation (WisDOT) conducted an initial inventory of high potential corridors for the presence of lupine along state highway ROW, using soil types as a simple key indicator. Management for the Karner blue butterfly also benefits a number of other state-listed species and federal species of concern, including plants, turtles, lizards, and other butterflies.

WisDOT's primary strategy for maintaining butterfly habitat is to manage ROW to provide for corridors of dispersal between larger butterfly population centers via habitat in the ROW along corridors controlled by DOT. USFWS and Wisconsin DNR see the corridors as important in creating connectivity, short-term refuge areas, and dispersal corridors. This strategy includes the following measures for areas with high potential for presence of the Karner Blue Butterfly (KBB), as determined by soil type: 1) selective mowing that avoids the growing season except immediately adjacent to travel lanes, 2) lupine seeding after construction projects in appropriate soils and locations, 3) removal of brush and trees during the non-growing season to assure continued lupine habitat (2-5 year basis for mowing), 4) mitigation for permanent take or removal, 5) monitoring KBB/lupine populations through annual surveys, and 6) public education WisDOT corridors meeting the following criteria were included in the agreement: 1) those within high potential range of KBB, typically upland sandy soil areas in central and northwestern Wisconsin, 2) corridors that already contain significant wild lupine populations or KBB, and 3) those close to, or connected with other KBB HCP lands that have potential for similar management.

WisDOT also implemented an internal education and training program for maintenance crews and other appropriate field personnel regarding KBB and lupine identification. Herbicide use is limited to spot applications for invasive weeds and cut stumps. WisDOT shares roadside management techniques and information with counties and towns upon request.

The overall Habitat Conservation Plan brought together 26 partners, including eight counties, the WisDNR, and WisDOT. WisDOT undertook a species and habitat conservation agreement with the state DNR, which, in turn, has a statewide HCP and Incidental Take Permit with the USFWS. The implementation agreement covers approximately 4,000 acres for 10 years.

Canadian Practices for Vegetation Preservation from Winter Maintenance

The Transportation Association of Canada makes the following suggestions for protection of sensitive plants in the ROW from winter maintenance practices:(*1078*)

- In urban areas protect newly planted conifers by erecting burlap screens during the winter months;
- In urban areas consider applying anti-desiccants and anti-transpirants to the tender shoots of sensitive plants;
- Sweep salt laden grit from turf areas as soon as possible in the spring;
- Shield natural areas from salt spray by planting buffers of salt tolerant species; and
- Where feasible and cost-effective consider using snow fences (living or structural) to reduce snow accumulation on roadways or to trap salt spray and prevent it from traveling far from the roadway.

Other Cultural Control Methods

While fostering native vegetation is the most common cultural control method, goats or sheep are used for control of herbaceous weed species in a few areas. Pulling of invasive weed species is the method of choice sometimes due to environmental constraints and high leverage gripping tools have been used to pull woody plants.(*1079*) The New Mexico State Highway and Transportation Department developed an experimental project for noxious weed control along a six-mile section of state highway in Taos County, using goats.(*1080*)

9.5. REDUCED MOWING POLICIES AND OTHER MECHANICAL VEGETATION STEWARDSHIP PRACTICES

Mowing provides sight distance and room for a vehicle to pull off the road. Intersections, bridges, sharp curves, and farm and field entrances require periodic mowing to maintain a safe ROW. Mowing roadsides is a highly visible aspect of vegetation maintenance that also contributes to corridor aesthetics and public satisfaction. It is also very expensive in terms of personnel hours, equipment hours, and fuel consumption. Reduced mowing practices, which were initiated as early as the 1950s by Wisconsin DOT, expanded to many more DOTs in the 1970s, when high energy costs forced vegetation managers to mow less and spot spray, with the positive consequences such as increased wildlife habitat, enhanced natural beauty, minimized herbicide use, reduced maintenance dollars, and public acceptance.(*1081*) NCHRP 20-5, 33-04 indicates that state DOTs remain heavily dependent on mechanical control methods, with the bulk of states cutting over 90 percent of their ROW, a smaller set having reduced mowing to 50 to 90 percent, and only Florida and Washington indicating less than 50 percent was managed using mechanical methods.(*1082*)

In recent years, mowing policies have been tied to impacts of habitat in the right-of-way for ground-nesting birds. DOTs are in the process of converting away from traditional turf species in the ROW to those that require less maintenance. Plant growth regulators have been used on less desirable species in some cases, to reduce maintenance inputs and mowing cycles;(*1083*) however, many DOTs are now exploring policies reintroducing or allowing native grasses and restricting mowing to one mower-width along the shoulders to conserve resources, foster habitat, improve the spread of native species and move toward the displacement of noxious weeds.

In sum, reduced mowing can provide the following environmental benefits:

- Conserve staff hours spent mowing;
- Conserve fuel usage and costs;
- Conserve air quality through reduced spent fuel emissions;
- Conserve habitat for protected and declining populations of ground nesting birds
- Conserve required equipment maintenance; and
- Conserve habitats through reduced fragmentation.

Developing a Mowing Policy

Mowing policies help make best use of maintenance staff time, assist in the prioritization of areas to be mowed and not mowed, help achieve environmental stewardship objectives, and increase safety for mowing staff and improve public relations. Mowing policies can also reduce environmental damage that can be caused by mowing, where mowing does occur. Improper mowing can generate additional maintenance problems and adverse effects to soils, roadside habitat, and nesting birds. Improper mowing height and overly frequent or poorly timed mowing can reduce root mass, plant vigor, and overall plant production potential. Operating heavy equipment on roadside slopes can destroy vegetation, weakening the plant community and making roadsides more susceptible to weeds and erosion. Planning and following a policy with regard to mowing and educating staff regarding proper mowing procedures can help DOTs avoid some of these problems.

When developing a mowing policy, a DOT should consider the prioritization of mowed and unmowed areas, safe operating practices, noxious weeds, and expected or required cost reductions. Mowing staff will be able to provide important input in a mowing policy that addresses safety concerns, identifies communication issues and procedures, and establishes the criteria for which areas are to be mowed and to what extent. Agreement on these issues and inclusion in a written plan results in all staff working towards the same goal.

The following practices will contribute to development of a good mowing policy:

- Objective of mowing
- Impacts if mowing is reduced
- A communication plan between mower operators and weed sprayer operators
- Areas that could be left unmowed with little negative effect
- Ways to blend areas that are left unmowed with areas that are mowed
- Treatment of those areas left unmowed
- Mower operator training needs
- Other maintenance activities that could be done if less time is spent on mowing
- Magnitude of slopes to be mowed and not mowed
- Person or persons who will determine the areas to mow and not mow
- Best time to mow certain vegetation types, based on growth, time of year, or height
- Alternative vegetation that could be planted that does not have to be mowed
- Nesting times for local wildlife
- Location of saturated soils

Reducing the amount of mowing and the extent to which areas are mowed gives workers more time to complete other activities and increases the efficiency of all maintenance operations.

Mn/DOT's Mowing Policy and Practices

Mn/DOT's mowing policy states that the primary purpose of maintaining vegetative cover is to prevent erosion. Roadsides are to be generally maintained in conformance with adjacent land use, and spot mowing is to be used to control noxious weeds.

Minnesota has a mowing law that regulates mowing outside the metro area, according to the following requirements:

- The first eight feet from the roadway surface may be mowed.
- The entire right-of-way may be mowed from July 31 to August 31 for any reason. The rest of the year, the entire right-of-way may be mowed only for safety reasons, and only to a minimum height of 12 inches.
- The entire right-of-way may be mowed to maintain sight distance.

- The entire right-of-way may be mowed, burned, or tilled for establishment of permanent vegetative cover or for prairie vegetation management.

Mn/DOT statewide requirements for mowing widths include:

- Mow all grass to a minimum height of 100 mm.
- Mow all of the shoulder.
- Mow two swaths of the mower on all in-slopes.
- Mow the entire median for those less than 17 m wide, and for medians greater than 17 m wide, mow two-swath widths.
- Develop a smooth transition when blending between mowed and unmowed areas.
- For safety reasons operators should avoid slopes greater than 3:1, be alert and slow down in high grasses, avoid traffic, and wear all approved safety equipment.
- Keep signs clear and their approaches mowed from approximately 150 m.
- Keep vegetation around guardrails controlled for approximately 0.5 m on either side to reduce the effects of trapping sand, snow, and dirt.
- Maintain sight distance at at-grade intersections, interchanges, and curves.
- Other highly recommended practices include:
- Identify noxious weeds that can and should be controlled by mowing (at least in part), identify location of patches, and thresholds when mowing should occur for these areas (such as when patch area exceeds a certain size).
- Identify noxious weeds that should not be mowed or conditions under which they should not be mowed, to avoid inadvertently spreading these weeds (e.g. leafy spurge).
- Communicate with other maintenance staff to avoid mowing areas soon after or just before spraying, and to avoid mowing areas of leafy spurge.

The Metro Area mows with an emphasis on quality, not quantity, and follows these principles:

Mowing for Safety

- Sight corners at same grade intersections of township, county, and state highways. Vegetation that obstructs the vision above a 30-inch sight line to crossing traffic should be mowed or cut within the boundaries of the right-of-way markers.
- Sight lines at interchange entrance ramps. Vegetation that obstructs the vision above a 30-inch sight line to mainline traffic should be mowed out within 300 feet of where the mainline and the merging lane join.
- Not to exceed 18 inches, and optimally 12 inches.

Mowing for Noxious Weed Control

- Mow heavily infested thistle patches over 50 square feet before the plants go to seed. Minimize scattered mowing patterns.

- Communication between mower operators and Mn/DOT or contract herbicide applicators is extremely important to prevent mowing right after spraying or mowing out areas to be sprayed in the future.
- Do not mow leafy spurge.

Aesthetic Considerations When Mowing

- Make attractive flowing mow lines that blend with features such as guardrails, delineator posts, traffic signs, light standards, retaining walls, etc.
- When a one- to two-swath cut results in mowing out over half the width of a narrow right-of-way strip, mow the entire strip to the retaining wall, noise wall, or other feature.
- Mow to the break in the slope on fill slopes even if it means mowing less than the capacity of the mower. It may even take mowing one instead of two swaths.
- When mowing out noxious weed paths, drive to the patch with the mower off and raised up unless a blending cut makes sense off the one- to two-swath cut.
- Conduct fall mowing/cleanup mowing before winter.

Mowing to Enhance Native Species

EPA's Great Lakes Environmental program recommends mowing as "the primary management tool used to prevent weeds from shading prairie seedlings:"(*1084*)

- During the first growing season the planting may need mowing a number of times. The cutting height should be 4 to 5 inches.
- Mow each time the weed growth is 6 to 10 inches high and do not allow weeds to set seed. Do not worry about cutting the tops off or crushing the seedlings. A flail-type mower is preferable for large areas because it chops cuttings into small pieces which will filter down and serve as mulch. If a sickle-bar or rotary-type mower is used, mow more frequently so cuttings will not have become large enough to smother native seedlings.
- Try to time the last mowing so weeds can grow to about 8 inches before winter. This will help protect young seedlings from heaving frosts. During the second growing season one mowing may be helpful in late spring or early summer if weeds are thick. This should be the last mowing needed for weed control unless a serious problem occurs. Raise cutting height to 6 to 12 inches if mowing during second year.

Nebraska Department of Roads' Mowing Policy

The Nebraska Department of Roads (NDOR)'s mowing policy states that limited mowing frees workers to do more important maintenance and provides benefits including a living snow fence and habitat for animals in some cases. Nebraska's policy allows for mowing only those slopes less than 3:1. Areas with slopes greater than 3:1 are marked with a sign, and all mowers have a slope indicator in them to provide additional information. NDOR mows to a minimum of 5- inch cut height. Its first mow is by Memorial Day. The width of the mowed area depends on the type of highway, whether the area is a median or shoulder, and whether or not decorative flowers are present.

Type of Highway	Area	Mow width
Interstate	Median	5-8’ if flowers present
		5-15’ if no flowers present
	Outside	15’ maximum
Other highways	Outside	5-15’ with surfaced shoulders 15’ with turfed shoulders

Nebraska performs a second mow sometime during the summer to provide sight distance. The final mowing is done after Labor Day, as needed to provide snow control and to finish total mowing. It does not use mowing to control brush, which is controlled with chemical application. To ensure that agencies have an equal understanding of its mowing policy, NDOR issued a memo of understanding with the state game and parks commission specifying frequency of mowing, mowing widths, and safety standards.

Wisconsin Department of Transportation Mowing Policy

The Wisconsin DOT adopted a Natural Roadsides philosophy in the 1950s when it became apparent that it would be fiscally impractical to mow the entire highway rights-of-way on the new 4-land divided highways that were being built. A limited mowing policy was written and is still in place today, with some modifications. WisDOT’s current mowing policy is to maintain a clear zone, free of woody vegetation within 25–30 feet of the roadway edge. Mowing in the clear zone beyond the shoulder cut is permitted every two to three years, and is only allowed from mid-July to the end of March to allow nesting birds to hatch. The grass is mowed to a minimum height of 6 inches and a width of 15 feet on the outside of the road and 5 feet on the inside. For safety reasons, no mowing is allowed where the slope is greater than 3:1. Mowing is allowed in the first few years after construction to control weeds. According to WisDOT, the policy has resulted in:

- More attractive roadsides
- Clear vision at intersections
- Safe pull-off areas
- Clear recovery zones
- Lower maintenance costs
- Smooth visual transition from roadway to vegetation beyond
- Preserved native vegetation
- Natural regrowth
- Improved wildlife habitat

NCDOT Mowing Program Modifications to Encourage Wildlife Native and Rare Plant Species

NCDOT implements their mowing program with an environmental perspective to encourage wildflowers, protect rare or endangered plants and protect or create wildlife nesting areas.

Currently NCDOT protects over 35 populations of rare plant species growing along its roadsides. Most of these plants are listed as federally threatened or endangered by the U.S. Fish and Wildlife Service (USFWS). Endangered species such as Smooth Coneflower, Schweinitzii's Sunflower, Michaux's Sumac, Rough-leaved Loosestrife and Cooley's Meadowrue often occur along roadsides and in powerline rights-of-way, or in natural habitats that were once dominated by fire but are now mowed to mimic fire maintained ecosystems. Other species are listed as significantly rare in North Carolina. NCDOT works with USFWS, the North Carolina Natural Heritage Program and the North Carolina Plant Protection Program as well as different utility companies to protect these roadside and powerline populations of rare species. Endangered plant populations are marked with white-topped wooden stakes, an indication to mowers that the area is off limits during the growing season. These areas are managed on a site by site basis according to their individual needs. Management strategies to control invasive woody vegetation include mowing during the dormant season, hand pruning and prescribed fire. Effective communication among environmental biologists and horticulturists, environmental engineers, and roadside maintenance personnel is crucial to the success of this program. NCDOT cooperates with the North Carolina Wildlife Commission in posting and managing small game wildlife habitat areas in the ROW. Properly timed cleanup mowings enhance wildlife habitat.(*1085*) For more information, see and overview of NCDOT's program in the section on Rare Plant Management in the ROW.

NYSDOT Stewardship Mowing Practices

General NYSDOT mowing guidelines are outlined in NYSDOT's Mowing Limits Manual, Highway Maintenance Subdivision Operational Guidelines, and Environmental Handbook for Transportation Operations. The Mowing Limits Manual addresses safety, water quality and erosion and sedimentation control, appearance and screening, landscape plantings and woody vegetation, and natural revegetation. NYSDOT's Environmental Handbook for Operations outlines the following stewardship practices and expectations for mowing, which go beyond mowing reduction policies to address other environmental features in the ROW: (*1086*)

- Ditches are mowed to control vegetation rather than mechanically cleaning ditches with heavy equipment because mowing causes less erosion of exposed soil and can result in improved water quality.
- Wetland mitigation areas are not mowed. Permanent markers are installed around these areas.
- Since many federally-protected ground nesting migratory songbirds and waterfowl nest prior to July 1, mowing of large relatively flat areas located outside of built up or developed areas (such as on the interstate system) is avoided or limited during nesting season. In advance of mowing likely nesting areas are identified and marked.
- Areas that are managed for wildflowers are not mowed more than once a year and after the first hard frost or in the late fall.
- A minimum 3 meter (10 feet) unmowed buffer strip is left along the edge of all streams and wetlands.

- Mowing is avoided on days when ozone levels are expected to approach or exceed unhealthy levels and voluntary actions are needed to reduce emissions and formation of ozone.
- Mowing is restricted or avoided in habitats for threatened or endangered species.

In addition, NYSDOT is implementing Conservation Alternative Mowing Plans (CAMPs) that preserve safety and aesthetics while maintaining safety and aesthetic standards. CAMPs involve identification of rich landscapes as part of the maintenance planning process, threshold values for several species and suitable habitat in the landscape, species or groups of species to be used as indicators, and the barrier effect of roads.(*1087*) CAMPs have been successfully developed and implemented on Interstates, Expressways and Parkways at NYSDOT through a multi-disciplinary team approach, culminating in the following guidelines, using four zones that describe to the operators what management is expected in the different zones. A High Management Zone is comprised of an intensely managed area immediately adjacent to shoulder or curb; a Frequently Mowed Zone next to it is mowed multiple times per year; an Annually Mowed Zone provides a transition between the Frequently Mowed Zone and No-Mow Zone (or left to regenerate naturally); and a No-Mow Zone is left in natural state or left to regenerate naturally. The following stewardship practices are taken from NYSDOT's draft CAMP guidelines: (*1088*)

- Generally, the Frequently Mowed Zone will be 30 feet in width or will be set at the back side of the drainage ditch. The limits of this zone may be reduced or extend further depending on actual site conditions.
- The limits of the Frequently Mowed Zone may require adjustment to preclude the development of annually mowed areas that are too narrow (less than 60 feet wide), too small (less than 2 acres), or too linear. Annually Mowed Zones will not be mowed until after August 1st. Annually mowed zones should be mowed no more than once per year, however to further increase the conservation benefits, these areas may be mowed less frequently but with due consideration of the desire to limit establishment of woody plants within periodically mowed zones.
- The decision to include an annually mowed zone should consider many factors including, the adjacent land use and the width and length of the area. Since the annually mowed zone is important for ground nesting birds, these areas should be at least 60 feet in width and greater than 2 acre in size to reduce nest predation and allow a large enough nesting territory. Annually mowed areas will be most effective when located adjacent to or in close proximity to existing grassy fields and in these situations should extend to the limits of the ROW. When the adjacent land use is mature forest, the annually mowed zone should not be included or should be combined with a no-mow zone, as appropriate.
- For consistency, Mowing Limit Markers should only be placed at the transition between the Annually Mowed Zone and the No-Mow Zone (the markers can be placed to create a natural appearing, meandering boundary.) Markers should be standard wooden or fiberglass stakes. Over time, the need for these markers should diminish as the demarcation of the zones becomes well established. These zones should also be captured electronically using GPS. Mowing Limit Markers should be placed with due

consideration of sight distance. This is especially important at entrance/exit ramps. The No-Mow Zone shall not encroach into the sight distance cone and restrict visibility.

- The No-Mow Zone can be left to regenerate naturally. This process is termed succession. The final stage of succession is a self perpetuating, sustainable, and interdependent community of plant and animal life. The establishment of No-Mow zones is intended, in part, to permanently reduce the amount of mowed area and to reduce the negative environmental effects of habitat fragmentation.
- On narrow medians (less than 120 feet between the High Management Zones), new No-Mow zones may be established between the 30 foot minimum Frequently Mowed Zones with due consideration for maintenance structures such as drainage ditches, deer reflectors, living snowfences, etc.
- New woody plantings can be included to the No-Mow Zone. The purpose of these plantings should be to increase diversity of the plant community.
- Careful consideration should be given to any new planting of trees and/or shrubs in the Annually Mowed Zone. In addition, new plantings should be grouped in such a manner as to preclude the necessity of maintenance personnel to mow around individual plants. Supplemental (new) plantings can be included to correct existing conditions by “filling in” the spaces between the existing plants where mowing is difficult or not possible. Living snowfences, wildflowers or deer reflectors may also be included in this zone. All new planting in this zone should be carefully coordinated with NYSDOT Maintenance to insure that it can be maintained without undue effort. Any exceptions to this rule must be agreed to by NYSDOT Maintenance.
- Any dead and/or dying trees should be carefully reviewed for potential hazard. If it is determined that the tree would not cause a hazard if it falls, consideration should be made to leave the tree standing. Dead trees provide cover, nesting cavities and perches for birds and small animals.
- Vegetation management practices may be modified depending on the characteristics of the land use adjacent to the corridor (urban, suburban, and rural). Urban corridors may be expected to have a greater proportion of High Management and Frequently Mowed vs. Annually and No-Mow Zones. Additionally, Parkways and Expressways may require different management due to the nature of the different roads.

Mowing Management in Southern Quebec, Canada

According to a study commissioned by the Ministère des Transports du Québec, traditional methods of controlling vegetation along the agency’s 2000 km of highway corridors in southern Quebec (Canada) “result in a boring landscape, deteriorate the various wildlife habitats and impoverish wild plant life while generating high maintenance costs.” Recently, the agency has pursued develop new maintenance methods, including elimination of multiple annual mowings, to improve the safety of the highway system’s users, satisfy neighboring residents, beautify the landscape and consider the plant life and wildlife present along the highways. The new approach eliminates multiple mowings except on the first two meters from the pavement, which will be mowed more frequently to ensure highway safety (visibility) and better control of the allergen, ragweed. The agency and its researchers have also been monitoring the slowly increasing biodiversity in the unmowed area since 1998.(*1089*)

Oregon DOT's Mowing and Brush Removal Practices

Oregon DOT's mowing, trimming, removal of brush and cleanup practices are designed to restore sight distance, reduce ice (due to shading), and to control/prevent slope failure.(*1090*)

- Local Integrated Vegetation Management Plans identify mowing areas, and are designed to minimize impact to receiving waters while still maintaining grassed areas.
- ODOT Maintenance actions will limit mowing to no more than 8 feet off edge of pavement in significant resource areas, unless needed to maintain proper functioning of highway features (e.g. drainage).
- Cut brush, in riparian areas, will be left in place where doing so does not interfere with sight distance, create safety issues, cause fire hazards, involve noxious weeds or the proper functioning of highway features (e.g. drainage).
- ODOT Maintenance will maintain shade trees along streams and rivers, unless those trees are danger trees (as determined by ODOT Forester and/or appropriate resource agency), could potentially impact bridge structures, or could impact line of sight. If trees provide shade or bank stabilization within 50 feet of streams and are determined to be danger trees that must be removed, tree removal will be coordinated with ODFW or other regulatory agency.
- Only brush within 20 feet (on either side) of and under all bridge structures will be removed. All other brush not within ODOT's clearzones will be left in its current condition, unless the brush interferes with sight distance, shades the structure, or the brush is a noxious weed (e.g. scotch broom). Mapping of sensitive resource areas may lead to additional areas not being brushed.
- On culverts 6 feet or greater, ODOT Maintenance will remove 10 feet of brush on both sides of the culvert, on the upstream end of the culvert and 10 feet on both ends on the downstream side, unless the brush around the culvert is a noxious weed. If other brushing needs are identified, ODOT will coordinate with ODFW. When removing mature trees (over 12-inch (30cm) diameter at breast height (dbh)) in riparian areas, ODOT will replant two seedling/cuttings for every tree removed. ODOT will coordinate with ODFW on species and location of trees to be replanted within the same watershed. ODOT will ensure that the replanted trees will not pose a future threat to ODOT structures.

Other DOTs with Brush Control BMPs

NCHRP 20-5, 33-04 reported that Arkansas, Connecticut, Illinois, Maryland, Pennsylvania, Texas, and West Virginia have identified BMPs for mowing brush/small trees on their roadsides. (*1091*) Illinois, Nebraska, New York, and Texas had BMPs for other horticultural activities including best management practices for controlling trees that are or may be roadside obstructions and tree trimming by contract, in addition to general brush control guidelines.(*1092*) Alaska, Connecticut, Illinois, Maryland, Nebraska, New York, Pennsylvania, Texas, and Utah indicated they have best management practices for controlling trees that are or may be roadside obstructions. (*1093*) The author is aware of brush control BMPs in use in Delaware, Kentucky, and Oregon, some of which are summarized in the previous section.

9.6. CONTROLLED BURNING

Controlled burning or prescribed fire is a carefully planned and controlled fire conducted to manage natural areas such as prairie, oak savanna, wetlands and oak woodlands. Prescribed or controlled burns have been used by land managers for over 25 years in modern history and for over hundreds of years by Native American tribes. Fire kills the above ground parts of shrubs and small trees. Prairie plants grow more vigorously when built-up plant materials and shade are removed. Spring fire uncovers the soil, so it warms sooner, thus extending the growing season. Roadside areas across the United States are the site of important remnant native grassland habitats, many of which can be enhanced by management by fire. Controlled burning offers the following benefits: (*1094*)

- Control weeds and woody invaders
- Stimulate the growth of many native prairie plants
- Remove thatch
- Recycle nutrients
- Warm the soil and give warm-season plants an earlier start.

After two growing seasons, planted prairies need to be burned annually for the next several years to become well established (mature prairies with no serious weed problems may need burning only once every two to four years).(*1095*)

- Always use caution when burning.
- Check local fire regulations and obtain permits.
- Try to burn or mow only one-third of the prairie area each year to preserve over-wintering insects, their eggs and pupae.
- Always plan fire safety into plantings, even if you are not going to use burn management. Prairie fires intentionally or accidentally set during fall or spring dormancy can burn very rapidly.
    - Use any existing features such as roads, driveways, streams, lakes, or mowed lawns as fire breaks.
    - In addition to paths through a prairie, also include a wide path around the perimeter.
    - A mowed lawn buffer 20 feet in width between buildings and prairie is advised.
- An alternative to burning is to mow in late fall after seeds set or preferably in early spring (late March to mid-April). Sites that are too wet in spring need fall mowing when soil is dry.
- If burning does not occur periodically, cuttings need to be removed to avoid a thatch layer buildup.

- Do not cut and then burn large quantities of plant material (creating thick piles) or you will sterilize the soil beneath.

Before undertaking a controlled burn, staff must be properly trained and plans developed. Planning considerations should include:

- Traffic safety. Any burning plan must include smoke management provisions for safety purposes.
- Weather conditions.
- Equipment.
- Staffing.
- Timing. Burning is most beneficial from mid-April to early May for warm-season grasses. As with spraying growing weeds, burning earlier is better for wildflowers, and waiting does more harm than good.

Controlled burning is practically explained by Wayne Pauley in his *How to Manage Small Prairie Fires.*(*1096*) The Missouri Department of Conservation recommends the following practices for controlled burns, drawing on Pauley's work:

While fire management requires training and knowledgeable individuals, it takes "as little as a few hundred dollars in equipment, including drip torches, rakes, and safety clothing…Roadside prescribed burns are easy. The road is one fire break and the others can be a mowed field of harvested hay or lawns."(*1097*) Staff undertaking burns should be forewarned that corn stubble and older fence posts smolder.

Additional information regarding proper burning procedures can be obtained from the Fire Management and Research Program at The Nature Conservancy (850-668-0827) or your state resource agency. The Texas Parks and Wildlife Department (TPWD) uses an on-line burn plan form for controlled burns on state property and provides a Sample Burn Plan.

Controlled Burning or Hay Removal as Roadside Grassland Management Alternatives to Mowing

Mn/DOT and the University of Minnesota have been exploring whether mowing can be as effective as yearly burning at encouraging native prairie grasses and discouraging botanical invaders. A research team investigated the impacts of burning and mowing on three separate test areas, examining above-ground vegetation and below-ground fungal communities, as well as measuring changes in various soil parameters. Findings and recommendations were as follows: (*1098*)

- Prescribed burning has the strongest effects on plant community composition and was the most effective method to increase aboveground plant biomass in a restored tallgrass prairie. Burning especially favors warm season grasses and legume species, though it also favors certain annual species. Also, when immediate grass cover is desired, burning is the best maintenance technique available to increase grassland productivity.
- When burning is not an option, haying may be the next best alternative. The addition of lime may be important to consider on restorations of former agricultural lands.

- Adding lime to hayed prairie may help benefit the cool-season plants, native and exotic.
- Spring haying is an acceptable alternative to spring burning, though its effects are less dramatic than the burn. In particular, haying does not favor warm season grasses as extensively and may not damage cool-season species as thoroughly as burning. Spring haying did not control exotic species.
- Burning and haying provided the greatest increase in arbuscular mycorrhizal fungal structures, which may correspond to the increases in plant growth on these treatments. In prairie restoration, addition of arbuscular mycorrhizal inoculum appears to provide long-term benefits.
- Mowing the prairie in the spring has a similar affect on the plant community as no management. It is only useful for the control of woody species. Mowing may decrease nitrogen mineralization rates temporarily. This may help to prevent invasive species but is not likely to do so if mowed annually.
- Frequent burning or haying should be performed in order to prevent the accumulation of inorganic soil nitrogen, which may favor many weedy species. If haying is used instead of burning, soil pH should be tested periodically to detect acidic soil. Although this did not become apparent on this experiment, it may occur on long-term hayed grasslands. Acidification may lead to decreases in certain plant populations or losses in productivity.
- The process of removing litter seems to be the most important cause of the ecosystem response to prescribed burning. Hayed plots are the most similar to burned plots in terms of soil moisture, temperature, and litter quantity. Hence, litter removal by haying will likely be a sufficient practice to replace prescribed burning at many sites.

Controlled Burning for Noxious Weed Management

Five acres of highway ROW were targeted to learn more about prescribed burns as a management tool in California. The Bear Creek Botanical Management Area, one of the last examples of Upland Wildflower Fields in California, contained a plant community remnant with more than 200 native California plant species. After careful planning, Caltrans District 3 forces coordinated the safe passage of vehicles and the California Department of Forestry and Fire Protection (CDF) conducted the burn. The key target was yellow star thistle which had invaded half the site within a short time. Observations following the fire have shown the prescribed burn to be more effective than the preceding years of mowing, spot spraying, and hand pulling of star thistle.(*1099*)

9.7. MANAGEMENT OF WOODY VEGETATION

Trees and shrubs are pruned to preserve their health, remove dead branches, protect utilities, maintain sight distances, preserve aesthetics and prevent property damage. In the name of safety, improved visibility and obstacle-free roadsides, roadside vegetation managers favor grasslands. Management of woody vegetation comprises a significant expense for many DOTs. For example, 60 percent of PENNDOT's roadside maintenance budget goes to brush removal, approximately $26 million annually for maintenance of approximately 250,000 acres of ROW land statewide; reducing encroachment of the roadway is a major focus and main roads receive brush control annually.(*1100*) A 1994 New Jersey study implied that mowing once every 4-5 years would be enough to discourage forest invasion into the roadside recovery zone.(*1101*)

Brush Control Guidelines

Minnesota DOT provides the following environmental stewardship practices for brush control in the ROW: (*1102*)

- Don't spray big brush; rather, chop it down. The extreme color change from spraying may cause public concern.
- Spray when trees and shrubs are small (less than 6 feet tall), and preferably in the fall
- Mow smaller brush before spraying.

Tree Care and Pruning Guidelines

- Remove trees greater than 4 inches in diameter from zone 2.
- When spraying, keep an adequate distance from desirable woody plants.
- Prune every two years on young trees and every five years on trees in intensively managed areas.
    - Prune early in a tree's life so that pruning wounds are small and growth occurs at the best location.
    - Begin with a visual inspection at the top of the tree and work downward.
    - Identify the best leader and lateral branches before pruning, and remove defective parts before pruning for form.
    - Aside from protecting against oak wilt, pruning cuts need not be protected if they are done properly. For aesthetics, you may feel better painting larger wounds with neutral color tree paint, but evidence shows that it does not prevent or reduce decay.
    - Keep tools sharp. One-hand bypass or scissors cut (not anvil-type) pruning shears with curved blades work best on young trees.
    - Make safety a number one priority. For high branches, use a pole pruner. Some, like the one shown in Figure 4-5, have both a saw and a shears on the same tool.
    - When you prune back to the trunk for a larger limb, branches too small to have formed a collar (the swollen area at the base) should be cut close. (Note in the figure of the pruning shears that the cutting blade is cutting upward for less effort and a close cut.) Otherwise, follow the rules of good pruning of larger limbs by cutting just outside the branch ridge and collar, at a slight down and outward angle, so as not to injure the collar. Do not leave a protruding stub.
    - When simply shortening a small branch, make the cut at a lateral bud or another lateral branch. Favor a bud that will produce a branch that will grow in a desired direction (usually outward). The cut should be sharp and clean, and made at a slight angle, about 1/4 inch beyond the bud.

- Don't ignore the mid-size tree.
- Follow safety and OSHA standards.

Further information on correct pruning methods can be found online.

Compost and Shredded Brush on ROWs

Compost consists of mixtures of peat moss, bark, processed wood chips, lawn grass chippings, manure, and other materials which interact to produce a healthy growing ecosystem, using debris that might normally be landfilled or burned. Over 50 percent of municipal sold waste compost is recycled.(*1103*) An important trend in tree, brush, and wood waste management is the fact that in most states, this material can no longer be burned or buried. As a result, more and more material is being processed on site or is being recycled in central locations as compost. Chippers and grinders are a cost-effective way to recycle wood waste into useable mulch.(*1104*)

9.8. Noxious Weed Management

Plants designated as noxious weeds include invasive plants that compromise agriculture, harm humans, or degrade natural areas. Invasive, non-native species can cause significant disruptions to ecosystems as well as cause economic harm to farmers and other land managers who are responsible for controlling these species. According to a recent Cornell study, invasive plants spread into another 4600 acres daily, impacting our nation environmentally as well as economically at a cost of $23 billion annually from problems such as the following: (*1105*)

- Contamination or competition with crops.
- Decrease in forage value of rangeland and pastures.
- Displacement of valuable wildlife habitat.
- Elimination of waterfowl migration stops.
- Reduction in property values and ability to acquire loans.
- Alteration ground water reserves.
- Change in aesthetics of the landscape and degradation of natural heritage and educational value.
- Increased fire threats.
- Compromise of roadside visibility and safety.
- Attraction wildlife to roadside.
- Addition costs of roadside maintenance.

Construction projects, transportation systems, spraying and mowing operations, use of forage mulches that have not been certified weed-free mulches and other erosion control products can facilitate the spread of plant and animal species outside their natural range, exacerbating the costs imposed by invasive species. In the past erosion control has involved the planting of many species that are now controlled as invasives, including aggressive sweet clovers, alfalfa, smooth brome, trefoil, and perennial rye. Importation of topsoils to projects often increases ragweeds, thistles, and sweet clovers. Ill-timed maintenance disturbances like blading, mowing, ditch dredging, and bare-grounding have been known to increase weeds such as kochia, foxtails, thistles, and milkweeds. Movement of construction equipment from a weedy site to a non weedy site can transport undesirable seeds.(*1106*)

Most states develop and maintain noxious weed lists particular to issues and species of concern in their state. A Federal Weed Seed list addresses the transfer of certain weed seed of agricultural concern. State DOT efforts with regard to noxious weed management have taken on renewed urgency since FHWA issued guidance on invasive species in August 1999,(*1107*) following Executive Order 13112 calling on agencies to work to prevent and control the introduction and spread of invasive species. It encouraged state DOTs to join interagency partnerships and to increase funding of maintenance efforts, research, and training.

The guidance specified that federal funds cannot be used for construction, revegetation, or landscaping activities that purposely include the use of known invasive plant species as listed by states or the National Invasive Species Council. Subsequent NEPA analyses required determinations of the likelihood of introducing or spreading invasive species and a description of measures being taken to minimize their potential harm. With regard to construction and maintenance, Federal-aid funds can be used for new and expanded invasive species control efforts under each state DOTs' roadside vegetation management program. Recommended prevention and eradication measures included:

- Statewide, right-of-way inventories of vegetation that map existing invasive plant infestations.
- Inspection and cleaning of construction equipment.
- Commitments to ensure the use of invasive-free mulches, topsoils and seed mixes.
- Eradication strategies to be deployed should an invasion occur.

A number of on-line resources are available to assist in the identification and development of management strategies for particular noxious weeds.

- Fact sheets available for invasive exotic species are available on-line at Penn State University.
- The University of Davis and The Nature Conservancy maintain national control information on specific invasive species, detailed methods, tools, and techniques for weed control , as well as an inventory of photographs, and lists of species resources.

Among the variety of ways of containing weeds are biological, cultural, physical, and chemical control methods. Cultural control of weeds includes planting native grasses or competing plant species to force out noxious weeds. Physical control of noxious weeds includes tilling, mowing, and burning areas to control weeds. Chemical control of noxious weeds has been the most common to date, and will be discussed in the section on herbicide usage. Biological weed control includes the use of insects or pathogens.

Mechanical methods can be used as part of a control strategy for many species of noxious weeds. Mechanical methods are discussed in detail under the section on "Reduced Mowing and Other Mechanical Vegetation Management Stewardship Practices." Such mechanical methods are often used in conjunction with cultural control methods to foster revegetation with native species, discussed below.

All equipment used for invasive species control, whether hand tools or power driven, must be cleaned prior to entering a new site and prior to leaving the site, in order to reduce transport of plant propagules and reduce the potential for new invasive introductions.

Revegetation and Noxious Weed Control by Fostering Native Species

As part of their commitments to reduce noxious weeds and to develop attractive and sustainable roadside environments which are better for native species and DOT budgets, many DOTs are turning to native revegetation projects and plans. Revegetation with native species is strongly encouraged federally as well. Federal agencies are directed or strongly encouraged to use native species by various Executive and Administrative Orders. These orders do not, as yet, specify sources; however, species collected near a disturbance tend to be more biologically suited for revegetating the site. Perhaps surprisingly, NCHRP 20-5, 33-04, reports that DOTs are averaging only 45 percent of use of native grasses for revegetation on projects, though this ranges to a high of 90-100 percent in a few states.(*1108*)

Revegetation with native species provides the following advantages:

- They are better adapted and appear more natural than introduced species.
- Introduced species have the potential to escape into the natural environment.

DelDOT-Livable Delaware Program to Revegetate with Natives

DelDOT's Roadside Environment program has undertaken to improve the appearance of Delaware roadsides by using landscape enhancements that include native plants that are adapted to the region, displace invasive species that are highly competitive and detrimental to most plant species, and to do so in a manner that is cost effective and does not result in more maintenance but will require the same level of maintenance or will reduce the frequency of maintenance operations.

While DelDOT made a commitment to improve the aesthetics of the roadsides of Delaware under the leadership of their former Secretary of Transportation and Roadside Environmental Administrator, DelDOT discovered that colorful mass plantings of annual wildflowers can be costly for labor and soil preparation and are sometimes lost due to highly competitive weed situations. As a result, DelDOT undertook a study, "Enhancing Delaware Highways" which recommended roadside trials of native plants to evaluate aesthetics, compatibility with existing vegetation, costs associated with installation and maintenance. DelDOT funded a 5-year initiative through 2006 with the University of Delaware Transportation Institute to determine how native vegetation alone and in combination with existing plant communities on DelDOT rights-of-way can provide aesthetically pleasing surroundings in a cost effective manner for motorists traveling the highways of the First State.

The effort is unique among DOTs in the extent to which it is examining use of trees and tree preservation within the right-of-way, to supplement the use of native grasses, wildflowers, and shrubs. The cost of maintenance is being estimated for any landscape enhancement proposed by the project team for large-scale implementation, along with a determination whether those costs will be offset by lower frequency of maintenance over a five-year period.

Iowa DOT Revegetation Program Controls Noxious Weeds

Iowa DOT and many Iowa counties have shifted from traditional roadside maintenance of a monoculture of exotic grass in favor management regimes which restore native vegetation and reduce the use of herbicides and mowing. Iowa DOT has identified maintaining a healthy stand of native grasses as the best way to control invasive weeds. These grasses have extensive roots that offer the toughest competition to Canada thistle. In addition, plant diversity along the roadsides creates a strong plant community. Prairie plants can adapt to a wide range of soil types, moisture levels, and climactic conditions. Most prairie grasses and wildflowers grow best during hot, dry summer months, providing excellent erosion control during the fall and spring.

Iowa DOT recently extended their landmark IRVM program to revegetate approximately 5,200 acres of roadside annually with native grasses and forbs. Forty percent of that acreage is restoration unrelated to construction.(*1109*) The program is documenting species diversity and wildlife benefits as well. Twelve roadside areas were surveyed for abundance and species richness of disturbance-tolerant and habitat-sensitive butterflies and compared with nearby roadside dominated by primarily nonnative legumes and/or grasses; species richness of habitat-sensitive butterflies showed a two-fold increase on restored roadsides compared with grassy and weedy roadsides. Abundance increased five-fold for native grass and forb habitat over nonnative. Tracking studies found butterflies were less likely to exit the restored roadsides, indicating mortality rates may be lower and offering preliminary evidence that roadsides have the potential to be used as corridors.(*1110*)

Iowa DOT recently released a roadside management guide containing collections of plant profiles, characteristics, requirements, and how theses species are used in roadside management.

Illinois DOT Enhancement and Maintenance Projects Restore Prairie, Native Wildflowers

Illinois DOT established the "Wildflowers of Illinois" program utilizing existing roadside enhancement and maintenance funding to plant native wildflowers and prairie plants in place of manicured turf along roadsides. Plant materials and labor will be contributed to the program by the Illinois Department of Natural Resources and the Illinois Department of Corrections. Illinois and other vendors will supply the balance of materials needed for successful planting and establishment of the gateways, which will be funded by existing roadside maintenance budgets. As part of the Governor's overall environmental emphasis and with support from the state's first lady, Illinois DOT anticipates that the program will foster economic development and tourism, promote responsible stewardship, encourage environmental understanding and reduce roadside maintenance costs.

Wildflowers for Communities will involve various communities throughout Illinois in 2004 and beyond. After signing an agreement with the department to participate in the program, each community will select locations along state highways within their communities, and develop a plan for the establishment of the wildflowers with the assistance and approval of department Landscape Architects. The communities will then install the plantings with contractors, their own employees, or community volunteers such as Master Gardeners. Watering, weeding and other similar cultural needs will be arranged by the communities, usually employing similar resources. The agreement provides for an initial grant from the department of up to $35,000 with a $5,000 local match per community. The local portion may be a cash outlay or in-kind services. The agreements provide for two years maintenance by the communities with a reimbursement of $5,000 per year for that work.(*1111*)

TxDOT Pilot on Context Sensitive and Natural Landscape Design in the Highway Right-of-Way

The purpose of TxDOT's pilot on context sensitive and natural landscape design in the highway right-of-way was to recreate the visual character of the regional native landscape and develop self-sustaining vegetation community groups that recycle nutrients, conserve soil moisture, regenerate themselves, and provide habitat for nesting birds. Their process included 1) identifying the environmental impacts of the highway on this site, 2) identifying the appropriate natural systems processes most suitable to solving these problems, and 3) gaining input and support from the community in developing design alternatives. Management needs placed a heavy emphasis on the reduction of maintenance while developing a publicly acceptable landscape aesthetic, and interviews with maintenance personnel provided the basis for the design program. Maintenance staff identified three problem areas:

- A large amount of hand maintenance was required around the guardrails, bridge columns and areas that equipment could not access.
- Steep slopes in parts of the project were difficult to mow without causing damage that would lead to erosion.
- Grass and weeds in the detention ponds were considered to be difficult to mow due to moist conditions in the ponds.

Based on these observations, the first three goals of the design plan were established as:

- Eliminate need for hand maintenance wherever possible, especially near travel lanes;
- Prevent erosion on slopes; and
- Improve the appearance and maintainability of the detention ponds.

This approach offered a design solution meeting specific goals regarding water quality and habitat in an urban area and while demonstrating visual acceptance by the public. The project elevated habitat, native plants, water quality, erosion control, reduced herbicide usage, and reduced mowing in TxDOT's design approach for roadside improvement projects.(*1112*)

TxDOT and Houston Green Ribbon Program

In the past four years the Houston District has improved and removed from TxDOT maintenance more than 100 acres of right-of-way through agreements with partners or landscape planting. Approximately 200,000 trees, shrubs, and vines have been installed on state right-of-way in the same period without increasing maintenance activities, as part of implementation of Houston's *Green Ribbon Project Corridor Aesthetics and Landscape Master Plan*, released in December 1999. Proudly Called the Bayou City, Houston is naturally laced with attractive green belts and waterways now obscured by highway overpasses. The goals of the Green Ribbon Project are to:

- Establish a higher level of visual appeal along the corridors through landscape and architectural improvements (aesthetics);
- Promote and enhance highway safety and maintain traffic flows (mobility);

- Promote fiscal responsibility in capital investments and reduce maintenance costs by the use of sustainable plantings, including the use of native trees, shrubs and grasses (sustainability);
- Reduce implementation and maintenance costs through the design of sustainable landscapes (sensibility);
- Promote public/private partnerships for implementation and maintenance of improvements (partnerships);
- Develop unifying themes through the use of art and neighborhood gateway markers to express the cultural uniqueness of adjacent neighborhoods (expression);
- Develop functional and innovative design solutions for architectural elements, including bridge components, walls, railings, barriers, sign supports, and lighting (innovation); and
- Integrate civic art of any material or medium that is permanent in nature and integral to the environment in which it is placed (artistic expression).

Since the establishment of the GRP, the impact to the freeways has been dramatic. The Green Ribbon Project routinely oversees the planting of literally thousands of native trees in intersections, hundreds of oleanders, crepe myrtles, and palm trees, as well as, the installation of irrigation systems. Over 1200 plants were installed at one freeway intersection, including some 80 palm trees, to emphasize the freeways Gulf connections. The Houston District has moved to a 100 percent naturally derived non-chemical landscape development and is currently working to reduce our chemical usage for herbicide control, as well.

In 2001, the Texas Legislature added Rider 57 to TxDOT's appropriation, requiring TxDOT to expand concepts from the successful program to other areas of the state. The guiding concepts or principles for the program are:

Five design principles guide the Green Ribbon Project. These are: —

- **Green First—**make new plantings or the preservation of existing plantings the first priority in recommended improvements;
- **Integration—**consider all improvements in context with each other and design solutions to emphasize the visual, as well as the physical, integration of all components;
- **Continuity—**design all improvements to create a continuous appearance;
- **Freeways are Public Space—**the freeway rights-of-way belong to the public and should provide a visually pleasing experience; and
- **Maintenance—**the planning and implementation of all improvements should include long-term maintenance costs with respect to plantings, structures, surface treatment and other materials along roadways.

TxDOT and the state legislature tied GRP improvements to air quality and CMAQ funds when measures when funding for landscaping and other enhancement activities occur in districts that are non-attainment and near non-attainment counties for air quality degradation. TxDOT's Design Division (DES) - Landscape Design Section now oversees the Green Ribbon Landscape Improvement Program so the GRP will continue to make a positive impact on TxDOT. The GRP program manager has facilitated integration of GRP principles into the project development process. TxDOT would not have the financial resources to implement all of the proposed design concepts and in response, the GRP manager has facilitated successful public/private partnerships with local governments in the six-county area – in Baytown, La Porte, Clute, Freeport.

In 1999, the project was recognized with the Highest Honor Award, the American Planners Association, Houston District, for its strategic planning effort. The Texas Forest Service gave the Texas Community Forestry Award of Merit to the project in 1999. The Park People, a Houston civic group, awarded the project its Visionary Award for 2000. Trees for Houston, another civic group, awarded the project its Arbor Day 2000 Award and the American Society of Landscape Architects-Texas Chapter honored the project with its Merit Award for 2000. In 2001, the Green Ribbon Project won the National Arbor Day Foundation's Lady Bird Johnson Award. It is awarded by the Foundation for individuals and organizations whose work sets a worthy example for others to follow in roadside beautification.(*1113*)

Chemical Control of Noxious Weeds

IVM stresses the need for selectivity, restraint and proper training and protections whenever herbicides must be used. On the shoulder and in other zones, too, noxious weeds must be controlled to protect against undesirable succession of plant communities, not only for the sake of the roadside zone itself, but also to prevent the roadside from becoming a refuge for invasive species and source of further spreading. Chemical vegetation controls are used to protect preferred vegetation, to provide fire protection and to improve roadside appearance. The primary subtasks include support equipment operation, mixing and loading chemicals and chemical application. Leaks, spills and improper application are possible pollutant sources that can result in release of: pesticides, fuel, hydraulic fluid, oil and sediment. Water used for chemical mixing or in application must be controlled to prevent unpermitted non-stormwater discharges.

Herbicides have conventionally allowed the effective and seemingly inexpensive achievement of these goals. Crews now have the computerized equipment and knowledge to be able to target weeds, use less product per acre, and document all conditions and location of the job. Nevertheless, citizens are still concerned about herbicide use in many places and some DOTs have taken up the goal of reducing herbicide usage. Caltrans and UC-Davis are undertaking research to develop an improved Intelligent Herbicide Application System (IHAS) to assist the Caltrans in reducing the amount of herbicide applied for roadside vegetation management. The system selectively applies post-emergent herbicide to weeds at the edge of the roadway and not to bare soil, reducing the amount of herbicide required for weed control.(*1114*) Likewise, the New Mexico State Highway and Transportation Department has undertaken internal research to minimize the use of herbicides while successfully controlling noxious weeds. As part of the study NMSHTD is conducting a review of methods or combinations of methods that are available for the control of noxious weeds and it finds existing policies and procedures in other states for minimizing the use of herbicides.(*1115*)

New Equipment to Focus and Minimize Herbicide Application

NCHRP 20-5, 33-04 on Integrated Vegetation Management reviews some of the equipment on the market today to focus and reduce herbicide applications.(*1116*)

- Commercial GPS/GIS systems can provide or record information, such as environmentally sensitive site locations, for use in planning or implementing integrated vegetation management programs. Tracking and record keeping systems that are linked to today's compatible high tech injection sprayers or roadside mowers are being marketed.
- Computer controlled spray equipment is on the market today. Injection type sprayers that measure and inject multiple ingredients used in herbicide applications make it possible for equipment operators to use computers to change materials and/or rates of materials as they move along the right-of-way. The total volume of mixed spray is controlled, allowing the equipment operators to vary their travel speed and area of coverage while moving. Onboard computers can generate the required pesticide application record information for downloading or storage in databases. Today's injection systems can be coupled with the use of packaged pesticide concentrates that are totally 'closed', minimizing the potential for spills and/or operator exposure associated with traditional material transfer from packaged materials to spray tanks.
- Nozzles and materials that reduce the potential for off-target drift of sprayed materials are available. Nozzles that reduce or eliminate the generation of spray particles that are under 200 microns in size reduce the potential for significant off-target movement of liquid applied herbicides. Nozzles have been developed which enable applications to be made to targets at the outside edge of many right-of-ways, improving the efficiency of roadside vegetation management applications without increasing the risk of off-target placement.
- Spray mix additives and/or special mixing equipment have led to roadside invert-emulsion spray equipment that can deliver large droplet, oil-rich, herbicide applications to target plants with minimal risks of drift, and with improved herbicide absorption by the target plant. This invert emulsion technology and equipment has been around for several decades but has recently been reintroduced to roadside vegetation management programs. A roadside vegetation management research report by the Commonwealth of Pennsylvania and Pennsylvania State University (*1117*) contains information about invert emulsion sprays, and other roadside vegetation management items.
- Recent research and development work by Purdue University has led to commercial production of an equipment system (*1118*), which can electronically identify individual weeds within its path and deliver a prescribed targeted application of herbicide, in a single pass over the roadside. This innovation has the potential to reduce the amount of herbicide needed to treat an acre of roadside, reducing costs, and minimize the amount of herbicide introduced into the roadside environment.
- Mowing equipment with herbicide application nozzles incorporated within the cutting head cowling has helped produce little or no `brownout' beyond that associated with the mowing operation.

Stewardship Practices Prior to Herbicide Use

IRVM-Related steps before use of herbicides include: (*1119*)

- Evaluating each site to determine if weeds really present a problem.
- Spot mowing to prevent annual weed seed production.

- Removing a [non-native species] and allowing desirable species to reclaim the area.
- Prescribing burning of prairie communities to promote healthy vegetation.
- Using biological controls as alternatives.
- Frequent roadside management equipment cleaning to help reduce seed transfer.

Mn/DOT Position Statement on the Use of Herbicides

Mn/DOT Position Statement on the Use of Herbicides states the agency's commitment to "using the least toxic, efficacious pesticides available for controlling identified pest species. Herbicides selection and use should be based upon scientific information, including but not limited to, efficacy on targets to be controlled, environmental fate, and toxicity. Selection and use of herbicides is further governed by state and federal laws and regulations. Herbicides selected and used are to be applied by licensed applicators except as allowed in the herbicide policy guidelines adopted here under. All applications should be in accordance with applicable laws, regulations, and label instructions."

In support of the policy Mn/DOT's Guidelines to Ensure Appropriate Herbicide Use calls for the following environmental stewardship practices (*1120*). Related and additional practices used by Caltrans (*1121*), NYSDOT (*1122*), and Oregon DOT (*1123*) are included.

- Herbicides should be considered only part of a more comprehensive and integrated roadside maintenance program.
- Alternatives that can control vegetation without using synthetic herbicides are investigated in an ongoing fashion.
- The use of herbicides should be based on target plants to be controlled, extent of the problem and site considerations. Herbicides will be used for roadside weed and brush control, but only to the extent necessary for effectiveness results.
- NYSDOT's policy is to restrict herbicide use to locations that cannot be mowed by conventional means, such as around guiderail and sign posts.(*1124*) Caltrans' states that chemical vegetative control measures will not be used on vegetated treatment BMPs except where Caltrans is directed by the California Department of Food and Agriculture to treat the BMPs for invasive weeds. Under Caltrans' goal is to reduce chemical usage, the agency follows an approved list of chemicals developed by Maintenance Headquarters that is generally more restrictive than herbicide use options available to other agencies and the public.(*1125*) Oregon DOT Maintenance does not use any restricted-use chemicals to control vegetation; herbicides used include broad-based foliar-active herbicides and soil residual herbicides.(*1126*)
- Inspect the route ahead of time and "flag" all cross culverts, streams and wetlands so that the sprayer can be shut off 20-30 feet before entering the sensitive area and its required buffer area. Identify these locations with permanent identification markers.
- Use chemicals approved for use near aquatic resources, or as directed by regulators.
- Herbicides are not applied within 30 meters (legally 100 feet) of a wetland without a wetland permit and an approved Integrated Vegetation Management Plan.

- Oregon DOT has attempted to eliminate spray activities on structures located over streams or adjacent to wetlands. Within riparian areas, necessary spraying around structures that require vegetation control is done by hand. Within 25 feet of riparian areas, boom spraying occurs no further than eight feet from the edge of pavement, and within 25 feet of an active, flowing stream, all boom spraying is prohibited.
- Herbicides should be used in accordance to EPA labels.
- Herbicides applications are avoided within 30 meters (legally 100 feet) of a dwelling, public building, or public park.
- Proper application techniques will be used to ensure that herbicides are not applied to non-target or sensitive areas.
- ODOT Maintenance follows an Integrated Vegetation Management program with mapped locations of sensitive natural resources and identifies areas where spraying does not occur. ODOT's IVM Plans include protection of sensitive fish species via modification of spray times and modifications of spray widths to protect riparian areas. Further minimization/avoidance measures are developed on a site-specific basis.(*1127*)
- Herbicides should be mixed, handled and applied strictly in accordance with the product labeling. Herbicides be applied in accordance with the product label and in a manner that will not cause unreasonable adverse effects on the environment, endanger humans, or damage agricultural products, food, livestock, fish, or wildlife. Herbicides may not be applied onto property beyond the boundaries of the target site, nor directly on a human by overspray. Workers in an immediately adjacent property may not be exposed.
- Only herbicides properly labeled for use on right-of-way and registered by the EPA, and the state Department of Agriculture will be purchased and used. In the event of conflict between the various regulations, the more restrictive requirements will apply.
- Herbicides should not be stored for more than 18 months. When storage is necessary, they will be stored inside and in accordance with Department of Agriculture guidelines.
- Spills of any herbicides are cleaned up as quickly as possible.
- When herbicides spill into a water body, environmental staff are notified.
- The spot spray application technique should be used to selectively treat areas infested with weeds, brush, or other harmful pests. Ideally herbicides should be spot sprayed, rather than blanket sprayed over an entire area, since blanket spraying may cover desirable plants and may weaken existing vegetation (thus increasing weed infestation).
- Calibrate the spray rig to ensure accurate application of herbicides.
- Use precision application technology.
- Do not spray chemicals when rainfall causing runoff is forecast within 12 hours.
- Spray drift should be minimized; most herbicide labels indicate methods for reducing spray. Apply herbicides using nozzles and low pressure to reduce drift. Also, certain additives will increase droplet size. Drift retardant can be used, and staff should avoid

using herbicides that drift the most. Staff should watch the wind—if above 15 miles/hour stop or go to side of road so that drift occurs over already sprayed area.

- The treated area must be posted if the labels indicate a specific time delay before safe human reentry or if the area is treated through irrigation systems. Except for those herbicides that are cleared for use in aquatic environments, herbicides must be introduced into the application equipment after it is filled with water.
- Herbicides should be applied at the proper time when weeds and/or brush are susceptible so that the minimum concentration is required. Areas where brush is undesirable should be identified and the brush controlled at an early stage. Undesirable brush should be controlled at a height less than six feet. In the event that undesirable brush is more than six feet in height, it will be cut and the regrowth treated if necessary. Herbicides work better when used at higher temperatures. Foliar herbicides must be applied during a rain-free period to be effective, and herbicides that are absorbed through the roots need rain directly after application to work best. Under all circumstances, herbicides should be sprayed when it is not windy in order to minimize drift.
- Weeds should be sprayed during the seedling stage and prior to flowering. To ensure that herbicides are applied at the proper time, modified work schedules and overtime for crews may be authorized.
- Spraying should not be attempted when noxious weeds or brush become too mature or tall for satisfactorily results. In the event that the noxious weeds are too mature, the infested area will be mowed as soon as possible and the regrowth treated with herbicide, if necessary.
- Avoid using overhead irrigation for as long as the chemical manufacturer recommends after applying herbicides.
- Herbicides will be applied by licensed applicators or trained non-licensed applicators. Applicators should be aware of integrated approaches to weed and brush control. Trained, non-licensed applicators may apply general use herbicides only such as glyphosate, pre-emergent herbicides, Ready To Use (RTU) stump treatments, and plant growth regulators to kill or suppress unwanted vegetation in rest area/travel information centers, headquarter sites, truck stations, storage yards, communication towers and around guardrails.
- Records should be kept of all herbicide applications. These records shall include, but not be limited to: the date of treatment, temperature, wind direction and velocity, units treated and dosage used, location, brand name of pesticide, U.S. Environmental Protection Agency (EPA) registration number, company name and license number of applicator, and signature of operator. Records should be retained in a location designated by the Maintenance Area for at least five years.
- Each District or Maintenance area shall develop and maintain a plan that describes its pesticide storage, handling, and disposal practices in accordance with existing laws and regulations.
- Drums, cans, and containers should be properly disposed of. When possible, drums and/or containers will be returned to the vendor or recycled.

- Herbicide application equipment or empty containers are not washed in ditches, streams, ponds or wetlands, nor is the wash water allowed to flow into any surface waters, including wetlands.
- Where computer-assisted spray trucks are owned, they will be utilized. Computer assisted spray trucks can manipulate the mixture and rate sprayed, and can stop and start spray activities to avoid impacting individual creeks.

Performance Indicators for Mowing and Herbicide Use

MoDOT Mowing and Herbicide Costs are included in the DOT's Dashboard Annual Report of high level indicators, under the strategic goal of improving maintenance of the state's highway system. MoDOT's has determined that herbicide use is more efficient than mowing and thus has designed a system to show reduced mowing costs and stable or increasing herbicide costs as a positive indicator, in the effort to reduce mowing. The agency acknowledges that the maximum amount of herbicide expense vs. mowing expense needed to reach the highest level of cost efficiency on roadside maintenance is unknown at the time the measure was drafted, but will be revised as the agency moves forward. In contrast, WSDOT is aiming for and tracking reduction in herbicide usage, as part of its IRVM program, though usage has increased in various years as noxious weed treatments have increased.

Biological Control of Noxious Weeds

Biological weed control includes the use of insects or pathogens. Biocontrols are a relatively inexpensive and safe alternative to chemical or mechanical control. The U.S. Department of Agriculture (USDA) is conducting a major biological control program that involves importing, propagating, and distributing weeds' natural enemies. These feeding insects inhibit the growth and reproduction of weeds, reducing their ability to compete with desirable native range plants. In general, insects are best used in areas of large infestation. Smaller infestations are better treated with herbicides.(*1128*)

Canada thistle was among the first 19 weed species selected as targets for biological control when the USDA Rome Laboratory was established in 1959 (Schroeder, 1980). However, most host specificity testing of agents for Canada thistle was conducted from 1961 to 1984 by staff of Agriculture Canada or by the International Institute of Biological Control (now CABI Bioscience) working with Canadian funding. The agents released in the United States have been those that became available as a result of the Canadian program, the results of which were reviewed in 2001.(*1129*) Most releases in the eastern United States were made by USDA, ARS staff at the Beltsville Agricultural Research Center; some studies were carried out by staff of the Maryland Department of Agriculture.(*1130*) MDSHA now includes reduction of acres of Canada Thistle in the ROW as one of its key environmental indicators. "Thistle Yellows" are one effective method that can be used against Canada thistle infestations.

Several DOTs have become very active in use of biological controls. The upcoming NCHRP 20-5, 33-04 on IRVM reports that biological control practices using predator organisms such as beetles and seed flies are in use on ½ to 2 percent of the ROW in Florida, Illinois, Kentucky, Maryland, Utah, and Washington.(*1131*)

- Caltrans has research underway on biological controls for Yellow Star thistle and Tumbleweed (Russian Thistle).(*1132*)

- In 1995, Mn/DOT launched their first school partnership in beetle rearing for roadside use, an educational and public awareness success story, after two beetle species released at a site in southern Ontario effectively reduced purple loosestrife infestation by over 90 percent over five years, allowing native plant populations to extend their reach.(*1133*) The Mn/DOT Office of Environmental Services uses beetles to control leafy spurge.(*1134*)
- Between 1997 and 1999, NHDOT and the Department of Agriculture (NHDA) monitored a beetle release at a mitigation site infested with purple loosestrife; by 2000 all loosestrife within and adjacent to the site was either dead or extremely stressed and dying and none of the remaining live plants appeared to develop flowers and therefore seed. Self-sustaining populations of beetles still were found among the remaining loosestrife plants. Indigenous vegetation, likely from seed in the existing soil bank, filled the void and restored diversity. NHDOT and NHDA released beetles at 12 additional sites the following year.(*1135*)
- The Michigan State University's lab produces 150,000 beetles per year, which MDNR has been releasing on state game areas infested with purple loose strife since 1994. The lab has trained local groups around the State to rear the beetles, release and monitor their affect, leading to an expected 80 percent reduction in density in 10-20 years.
- The Vermont Agency of Natural Resources and VTrans have mapped purple loosestrife populations and VTrans is testing three approaches: 1) release of beetles without mowing or spraying; 2) mowing right after flowering begins for easy identification yet not be mature enough to disperse seed; and 3) spraying.(*1136*)
- Rive beetles are available for use with leafy spurge. A leaf-eating beetle is available for use on purple loosestrife. Spotted and diffuse knapweeds can be controlled using one of 12 insect species cleared by the USDA for use in the United States. In Tennessee, the DOT was able to reduce musk thistle infestations by 95 percent with one such biocontrol beetle.(*1137*)

State DOT Partnerships to Manage Noxious Weeds

The imperative to control the spread of invasive species and noxious weeds has led to a variety of comprehensive DOT noxious weed control efforts and innovative partnerships.

NYSDOT's 10-Point Invasive Species Management Plan

NYSDOT's 10-point invasive transportation vegetation management plan consists of the following components: 1) Developing a prioritized list of threatening flora or fauna based upon regional environments, 2) Field and GIS mapping of existing invasive populations, 3) Integration of invasive species identification and analysis as part of the department's normal NEPA /SEQR processing, 4) Evaluation of potential impacts caused by construction or maintenance activities, 5) Development of preventive best management practices, 6) Testing, execution and evaluation of eradication measures, 7) Annual reviews and updates of the vegetation management plans, 8) Progression of innovative design solutions to reduce the opportunities for the introduction or spread of invasive species, 9) Promote a climate of interagency cooperation and sharing of coordinated research with public and private sectors, 10) Increase employee and public knowledge through outreach training of the effects of invasive species to the users.*1138*

In the environmentally sensitive Adirondack Park, NYSDOT regional maintenance staff, the Adirondack Park Agency and the Adirondack Chapter of The Nature Conservancy have jointly initiated a demonstration knotweed control program. The pilot demonstration project involves hand cutting individual knotweed plants, properly disposing of the harvested plants and using NYSDOT-certified herbicide applicators to swab the residual cut knotweed stems with "Rodeo." This project incorporates a training component by inviting local Department of Public Works (DPW) maintenance workers and resource agency staff to observe and participate.

Wyoming DOT MOU with Ag Department and County Weed and Pest Districts

By 2001, Wyoming DOT had inspected 95 percent of all State and federal centerlane miles for noxious weeds, the result of an effort begun in 1985 as a Memorandum of Understanding (MOU) with the State Agriculture Department and County Weed and Pest Districts to control weeds in public rights-of-way. The inspection and tracking effort resulted in the spraying of 4,600 rights-of-way acres and the use of native, competitive plants for revegetation since 1991. WYDOT has required certified mulches on construction projects since 1986, a proactive approach which has saved significant state dollars.(*1139*)

Coordinated Weed Management Areas in New Mexico

In 2001, New Mexico Highway and Transportation Department (NMHTD) and 32 other groups signed a Memorandum of Understanding (MOU) drawing together all levels of land managers to participate and support Coordinated Weed Management Areas (CWMAs) covering the state. The signatories of the agreement jointly inventory, manage, prevent, and eradicate whenever possible, plants designated as noxious pursuant to the New Mexico Noxious Weed Management Act of 1978, using the New Mexico Strategic Plan for Managing Noxious Weeds, as a basis for coordination. New Mexico built on the experience of Idaho, Montana, Wyoming and the Dakotas. NMHTD implements Noxious Weed Management Plans for individual projects and is reviewing maintenance strategies to further improve its weed reduction efforts.

On-line Resources for Noxious Weed Control

FHWA and others have compiled on-line resources for control of noxious weeds: (*1140*)

- Federal Interagency Committee for the Management of Noxious and Exotic Weeds is home of the (FICMNEW), an interagency partnership to pull together all stake holders since 1994.
- National Invasive Species Council (NISC).is the gateway to the federal effort based on EO 131112: There you can find a copy of the national invasive management plan and related information.
- The information for Cornell's program in Biological Control of non-indigenous plants is online.
- Natural Resources Conservation Service contains the view of federal and state weed law, Invasive Plants including the federal noxious weed list as well as the noxious weed laws of most States.

- TNC's Wildland Invasive Species Program offers decision-makers years of land management experience form The Nature Conservancy (TNC) regarding problem plants, control methods, a power point presentation you can use, a press release template, and ways to utilize volunteers.
- Center for Aquatic and Invasive Plants is a site that contains images and information for 383 native and non-native species found in Florida plus.
- The Prairie Region website targets weeds. It includes the Heibert ranking assessment.
- INVADERS Database Systemis the website from the University of Montana. It contains the INVADERS Database System provided by the Agricultural research Service (ARS), USDA. The site includes the U.S. and Canadian noxious weed lists.
- The New England Wild Flower Society addresses invasive plants in New England.
- Southwest Exotic Plant Information Clearinghouse serves the southwest. This site is filled with practical information for this region.
- Center for Invasive Plant Management is home to an in-depth western weed clearinghouse of information. The information comes to us from Bozeman, Montana. It is made up of seed science professionals in the western U.S. and Canada.

Tracking Progress in Control of Noxious Weeds with GIS and GPS

Many DOTs are using their noxious weed inventory effort as part of a continual process for tracking and improving management of noxious weeds. Partnerships with 4-H, The Nature Conservancy, other volunteer citizen groups, Natural Heritage Programs, and county organizations have supplemented the tracking efforts of DOT maintenance forces in some states.

CHAPTER 10: ROADSIDE MANAGEMENT AND MAINTENANCE: BEYOND VEGETATION

Highway agencies manage over six million hectares (17 million acres) of land in the U.S., approximately one percent of states with more dense road networks.(*1141*) Due to the tendency of the highway system to follow streams, coastlines and other natural landscape features, this land is often located within, over, and/or adjacent to many environmentally sensitive areas.

All ROWs are managed with the general goal of providing for safe and reliable transport. In most all ROW scenarios, active management is needed to create specific vegetation and related environmental conditions.(*1142*) Roadside management objectives vary with the zone that is being addressed. Typically the gravel shoulders of roads are maintained as a vegetation-free area, to allow surface water drainage off the pavement and into the drainage ways. Off the shoulder, an operation zone of grass or small trees and shrubs is maintained through mowing to allow for visibility of signs and traffic at interchanges and curves. Large trees are also removed for safety in case vehicles accidentally leave the road. Herbicides are used very selectively for control of noxious weeds and sometimes for brush control. A wider buffer zone beyond that area is frequently maintained in natural or native, low-maintenance vegetation.

Common objectives for management of the ROW include:

- Managing the immediate shoulder for use as a recontrol zone for errant vehicles and inhibit weeds from growing into the pavement.
- Preserving sight distances for reading signs and for cornering.
- Offering space for utilities.
- Screening on-coming traffic on divided highways.
- Maintaining slope stability, encouraging drainage of water off the roadway, protecting water quality, protecting habitat for wildlife and preserving or restoring native plant communities.
- Maintaining open space, green corridors, or a refuge for biodiversity.
- Protecting roadside areas against infestation and spread of noxious weeds.
- Keeping vegetation back from the edge of the road to improve visibility of wildlife and reduce chance of road kill.
- Providing on-site area for wetland mitigation in some cases.

This section focuses on non-vegetative environmental stewardship practices for management of the ROW. Vegetative and Integrated Vegetative Management practices will be discussed in detail in the following chapter.

10.1. ENVIRONMENTAL ENHANCEMENT PRACTICES AND PARTNERSHIP EFFORTS

Water Quality Retrofit Programs

Most DOTs have developed or utilize existing design manuals for runoff control and stormwater quality. Increasingly, DOTs are having to decide where stormwater quality retrofits may be sufficiently valuable to implement, and in what order these investments should be prioritized. In addition to extensive design guidance available in both manual and on-line formats, a number of BMP selection and evaluation systems are emerging. NCHRP 25-25(01) is designing a BMP effectiveness and evaluation system that will be available in late 2004.

MDSHA's Water Quality Improvement and Retrofit Program

MDSHA's NPDES program was implemented as part of mandated EPA regulations; however, the program's many activities have exceeded the regulatory requirements due to SHA's environmental policy to go beyond the basics and explore new ways to implement environmental stewardship in the context of the sensitive Chesapeake Bay Watershed. The agency leadership as well as the staff have become very active in advancing the cause of the environmental protection through technology development and enhancement. Funds have been provided and partnerships have been forged to leverage the State dollars and maximize the best management practices at an unprecedented level.

As part of the agency's environmental quality improvement efforts, MDSHA has implemented a very structured improvement program for the 1,500 stormwater management facilities owned by SHA, with inspection teams of trained staff who identify further environmental improvements that can be made. MDSHA has complimented this work by mapping the entire state for opportunities for retrofitting best management practices (BMPs), for pollution prevention and stream restoration beyond requirements, and for development of a plan for systematic implementation of those improvements.

The grade-based rating system for stormwater management facilities includes an inventory, database, and photo record of all facilities statewide and their maintenance status. Under the rating system, those graded A or B are considered functionally adequate. As of late 2003, between 73 and 75 percent of MDSHA stormwater were functionally adequate (A=everything fine, working fine, no maintenance required, B= minor maintenance, need mowing or trash removal), leaving approximately 25 percent needing maintenance or retrofitting to achieve functional requirements. MDSHA aims to have 80 percent or more of SHA stormwater management facilities rated functionally adequate by 2006, and 95 percent of facilities by 2010.

To accomplish the above and with continuous improvement as an inherent strategy, the NPDES team has accomplished many major goals since its inception in 1999:

- Developed NPDES Strategic and Timeline Plan to guide the overall implementation effort.
- Developed several pilot projects to streamline the integration of technology into the field data collection and analysis process.
- Established field inspection protocols and tools for data collection, including a Standard Procedures Manual to streamline the database development, inspection protocols, and training program for inspecting stormwater management facilities.
- Established auxiliary programs and management structures to support the goals of the NPDES program.
- Partnered with several local jurisdictions in their watershed assessments and restoration efforts – SHA is now partnering on eight different watershed improvement plans

- Constructed multitude of stormwater retrofit and enhancement projects throughout Maryland with immediate benefits to the environment. Many more are underway.
- Developed many cutting edge technologies for stormwater management such as Low Impact Development (LID) for highway environment and out-of-kind stormwater mitigation such as stream restoration.
- Developed the nation's first and only Visual and Environmental Quality Guidelines for Stormwater Management Facilities. Implementation of the draft guidelines already resulted in facilities that benefited from this context-sensitive approach.
- Developed a Geographic Information System (GIS) for drainage infrastructure.
- Developed Geographic Information Management System (GIMS) for systematically inspecting and maintaining the performance of stormwater management facilities.
- Initiated efforts to develop new state-of-the-art BMP remediation technology.
- Developed a work delivery system using operating and capital programs.
- Developed a flow chart for SWM facility remediation action along with cash flow estimates.
- Developed a budgetary cash-flow estimation system with the help of pilot projects.
- Developed training for designers on stormwater management based on data found in the inspection program.
- Performed Discharge Characterization of stormwater to analyze quality of highway runoff.
- Prepared a report on SHA's on-going Public Education and Outreach Programs and initiated new efforts (Environmental Responsibility Booklet, Cable-broadcast video, informational presentations).
- Established Pollution Prevention Teams at all 35 SHA Maintenance Facilities to implement the Stormwater Pollution Prevention Plan in an environmentally responsible manner – includes pollution prevention training to personnel.
- Customized pollution prevention plans and strategic retrofit plans for all SHA maintenance facilities to systematically upgrade them to perform at an environmentally acceptable level.
- Initiated technology transfer and guidance to other Maryland Department of Transportation (MDOT) modals

The Managing For Results (MFR) portion of MDSHA's business and stewardship plan is being used to measure the progress and success of the NPDES program and define timelines and milestones for the numerous elements of the program. Using the MFR approach, progress is measured every month for each of the major elements, and every six months for all the elements of the program. An example of this is the tracking of the required number of source identification efforts that needed to be completed: The strategic plan as well as the MFR goals called for measurable completion of work in specified counties by a prescribed date. Another example is the stormwater management retrofits that needed to be completed by December 2003. The retrofit completion progress is tracked every month and new strategies were developed continuously. As a result, this requirement was exceeded by 300 percent. Individual projects, such as watershed retrofits, stormwater improvements and watershed partnerships that are generated as a part of the program are managed using MS Project and milestone reviews.

For maintenance facilities, the discharge sampling of the outfalls is a direct method for measurement of success, which is defined based on state and federal requirements. As a stewardship measure, MDSHA tracks implementation of strategic upgrades to the facilities identified during the pollution prevention plan development and needed changes in systems identified by the independent inspection program.

Charts are developed for all the major programs to visually demonstrate successes and progress. Once a year, an annual report summarizing all the activities, including compliance with the NPDES program is prepared and submitted for review to the Maryland Department of the Environment (MDE). So far, every report was thoroughly reviewed and approved by MDE, which means SHA remains in compliance and is actually being commended for showing stewardship by exceeding the permit requirements. A copy of the recent annual report is attached.

Outfall Categorization and Improvement at Florida and Washington State DOTs

In the late 1990s WSDOT and FDOT also developed systems for categorizing and improving outfalls.(*1143*) In the case of WSDOT, assessing which projects provide the best return on investment in terms of environmental effectiveness and pollution reduction. WSDOT's system included a condition indexing methodology and support program that enables users to quickly evaluate and compare projects and generate benefit-cost ratios for projects. (*1144*)

Further information on outfall improvements is available in descriptions of WSDOT's program, as well as that of Oregon DOT, in the section on Fish Passage Improvements.

Wetland Enhancement

PennDOT Staff Partner to Enhance Local Wetlands

PennDOT construction and maintenance workers are involved in a pilot program to improve eight wetlands in the state's District 9 territory. In 1995, the six-county region was chosen as the lead for PennDOT's wetland banking program to help save the state's natural resources. Working with several organizations — including the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers and the Federal Highway Administration — PennDOT and the agencies are identifying wetland enhancement sites, some of which may serve as compensation for past and future wetland impacts. The largest restoration area thus far is a 40-acre site prepared by PennDOT staff. In the summer of 2000, PennDOT workers, with assistance from the state's game commission, removed all of the drains and constructed berms to hold in water. Workers planted trees, warm-season grasses and thick, shoulder-high shrubs and brush to attract wildlife. The game commission donated bird, duck and bat "boxes" (houses). Ducks, pheasants, shorebirds, turtles, deer, muskrats and other species are flourishing in restoration area and predators as coyotes, foxes and an assortment of snakes have returned. The project cost less than $3,500 per acre to complete; the agency estimated the project would have cost an extra $1.4 million if a contractor had been assigned to do the work, as $100,000 an acre is a going price. Schools became involved in the planting, also saving taxpayer dollars, and students returned to the area on field trips.(*1145*)

Terrestrial Habitat Enhancement

Native habitats and populations of native cavity nesting birds have been in long-term decline across the country. Loss of suitable nesting sites and competition from non-native birds are the major factors in these population declines. Some DOTs are taking this problem on by trying to enhance the habitat under DOT ownership. These extend from large scale efforts to help state resource agencies and the governor's office implement greenway plans in Maryland, Florida, and Pennsylvania, to DOTs placing nesting platforms for ospreys in the right-of-way.

NYSDOT's Guidance for Placing Nest Boxes in ROW

NYSDOT has estimated that the agency owns and maintains approximately one percent of the state's land area and thus that the DOT has the potential to enhance nesting opportunities for native cavity nesting birds through well-considered design and placement of nest boxes. Nest boxes must be of the appropriate type, placed in suitable habitat and monitored on a regular basis during the nesting season, as failure to consider these factors can result in inadvertently enhancing nesting opportunities for non-native birds and further erosion of the ecological niches of native species. NYSDOT developed a bulletin on Nest Boxes for Native Cavity Nesting Birds that provides basic information and recommendations regarding the proper use of nest boxes on and adjacent to NYSDOT property. The guidance also provides Attachment A: Reference and Attachment B: Internet Sites for Nesting Box Designs.

NYSDOT Region 6 environmental and maintenance staff developed a program that involves a federally licensed bird bander and volunteers to manage a roadside trail of 15 artificial nest boxes. NYSDOT maintenance workers constructed nest boxes for the American Kestrel and installed them on the support posts of existing large expressway signs. Environmental staff and volunteers regularly monitor the boxes and NYSDEC biologists band the hatchling kestrels to collect scientific information.

DOT Bat Boxes

Bat roost enhancement projects for roadways can often be conducted onsite. Commercially produced bat houses are available that can accommodate up to tens of thousands of bats. Retrofitting options for bridges are discussed in the Bridge Construction and Maintenance Environmental Stewardship Practices section.

Best practices for constructing or buying bat houses are outlined below, excerpted and summarized from *The Bat House Builder's Handbook*, based on 12 years of bat house research conducted across the U.S, Canada, and the Caribbean.(*1146*)

- *Design* — All bat houses should be at least 2 feet tall, have chambers at least 20 inches tall and 14 inches wide, and have a landing area extending below the entrance at least 3 to 6 inches (some houses feature recessed partitions that offer landing space inside). Taller and wider houses are even better. Rocket boxes should be at least 3 feet tall and have at least 12 inches of linear roost space. Most bat houses have one to four roosting chambers- the more the better. Roost partitions should be carefully spaced 3/4 to 1 inch apart. All partitions and landing areas should be roughened. Wood surfaces can be scratched or grooved horizontally, at roughly 1/4- to 1/2-inch intervals, or covered with durable square, plastic mesh (1/8 or 1/4 inch mesh). Include vents approximately 6 inches from the bottom of all houses 24 to 32 inches tall where average July high temperatures are 85º F or above. Front vents are as long as a house is wide, side vents 6 inches tall by 1/2 inch wide. Houses 36 inches tall or taller should have vents approximately 10 to 12 inches from the bottom.

- *Construction*—For wooden houses, a combination of exterior plywood (ACX, BCX, or T1-11 grade) and cedar is best. Plywood for bat house exteriors should be ½-inch thick or greater and have at least four plies. Do not use pressure-treated wood. Any screws, hardware or staples used must be exterior grade (galvanized, coated, stainless, etc). To increase longevity, use screws rather than nails. Caulk all seams, especially around the roof. Alternative materials, such as plastic or fiber-cement board, may last longer and require less maintenance.
- *Wood Treatment*—For the exterior, apply three coats of exterior grade, water-based paint or stain. Available observations suggest that color should be black where average high temperatures in July are less than 85º F, dark colors (such as dark brown or dark gray) where they are 85 to 95° F, medium colors where they are 95 to 100º F and white or light colors where they exceed 100º F. Much depends upon amount of sun exposure; adjust to darker colors for less sun. For the interior, use two coats dark, exterior grade, water-based stain. Apply stain after creating scratches or grooves or prior to stapling plastic mesh. Paint fills grooves, making them unusable. Darker colored bat houses are recommended in northern climes.
- *Sun Exposure*— Houses where high temperatures in July average 80º F or less, should receive at least 10 hours of sun; more is better. At least six hours of direct daily sun are recommended for all bat houses where daily high temperatures in July average less than 100º F. Full, all-day sun is often successful in all but the hottest climates. To create favorable conditions for maternity colonies in summer, internal bat house temperatures should stay between 80º F and 100º F as long as possible.
- *Habitat*—Most nursery colonies of bats choose roosts within 1/4 mile of water, preferably a stream, river or lake. Greatest bat house success has been achieved in areas of diverse habitat, especially where there is a mixture of varied agricultural use and natural vegetation. Bat houses are most likely to succeed in regions where bats are already attempting to live in buildings.
- *Mounting*—Bat houses should be mounted on buildings or poles. Houses mounted on trees or metal siding are seldom used. Wooden, brick, or stone buildings with proper solar exposure are excellent choices, and locations under the eaves often are successful. Single-chamber houses work best when mounted on buildings. Mounting two bat houses back to back on poles is ideal (face one house north, the other south). Place houses 3/4 inch apart and cover both with a galvanized metal roof to protect the center roosting space from rain. All bat houses should be mounted at least 12 feet above ground; 15 to 20 feet is better. Bat houses should not be lit by bright lights.
- *Protection from Predators*—Houses mounted on sides of buildings or on metal poles provide the best protection from predators. Metal predator guards may be helpful, especially on wooden poles. Bat houses may be found more quickly if located along forest or water edges where bats tend to fly; however, they should be placed at least 20 to 25 feet from the nearest tree branches, wires or other potential perches for aerial predators.

- *Avoiding Uninvited Guests*—Wasps can be a problem before bats fully occupy a house. Use of 3/4-inch roosting spaces reduces wasp use. If nests accumulate, they should be removed in late winter or early spring before either wasps or bats return. Open-bottom houses greatly reduce problems with birds, mice, squirrels or parasites, and guano does not accumulate inside.
- *Timing*—Bat houses can be installed at any time of the year, but are more likely to be used during their first summer if installed before the bats return in spring. When using bat houses in conjunction with excluding a colony from a building, install the bat houses at least two to six weeks before the actual eviction, if possible.
- *Importance of Local Experimentation*—It is best to test for local needs before putting up more than three to six houses, especially comparing those of different darkness and sun exposure.

DOTs have also contributed to bat conservation and recovery through assisting mine gating efforts. Sealing abandoned mines without first evaluating their importance to bats is one of greatest threats to North American bat populations, which use caves as hibernacula.

Bridge Related Enhancements

Techniques to minimize construction and maintenance impacts on bats are discussed at length in the section on environmental stewardship practices in bridge construction and maintenance. Impacts to birds and practices to benefit birds are discussed in that section as well, to a lesser extent. Practices that benefit ground-nesting birds are discussed in the section on Roadside Vegetation Management, in particular, those related to Reduced Mowing.

Reduced Mowing at DOTs to Conserve Resources, Bird Habitat, and Native Species

As part of their Integrated Roadside Vegetation Management or other conservation plans Colorado DOT, Iowa DOT, Mn/DOT, WisDOT, NYSDOT, and Utah DOT have implemented mowing reductions to conserve resources and benefit native species. These programs preserve habitat for ground-nesting birds and other native species by limiting mowing to one mower width along the roadway, in most cases. For more information, please see the vegetation management section in this report.

Iowa DOT Roadside Native Species Restoration Program in Maintenance

While many state DOTs have begun to mandate use of native species when revegetating construction sites, Iowa DOT has extended their landmark IRVM program to revegetate approximately 2,200 acres annually of targeted roadside areas not connected to any construction projects. Another 3,200 acres of roadside on construction sites are seeded annually with native grasses and forbs. The state's transportation commission actively supports the program.

Identifying and Implementing Aquatic Connectivity (Fish Passage) Improvements

Oregon DOT Culvert Retrofit and Replacement Program Agreement

In 2001, the Oregon Department of Transportation (ODOT) and the state Department of Fish and Wildlife (ODFW) signed a Memorandum of Understanding (MOU) that repairing or modifying ODOT-maintained culverts is a priority for the agencies that will take decades to resolve. The ODFW completed culvert inventories for the entire state of Oregon in 1999 and found that 96 percent of the barriers identified were culverts associated with road crossings. The project also identified high priority culverts for fish passage remediation.

ODOT has an ongoing program of culvert installation and maintenance, with the goal of making all ODOT culverts passable to fish. After research monitoring results demonstrated the effectiveness of baffle and weir designs in culverts, ODOT modified their culvert replacement programs to use these designs, significantly reducing the cost of improving fish passage at ODOT culverts. The designs improve fish passage by slowing water velocity and raising stream elevations to reduce entry jump heights or backwater culvert outlets. Use of retrofit designs are allowing culverts that are otherwise in good physical condition to be retrofitted until their service integrity is compromised, at which time they will be replaced with designs that more fully meet fish passage criteria and standards. Use of retrofits will thus allow many more culverts to be remediated each year, increasing the scope and pace of ODOT's contribution to salmon recovery in Oregon. The baffle and weir retrofits also provide ODOT an alternative to fish ladders, which have become increasingly problematic for ODOT from a maintenance standpoint.

According to the MOU, ODOT will continue internal education regarding the needs and requirement of fish passage, and prioritize its resources and culvert modification needs on an annual basis, demonstrating good faith in addressing culvert passage problems. On replacement culvert projects, ODOT will strive to simulate a natural stream and will determine if changes in culverts result in flows detrimental to fish passage. ODFW is supporting ODOT's efforts by providing the master inventory of culverts that do not provide adequate passage, along with technical assistance on educational activities, design, and construction techniques.

Installation/Improvement of Public Fishing Access

NYSDOT Public Access Enhancement and Partnership

NYSDOT has been exploring and extending the highway system's larger role of connecting people and places of interest. Looking out for these needs, the NYSDOT Niagara County maintenance staff took the lead in forming a partnership with local business, the NYS Office of Parks Recreation and Historic Preservation and NYSDEC to provide a public fishing access site and picnic area at a popular salmon and trout stream — Keg Creek. Anglers formerly parked haphazardly along the state highway and traversed a very steep, slippery and dangerous ravine to fish for Lake Ontario's world famous migrating trout and salmon. This created a safety problem for passing motorists and for the anglers themselves. NYSDOT maintenance crews designed and constructed a paved parking area, a series of wooden stairs and a picnic area with lumber donated by a local company and tables donated by the State Parks Department.(*1147*)

Extending Highway Maintenance Activities to Bike Trails

Under the "Livable Delaware" Plan, Delaware DOT is extending Highway Operations Maintenance Policy to care for an increasing number of bike paths and sidewalks. Until the recent past, there have been relatively few bike paths and sidewalks within the state's right-of-way. Public input was relatively infrequent, requests for service were handled individually, and actions were very specific to satisfy only the scope of the complaint being responded to.

DelDOT assessed the current situation and is implementing the following practices for bike paths: (*1148*)

- For those bike paths which have been, or will be created within the paved surface of the roadway, and designated by paint striping, cleaning and repair of these facilities will be accomplished within the existing established procedures and policies governing highway sweeping and pot hole repair.
- Develop policy guiding frequency of cleaning and standards defining an acceptable level of maintenance where bike paths are constructed as separate, stand-alone facilities.
- Obtain specialized equipment not currently in the Department's inventory or contracted services that will be required to properly maintain separate paths. Existing equipment is designed for roadway service, and is too large and heavy to be utilized on stand-alone bikeways without damaging the physical structure of the path.

DelDOT noted that sidewalks located within the state's right-of-way along maintenance numbered roadways outside of municipal boundaries have long been given minimal attention, and that no standards or policies define frequency of cleaning or serviceability. Where failures occur, they are not addressed unless significant public input is received. DelDOT has formed a committee to develop overall maintenance policies for sidewalks outside of subdivisions in general.

The committees for bike paths and sidewalks were appointed by the Directors of Highway Operations, Pre-Construction, and Planning since planning and design considerations must be considered in development of an adequate and rational maintenance policy; e.g. where a sidewalk and/or bike path is placed relative to the roadway will have significant impact on the ease of cleaning and maintaining the facility, requiring that these long-term activities be fully considered in the project development phase. The Delaware Bicycle Council, County governments, and numerous municipalities are feeding into the process.

10.2. PROTECTION OF CULTURAL AND HISTORIC RESOURCES

Federal and state laws prohibit destruction or damage of an archaeological or historical site through routine maintenance. Cultural resource sites are considered as any prehistoric or historic archaeological site, historical site, historical architectural site, paleontological site, or Native American Traditional Cultural Property. To be in compliance with these laws, maintenance activities off the pavement in cut or fill slopes, in existing or new sources, or material sites shall be should be cleared with the District Environmental Planner or the Archaeologist in the environmental Section in headquarters.

Some maintenance activities can disturb or affect National Register of Historic Places eligible or listed archeological remains within the soil or historic buildings, districts, bridges, canal features, or their settings. NYSDOT's environmental handbook for maintenance lists the following examples and practices: (*1149*)

Example 15: NYSDOT Maintenance Practices in Areas with Cultural Resources

Excavation and related work

Work areas are inspected and the DOT Cultural Resources Coordinator (CRC) is contacted if 1) the ground looks as if it has never been disturbed, 2) you believe the area was the location of an early building or archeological site, 3) you see building or foundation remains or if you find arrowheads, ceramics, bottles or other; or 4) If you find unusual whole or broken historic artifacts.

Work in front of a building greater than 50 years old

Notify the CRC before you remove any mature living trees, stone sidewalks, fence or walls, lights, or other landscape features near a building that appears to be over 50 years old. Such buildings may be eligible for listing on the National Register of Historic Places and the above mentioned features may contribute to the importance or historic value of the building.

Bridges

Many bridges that are greater than 50 years old have decorative railing or lighting. Before removing or replacing any features that could be considered historic, contact the CRC to determine which bridges are eligible to be or are listed on the National Register of Historic Places.

Buildings on state canal lands and canal features

For State Canal Systems eligible for listing on the National Register of Historic Places consult with State Office of Parks, Recreation and Historic Preservation before altering or renovating these canal-related bridges, buildings or features.

Parkways

For Parkways eligible for listing on the National Register of Historic Places. CRCs call before doing work that alter or remove features that may contribute to the character of these parkways, such as historic guide rail, lights, bridges, turf shoulders, stone curbing, medians, signs or landscape features.

Stream Corridors

Since stream corridors have been a powerful magnet for human settlement throughout history, it is not uncommon for historic and prehistoric resources to be buried by sediment or obscured by vegetation along stream corridors. It is quite possible to discover cultural resources during restoration implementation (particularly during restoration that requires earth-disturbing activities).

10.3. Maintenance in Wetlands

Compensatory mitigation sites are often retained by the DOT and maintained according to a management plan, or as needed, based on the monitoring report. Except for the plant establishment period and trash pickup, no maintenance activities take place in created wetlands unless otherwise stated in the management plan, the contingency plan for the wetland, or the wetland monitoring report. In most cases this restriction on maintenance activities also applies to the designed upland buffer around the wetland.

In wetland mitigation sites, some vegetation management may be performed in accordance with management or contingency plans for the site. Long-term maintenance required in the management plan may include: (*1150*)

- Repairing damage to the site from vandalism, storms, or fire.
- Control of exotic and invasive weed species.
- Eradication of state-listed noxious weeds.
- Plant replacement, if necessary, to meet permitting requirements.
- Selective removal of some types of trees to facilitate the natural succession of desirable plant communities. This decision is made in conjunction with the DOT Biologist and Landscape Architect.
- Other activities required to maintain a functioning wetland as determined by the DOT environmental specialists.

Primary environmental stewardship practices for maintenance of wetlands include the following: (*1151*)

- Develop a long-term maintenance plan with the cooperation of DOT Maintenance, Biologists, and Landscape Architects.
- Establish a feedback loop for typical maintenance problems that might arise specific to the selected site. Include the region's Environmental Office, OSC Monitoring, the design Biologist, and the Landscape Architect in that loop.
- Wetland vegetation should not be sprayed, mowed, or cleared except when necessary to maintain designated roadside ditches or detention ponds.
- Designate herbicide restrictions near wetlands. Application of herbicides in wetland mitigation sites requires an aquatic certification on the applicator's license.

All emergency actions in or adjacent to streams, wetlands, lakes, ponds or other water bodies, or historic resources require some form of environmental review and notification to regulatory agencies and thus are coordinated through the environmental staff. Typical maintenance environmental stewardship practices in emergency situations include: (*1152*)

- Written notification of emergency work includes a description of the proposed action; a location map and plan for the proposed project; and reasons why the situation is an emergency.
- Emergency projects that require authorization from the USACOE are coordinated appropriately.
- All emergency work should be performed to cause the least modification, disturbance, or damage to the course or bed of a stream and its banks, or any adjacent wetlands.
- No equipment should be operated in the water unless it has been approved by the state's Department of Environmental Conservation.
- When conducting emergency work, all general and special permit conditions should be followed.
- When significant project modifications occur during construction, such changes should be coordinated with environmental staff and/or the permitting agencies.

10.4. MAINTENANCE NEAR WATERBODIES

Maintenance activities occasionally require equipment or personnel to enter a stream, river, channel, wetland or other water body. Cleanup/Repair, Drainage Ditch and Channel Maintenance, Bridge Repairs and Draw Bridge Maintenance are among that maintenance work items that can require work in or near a water body. In maintenance work near waterbodies, the following environmental stewardship practices should be followed.(*1153*)

- Maintenance equipment should not enter a water body without the required regulatory permits (e.g., Army Corps of Engineers Clean Water Act Section 404 permit, State Clean Water Act Section 401Water Quality Certification). A DOT environmental specialist or stormwater coordinator should be contacted to identify the appropriate permits.
- Evaluate alternatives to performing work in the water body.
- Tires should be cleaned before entering a water body.
- Heavy equipment driven into a water body to accomplish work should be clean of petroleum residue.

- Water levels should be below the gear boxes of the equipment in use, or equipment lubricants and fuels should be sealed such that inundation by water should not result in leaks.

Kentucky Transportation Cabinet's New BMP Manual for Maintenance Activities In and Around Streams

The Kentucky Transportation Cabinet (KYTC) developed a manual of *Best Management Practices* (*BMPs*) *For Maintenance Activities In and Around Streams*. The manual was developed to introduce the U.S. Army Corps of Engineer's state programmatic general permit for highway maintenance, and to give engineers and maintenance personnel practical guidelines when performing activities in and around streams. The guidelines were endorsed not only by the Corps but by multiple state agency divisions and several KYTC maintenance districts. Though activities deemed detrimental to the environment or damaging to the general public interest may be revoked from coverage by the Corps' District Engineer, the effort is clarifying expectations and improving performance on a programmatic level.

The manual prohibits stream channelization or channel deepening as part of cleanup operations and avoids placement of equipment in-stream, whenever possible. Work is also to be performed during low-flow conditions whenever possible and disturbance to existing stream bank vegetation is not to occur "unless absolutely necessary." Removed material must not be placed on the streambanks or in the floodway, and disturbed areas must be seeded and mulched.

The maintenance activities covered under the state programmatic general permit, and in the BMP manual include:

- Drift Removal from Bridges and Culverts
- Beaver Dams
- Stream Clean-out/Culvert Sediment Removal
- Embankment Repair and/or Protection
- Scour/Erosion and Miscellaneous Repairs to Bridge Elements
- Bridge and Culvert Replacement
- Erosion Control and Project Restoration
- Bioengineering

Activities not covered under the general permit are: bulldozer work, work areas in excess of 200 linear feet of stream, and work in "Outstanding Resource Waters" or designated components of national or state Wild and Scenic River Systems or wildlife management areas. This and other work that cannot be accomplished according to the conditions in the permit require submittal of a "Site Specific Project Sheet." Permits for disposal of debris or excavated material occur separately.

10.5. MAINTENANCE OF STRUCTURES FOR WILDLIFE

NCHRP 25-27 will explore methods used by state transportation agencies in tracking and funding maintenance needs, tracking wildlife-vehicle collisions, and the extent to which such information is eventually used in identifying sites for mitigation measures. One of the best sources of existing information is NCHRP Synthesis 305, **Interaction between Roadways and**

Wildlife Ecology: a Synthesis of Highway Practice, which reviews a number of opportunities and best practices related to maintenance of structures. These are excerpted as follows: (*1154*)

Bats and Birds in Bridges

An emerging area for maintenance related to wildlife concerns bats in bridges. Keeley and Tuttle (1996) describe the use of highway bridges and culverts as bat habitats and provide guidance for maintenance and demolition of bridges occupied by bats. They report that some states, such as Texas, are managing bridges for bats with great success. Washington State DOT has developed tracking programs for birds in bridges and maintenance inspection personnel. Maintenance personnel must be aware that some species of bats and birds are listed as threatened or endangered. It is usually necessary to bring in environmental professionals when bats and birds are founds.

Culverts

Materials used in modern culvert construction (concrete and metal with protective coatings) and the actual design (corrugated) can result in a structure with a long life span and potentially little maintenance. Several states have developed manuals to address the problems associated with culvert maintenance. A common problem with the maintenance of ordinarily dry culverts in upland areas is the control of vegetation in keeping the structure open and accessible. Deposition soil around the mouth of small pipe culverts as a result of wind and rain can result in decreased effectiveness for wildlife movement.

Underpasses

Because wildlife underpasses are essentially bridges over land and water, maintenance personnel can expect routine structural inspection and maintenance activities as for any bridge structure. Slope maintenance around these crossings is often problematic because of the need to maintain a built-up fill section for an elevation that provides for a smooth transition into the bridge while also maintaining suitable conditions for animal movement under the bridge. Slope stabilization with headwalls, riprap, reinforced earth, or vegetation can greatly reduce maintenance frequency, expense, and disturbance to the wildlife underpass. Many underpasses are large enough that maintenance of the cross-sectional opening is not as problematic as it can be in some drainage culverts. It is important that cover for animals be a consideration in the maintenance plan for the structure. If organisms sensitive to the need for cover are to use the structure, maintenance of sufficient cover will be required. Research from Europe has indicated that cover, such as rows of debris under the crossing, can facilitate small mammal and reptile/amphibian movement under the crossing.

To assure visibility of the crossings for animals, vegetation control is the primary maintenance function for these structures. Therefore, it may be necessary to size structures so that mowers can move through the underpass and the area in and around the structure. Graffiti and vandalism are also maintenance problems in areas that have access to humans.

Overpasses

Overpasses for wildlife are so recent in the United States that good information about their maintenance is not available. In Europe, maintenance on overpasses is performed for native vegetation and even wetland systems, similar to that for adjacent roadside communities. Various structures for wildlife cover, including large rocks and stumps, are also maintained on European overpasses. With the exception of planting and maintenance of native vegetation, Europeans do little else to maintain their wildlife overpasses. In Canada, one innovative measure being used in Banff National Park involves the placement of piles of used Christmas trees to provide cover for habitat and movement of small animals across the overpasses.

Fencing

Fence maintenance can be one of the most expensive activities for wildlife mitigation techniques. Run-off-the-road vehicles and falling trees often damage fences and unless quickly repaired animals will find their way through these breeches and on to the rights-of-way. Vegetative growth along fences can also present a maintenance problem. Spraying with herbicides seems to be the most popular maintenance measure, although this can present problems in particularly sensitive aquatic areas and areas with listed protected plants.

10.6. MAINTENANCE OF STORMWATER FACILITIES

Thirty percent of state DOTs have produced manuals or internal guidance for stormwater protection at non-highway maintenance facilities. General practices for maintenance of stormwater facilities include the following:

- Maintenance Supervisors should be charged with line responsibility for inspecting stormwater drainage systems and assessing the need for cleaning or clearing.
- The DOT should observe culverts and drain inlets annually in the fall and throughout the winter as needed to determine if cleaning or repairs are required.
- Culverts should be cleaned when sediment impairs culvert function.
- Ditches should be cleaned prior to the rainy season to maintain the hydraulic capacity of the ditch.
- Ditches and gutters should be sealed or repaired when structural integrity is endangered.
- Downdrains should be inspected annually and cleaned or repaired as necessary.
- Solid and liquid wastes generated by the cleaning of stormwater drainage system facilities should be disposed of in accordance with federal, state and local liquid and solid waste disposal regulations.
- Baseline inspection and cleaning activities should be reported annually by section of highway and information used as a tool to evaluate the program.

State DOT Inventory, Tracking, and Prioritization Systems

MDSHA Inventory System for Water Quality Improvement/Retrofitting

MDSHA has mapped the entire state for opportunities for retrofitting BMPs, for pollution prevention and stream restoration beyond requirements. The agency has developed a thorough and duplicable grade-based rating system for stormwater management facilities and has developed an inventory, database, and photo record of all facilities statewide and their maintenance status. Inspection teams of trained staff identify further environmental improvements that can be made. Under the rating system, those graded A or B are considered functionally adequate. As of late 2003, between 73 and 75 percent of MDSHA stormwater were functionally adequate (A=everything fine, working fine, no maintenance required, B= minor maintenance, need mowing or trash removal), leaving approximately 25 percent needing maintenance or retrofitting to achieve functional requirements. The state has now been developing and implementing a plan for systematic implementation of those improvements. By 2010 MDSHA is aiming for 95 percent of facilities functioning adequately.(*1155*)

Minnesota DOT System for Inventorying Hydraulic Conveyance Structures

Mn/DOT system for inventorying hydraulic conveyance structures, a requirement in many states for NPDES Phase II, is called “HYDRINFRA.” Mn/DOT plans to add an inventory of ditches and erosion problem areas to the database in the future. Mn/DOT uses and employs consultant services for three levels of inspection, location, and repair of hydraulic structures.

- MS4/HydInfra Inspection may include inspection, GPS location of hydraulic structures, and/or development of an electronic map (“stick map”) showing all hydraulic structures located during either the inspection and/or cleaning. The map will also show flow connection and direction for all structures as listed above and rating/evaluation of hydraulic structure condition. Any indicators of illicit discharges to the system are noted on reports.
- Video Inspection is completed for hydraulic structures (pipes, culverts, manholes, catch basins, drop inlets, etc.) and is conducted using remote controlled, self-propelled, explosion-proof video cameras. Video inspection includes providing video of the entire damaged structure. Defects along the pipe are identified, indexed, and stamped on the screen to allow for easier processing by Mn/DOT personnel. Video must be provided in digital (MPEG-1) format for use of storage and filing.
- Hydraulic Structure Cleaning includes removal and proper disposal (including certification) of material from all types of hydraulic structures.

Michigan DOT and Local Studies to Prioritize Funding of Stormwater Retrofits

Road-stream crossing features contribute varying amounts of sediment and non-point source pollutants to rivers and streams. In an effort to combat the influx of these types of pollutants, the Michigan Department of Transportation (MDOT) used federal Transportation Enhancement funds to support planning studies that inventory road-stream crossings in several locations throughout the state. These studies are used to prioritize funding for additional efforts to mitigate pollution from highway runoff. One such inventory was the Ionia County Road Commission’s planning inventory of all bridge and culvert road-stream crossings in the county. As a preventative measure the study was intended to highlight potential problem locations and increase reaction times in resolving water impairment issues. Field crews from a local university collected site data from more than 700 locations. The sites were ranked and the data was entered into a Geographic Information System (GIS) that included information on soils,

Figure 17: Field Crews Collect Information on Stormwater Retrofit Needs at MDOT Stream Crossings

land use, drains, school districts, and road ratings. The project was the cooperative effort of several county agencies, MDOT, and Grand Valley State University.(*1156*)

10.7. Maintenance of Roadside Public Facilities

Roadside public facilities include safety roadside rest areas, weigh stations, park and ride lots and vista points. Maintenance of such facilities includes a range of custodial responsibilities that may include restrooms, fountains, picnic areas, and other public facilities. Maintenance of appurtenances such as roadway surfacing, signs, pavement markings, buildings, landscaping and electrical installations may also occur in conjunction with maintenance of these facilities.

Potential Pollutant Sources and Environmental Stewardship Practices

Potential pollutant sources at public facilities can include trash, litter, sewage, chemical vegetation control, erosion, illegal dumping, graffiti, spills and leaks, resulting in sewage, pesticides, sediment, sandblast grit, paint, fuel, hydraulic fluid and oil entering the environment. To prevent such pollution, recommended environmental stewardship practices include illicit connection/discharge reporting and removal, scheduling and planning, safer alternative products, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, liquid waste management, sanitary/septic waste management, concrete waste management, spill prevention and control, material use, material delivery and storage, maintenance facility housekeeping practices, litter and debris, sweeping and vacuuming, anti-litter signs, potable water/irrigation and water conservation practices.(*1157*)

Graffiti Removal

The following environmental stewardship practices are recommended for graffiti removal: (*1158*)

- Schedule graffiti removal activities for dry weather.
- Protect nearby storm drain inlets prior to removing graffiti from walls, signs, sidewalks, or other structures needing graffiti abatement.
- Clean up afterwards by sweeping or vacuuming thoroughly, and/or by using absorbent and properly disposing of the absorbent.
- When graffiti is removed by painting over, implement the procedures under Painting and Paint Removal.
- Direct runoff from sand blasting and high pressure washing (with no cleaning agents) into a landscaped or dirt area. If such an area is not available, filter runoff through an appropriate filtering device (e.g. filter fabric) to keep sand, particles, and debris out of storm drains.
- If a graffiti abatement method generates wash water containing a cleaning compound (such as high pressure washing with a cleaning compound), plug nearby storm drains and vacuum/pump wash water to the sanitary sewer.
- Consider using a waterless and non-toxic chemical cleaning method for graffiti removal (e.g. gels or spray compounds).

Electrical Maintenance

The electrical area of activities includes all work performed on highway facilities used for control of traffic (e.g., traffic signal systems, highway and sign lighting systems, toll bridge electrical systems and other related systems). Detector loops are electrical sensors used to trigger a traffic control signal at an intersection and/or for long-term traffic counts. Installation of detector loops is accomplished by cutting into the road surface with a concrete saw, inserting electric wire into the cut and sealing the cut with loop sealant. Subtasks include support vehicle operation, sawcutting, hauling and disposal and pavement repair. Pollution control activities focus on ensuring that debris and maintenance and repair materials remain controlled and are not released to the environment.

- Control potential pollution from concrete, sealant, fuel, hydraulic fluid and oil. Utilize stormwater protection practices, including illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, concrete waste management, liquid waste management, material use, water conservation practices and sweeping and vacuuming.
- Water applied during sawcutting operations should be controlled to prevent unpermitted non-stormwater discharges.

10.8. Management of Portable Sanitary/Septic Waste Systems

Sanitary/septic waste management procedures and practices are designed to minimize or eliminate the discharge of sanitary/septic waste materials to storm drain systems or watercourses and should be implemented for all maintenance activities that use portable sanitary/septic waste systems.(*1159*)

- Sanitary facilities should be located away from drainage facilities and watercourses. When subjected to risk of high winds, sanitary facilities should be secured to prevent overturning.
- Wastewater should not be discharged (unless the discharge is to a permitted leach field or pond) or buried within the highway right-of-way.
- Sanitary/septic waste should be discharged to a sanitary sewer or managed by a licensed hauler.
- Sanitary/septic waste storage and the disposal procedures should be managed to prevent non-stormwater discharge.
- A foreman and/or construction supervisor should monitor on-site sanitary/septic waste storage and disposal procedures.
- For emergency procedures related to large spills, review the *District Hazardous Materials Spill Contingency Plan*.

10.9. Maintenance of Shoulders and Roadway Appurtenances

Areas adjacent to surfaced and unsurfaced road shoulders require maintenance to prevent the loss of lateral support, to prevent the deterioration or failure of the road edge and to maintain roadside drainage patterns, and to prevent excessive sedimentation and pollution from applied abrasives. Potential pollutant sources may include disturbed soil, leaks and wind erosion which can then release pollutants like sediment, fuel, hydraulic fluid and oil.

- Water applied during sweeping operations should be controlled to prevent unpermitted non-stormwater discharges.
- Use applicable water quality management practices such as illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, compaction, material use, spill prevention and control, sweeping and vacuuming and water conservation practices. Subtasks include equipment operation, grading, rolling, import and fill and post-sweeping.(*1160*)

Cleaning/Sweeping of Shoulders

Sweeping operations remove litter and debris from the traveled way and shoulder to reduce traffic hazards and improve aesthetics. Subtasks associated with highway sweeping operations include operation of support vehicles, sweeper operation, stockpile management and material disposal. Potential pollutant sources include spills, leaks and stockpiles.

The following environmental stewardship practices are utilized on the municipal level and may be used by state DOTs: (*1161*)

- Care should be taken to minimize dust as much as possible.
- Water applied during sweeping operations should be controlled to prevent unpermitted non-stormwater discharges.
- Stormwater quality control measures should be employed, including illicit connection/illicit discharge reporting and removal, scheduling and planning, safer alternative products, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, liquid waste management, sweeping and vacuuming and water conservation practices.(*1162*)
- Equipment should be in good working order and contain filters and/or other controls as feasible.
- Avoid wet cleaning or flushing of street, and utilize dry methods where possible.
- Consider increasing sweeping frequency based on factors such as traffic volume, land use, field observations of sediment and trash accumulation, proximity to water courses, etc. For example:
    a. Increase the sweeping frequency for streets with high pollutant loadings, especially in high traffic and industrial areas.
    b. Increase the sweeping frequency just before the wet season to remove sediments accumulated during the summer.
    c. Increase the sweeping frequency for streets in special problem areas such as special events, high litter or erosion zones.
- Maintain cleaning equipment in good working condition and purchase replacement equipment as needed. Old sweepers should be replaced with new technologically

advanced sweepers (preferably regenerative air sweepers) that maximize pollutant removal.

- Operate sweepers at manufacturer requested optimal speed levels to increase effectiveness.
- To increase sweeping effectiveness consider the following:
    d. Institute a parking policy to restrict parking in problematic areas during periods of street sweeping.
    e. Post permanent street sweeping signs in problematic areas; use temporary signs if installation of permanent signs is not possible.
    f. Develop and distribute flyers notifying residents of street sweeping schedules.
- Regularly inspect vehicles and equipment for leaks, and repair immediately.
- If available use vacuum or regenerative air sweepers in the high sediment and trash areas (typically industrial/commercial).
- Keep accurate logs of the number of curb-miles swept and the amount of waste collected.
- Dispose of street sweeping debris and dirt at a landfill.
- Do not store swept material along the side of the street or near a storm drain inlet.
- Keep debris storage to a minimum during the wet season or make sure debris piles are contained (e.g. by berming the area) or covered (e.g. with tarps or permanent covers).

Shoulder Grading, Widening, Blading, or Rebuilding

Shoulder Blading/Rebuilding includes shoulder blading and rebuilding to correct rutting and buildup of materials, to remove weeds, for safety, and to maintain proper drainage. This activity can be similar to ditching, and has similar stewardship practices to avoid and minimize environmental impacts.

- When conducting shoulder maintenance activities in areas with narrow shoulders or steep slopes, inspect the area and/or consult with environmental support staff to determine if there are wetlands, waterbodies, or sensitive cultural resources (such as historic buildings or parkways) in the area.
- Contact environmental support staff before placing excess material to widen the shoulders or smooth out the slopes,
- Install check dams to protect sensitive resources, when appropriate.
- Specific sites will be evaluated for alternatives to blading, such as berming, curbing or paving shoulder.
- Where practicable, evaluate the width of the blading activity and if appropriate, modify the width to minimize disturbance of vegetation.
- Where possible, blade in dry weather, but while moisture is still present in soil and aggregate (to minimize dust).
- Incorporate this activity into local IVM plans to consider and minimize impacts of this activity on streams.

- Where appropriate, permanently stabilize disturbed soils using BMPs (seeding, plants, etc.).

Guardrail Replacement

Guardrail replacement involves repair and replacement of existing guardrail sections. To avoid and minimize environmental impacts:

- Consider new technologies in guardrails such as wire rope safety fence (WRSF) can both improve safety, hasten repair times, and reduce material usage and disposal issues. Furthermore, during repair, guardrail usually requires heavy equipment and a lane closure greatly slowing traffic (fuel and emissions). WRSF can be repaired with one man in a pickup without a lane closure in normally less than 30 minutes. The design allows small animals to pass through and can minimize snow accumulation. WRSF can also blend into surroundings and help minimize the approach slope needed; concrete barrier and guardrail require 10 to 1 approach slopes while WRSF can have 6 to 1 slopes, adding a land consumption benefit in some cases.(*1163*)
- In unstable situations, protect areas downslope from guardrail replacement with erosion control measures (silt fences and other appropriate devices) where appropriate to minimize additional sediment loadings into aquatic systems.

Attenuator Maintenance

Attenuator Maintenance involves service, repair, replacement, and realignment of damaged attenuators (physical systems that are strategically placed along exit ramps, bridge abutments, etc. to minimize impacts and cushion vehicles). Following impact, attenuators compact, releasing fluid (often ethylene glycol) which can flow directly to drainage systems. Practices to avoid and minimize such impacts include: (*1164*)

- Use non-chemical systems when installing new attenuators.
- When replacing attenuators, install those devices found to be the most environmentally sound.
- Use absorbent dams or diapers around attenuators during repair or maintenance.
- Identify and close inlets (if appropriate and can be done safely) during attenuator maintenance.

Luminaire Replacement to Reduce Light Pollution and Increase Energy Efficiency

Roadway lighting is an important part of a highway system. It contributes to a safe environment and facilitates traffic flow for the traveling public during evening or nighttime driving. Lighting shows drivers changes in direction, obstacles, and roadway surface conditions. Exterior lighting may also have a significant impact on economic development. At present, roadway lighting standards are based almost exclusively on traffic safety.

The impact of roadway lighting practices on the surrounding environment is of increasing concern to the public and DOTs, out of concern for impacts on wildlife as well as energy efficiency and cost. Light pollution is an unwanted consequence of outdoor lighting and includes such effects as skyglow, light trespass, and glare. “Sky glow” is a brightening of the night sky caused by natural and human-made factors. "Glare" is an objectionable brightness or reflection of light and a driving hazard especially bothersome for older drivers. "Light trespass" is the actual light that falls off the right-of-way and can be measured and quantified. In fact, many professional lighting designers have been obliged to go out at night and take measurements of the light that is falling off the right-of-way and onto a concerned citizen's property.

Cities and states in some cases have responded with lighting ordinances and requirements regarding certain types of fixtures, minimum and maximum lighting levels, lumen/acre limits, and eliminating lighting in some cases. Legislation has been adopted in Arizona, California, Connecticut, Colorado, Maine, New Mexico, Texas, Georgia, and New Jersey. Such legislation has been proposed or introduced in New York, Iowa, Massachusetts, Michigan, New Hampshire, Maryland, Pennsylvania, Rhode Island, Virginia, and Wyoming. Environmental impacts of lighting are of increasing concern to biologists and members of the public concerned about wildlife as well. These issues are described in greater detail in the Design section on Lighting Control and Minimization, which also includes sections on Common Lighting Approaches and Deciding How Much Light Is Enough; Practices in Assessing Lighting Needs; Comparison of Lighting Sources, Issues, and Costs; and Research to Improve Lighting Practices.

Light Minimization and Energy Efficiency Practices

- Realign the fixture (change angle of mounting arm or rotate fixture head) so the source of light is not directly visible outside the ROW.
- Apply a shield to a drop globe fixture.
- Change an open bottom or drop globe fixture to a cutoff fixture.
- Apply a shield to a cutoff fixture.
- Reduce the mounting height of the fixture.
- Reduce the lamp wattage.
- Change the lamp socket position in the fixture to compress the lighting footprint.
- Change to a fixture with a different type of reflector providing a more favorable lighting footprint.
- In addition to other shielding and light reduction measures: Install a flat 2422 acrylic amber lens in a cutoff fixture with an HPS lamp of 70 watts or less (e.g., GELS 70W M250).
- Turn the light off
- Remove the fixture.
- Relocate the fixture to block light from extending to sensitive resources.
- Change to an LPS fixture (if the light is customer-owned).
- Create a vegetated berm/buffer or other light shield between the roadway and the sensitive resource.

Electric utilities can generally provide the following options:

- Seasonally turn the lights off,
- Relocate or redirect the light fixture,

- Change a drop globe fixture to a cutoff style fixture,
- Remove the fixture,
- Lower mounting height,
- Reduce wattage,
- Selectively install amber-colored filtering lenses (on cutoff fixtures of 70-watts or less and only in addition to other modifications), and
- Install a light shield.

An overview of roadway lighting fixtures is available at the MetroLux Lighting website.(*1165*)

Oregon DOT Illumination Reduction Practices

Oregon DOT (ODOT) involved all District and Regional Managers in response to possible energy shortages in the Pacific Northwest and directives from the Governor's office that all state agencies review power usage and develop conservation measures. Specifically, ODOT considered reducing highway illumination as a temporary measure, and undertook case studies to assess any differences that occurred with lighting reductions.

Region Traffic Engineers and District Maintenance staff worked together to determine specific luminaries to be turned off. The Traffic Management Section assisted in reviewing specific requests to assure the state continued to meet AASHTO standards for lighting on a statewide basis. In addition, ODOT's Traffic Engineering Services Unit conducted a comprehensive crash analysis, including a field review during both dark and dark/wet conditions, of the freeways in the Portland metro area. The crash analysis indicated no significant difference in the ratio of night-to-day crash rates by lighting condition. In fact, in most sections the night crash rate was substantially lower than the day crash rates. As a result of their research, ODOT developed the following guidelines for reducing illumination that may be utilized as practices for consideration by other state DOTs.

Lineal Lighting

ODOT's practices specified that lineal lighting along freeways and freeway-like facilities could be turned off unless the facility has the following characteristics:

- Inadequate outside and median shoulders.
- Vertical or horizontal alignments such that illumination may be beneficial to driver safety.
- A crash analysis indicates that the night-to-day crash rate ratio is greater than 1.0
- Section of highway has high levels of pedestrian and/or bicycle activities during times of darkness.
- Sections where there are three or more successive fully-illuminated interchanges located with an average spacing of one mile or less between successive interchanges: (Note: This exception does not apply if the interchanges are partially illuminated. That is, if interchanges are partially illuminated, lineal lighting should be turned off regardless of spacing.)
- Pavement markings and delineation should be in good condition when deciding to turn off lineal lighting. Durable striping is desirable.

- Under certain designs (such as narrow median widths) it may be possible to reduce the lighting to only one side of the highway.

Interchange Lighting

Full interchange lighting should be reduced to partial interchange lighting unless the interchange has the following characteristics:

- Ramp and/or interchange alignment and grade is complex or unusual.
- Interchange area has high levels of pedestrian and/or bicycle activities during times of darkness.
- Interchange that contains important decision point(s) and/or existing roadside hazard areas that would not be covered with partial illumination.

General Guidelines in Considering Luminaires to Turn Off

- *On Ramps* - Standard of three continuous poles as a group on gore and merging sections minimum coverage is 150 meter (500 feet). Ramps with high truck traffic and/or longer acceleration lanes may need more coverage.
- *Off Ramps* - Standard of three continuous poles as a group for gore (decision making point) including a 'pull through' light. Highway alignment may require four poles to make a group.
- *Ramp Terminals* - Standard of two poles on opposite corners of the intersection. At a rural intersection with a two-lane facility without a designated crosswalk, one pole at the intersection may be sufficient.
- *Underdeck Illumination* - Should be turned off if no pedestrian and/or bicycle activity is expected and there is no current safety problem.

ODOT's illumination reductions were implemented as a temporary measure as a means to reduce energy consumption; however, the agency is considering permanent reductions if safety is not impacted. Assessment of reduced lighting is continuing. Changes from whole to partial interchange lighting at the entry and top of ramp and reductions in high tower illumination were the most common changes. Meanwhile ODOT produced a Traffic Lighting Design Manual in January 2003, which implements some lighting reductions, including a study on whether light removal would be possible.

Use of Light-Emitting Diode (LED) Traffic Signals to Reduce Energy Usage

The California Department of Transportation (Caltrans) reduced agency-wide energy consumption by 21 percent in response to threats of rolling blackouts in 2001. More energy-efficient facilities such as the new building in downtown Oakland are one source of savings. Another is the award-winning light-emitting diode (LED) traffic signal upgrade effort, which, when complete, will reduce signal grid demands by 92 percent. Lighting plans can make better use of lights, conserve energy and make roadways safer by reducing the number of poles and fixtures. The department also contracted with a private company to conduct energy audits and implement efficiencies under a savings-sharing system. After examining other areas, such as bridge and tunnel lighting, bulk energy procurement and roadway sign lighting, Caltrans has identified about $181 million over 10 years in savings.(*1166*)

10.10. Sweeping and Vacuuming of Roads, Decks, Water Quality Facilities, and Bridge Scuppers

Sweeping and vacuuming are performed to remove litter, debris and de-icing abrasives from paved roads and shoulders. Sweeping to reduce track-out generally involves manual sweeping or use of small equipment, but does not exclude the use of sweepers should the need arise (e.g., for slides and slipouts). Curbs and bridge decks may also be flushed or swept to remove dirt and debris, and scupper (weep holes or direct drains on bridges) cleaning. Materials are recovered and disposed of or in some cases sidecast. Stewardship practices for minimizing water quality impacts from highway, bridge deck and scupper sweeping include the following recommendations from Caltrans and Oregon DOT: (*1167*)(*1168*)

- Store/dispose of removal materials at an appropriate site in an appropriate manner as part of the local material disposal plan. Removed material may be temporarily stored in stable locations to prevent the material from entering wetlands or waterways.
- Recycle sweeping materials where appropriate.
- Where feasible, schedule sweeping during damp weather, to minimize dust production.
- Remove sweepings produced within 25 feet of identified sensitive spawning areas as identified in coordination with resource agencies, if the design of the facility allows.
- Where appropriate and practical, place sediment barriers in site-specific locations along stream routes or direct drainage routes, route sweeping material away from watercourse.
- Scupper cleaning involves sweeping of material away from clogged scuppers. Clogged scuppers are normally freed using a steel rod.
- Use water (as needed) to reduce dust during sweeping.
- Where feasible, coordinate crews to follow sweeping/flushing with bridge drainage cleaning.
- Sweeping and vacuuming operations are appropriate for removing de-icing abrasives, material from small slides, litter and debris. Sweeping and vacuuming may be implemented anywhere sediment is tracked from off-road maintenance activity sites onto public or private paved roads typically at the points of egress.
- Do not sweep up any unknown substance that may be potentially hazardous. If a substance is known to be hazardous, suspected of being hazardous or cannot be identified, notify the District Maintenance HazMat Manager immediately.
- If an illegally dumped substance within the DOT ROW has the potential of entering a municipal drain system, the immediate supervisor and the District Stormwater Coordinator must be notified so that the downstream municipality can be contacted.
- Adjust brooms to maximize the efficiency of sweeping operations.
- Do not load hoppers beyond their capacity.
- Dispose of waste to a landfill or approved site in accordance with local regulations and solid waste management best management practices (see waste management and recycling section). Clean materials may be incorporated into the maintenance activity area.

10.11. MAINTENANCE STEWARDSHIP PRACTICES FOR SLOPES, DRAINAGE DITCHES, SWALES, AND DIVERSIONS

Maintenance activities related to slopes, drainage and associated vegetation include repair, replacement and clearing of channels, ditches, culverts, underdrains, horizontal drains and other elements of the stormwater drainage system. Protective measures such as soil stabilization using vegetation or rock on stream banks, slopes, benches or ditches are also part of the these activities.

Drainage Ditch and Channel Maintenance

Channels and drainage ditches are maintained to avoid obstruction and maintain flow. Ditch cleaning includes use of equipment for cleaning and reshaping of ditches including loading, hauling, and disposing of excess materials. Vegetation located in the ditch is removed during cleaning. Material is removed to an appropriate location for disposal or storage.
Subtasks include vehicle operation, mechanically cleaning, and stockpiling and disposal of removed material. Fill material may be imported to repair eroded channel walls.

- Use water quality management practices to control potential pollution from disturbed soil, leaks and stockpiles, and release of pollutants such as sediment, litter, fuel, hydraulic fluid and oil. Such pollution prevention practices may include scheduling and planning, illegal spill discharge control, illicit connection/illicit discharge reporting and removal, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, liquid waste management, concrete waste management, contaminated soil management, sanitary/septic waste management, sandbag or gravel bag barrier, straw bale barrier, fiber rolls, check dam, hydroseeding/ handseeding, compaction, clear water diversion, material use, tire inspection and sediment removal, baseline stormwater drainage facilities inspection and cleaning and water conservation practices.(*1169*)

Ditch Cleaning Practices

A summary of other state DOT environmental stewardship practices for ditch or swale cleaning are outlined below:

- Maintenance ditch cleaning is only done in areas where the ditch's function is impaired. The ditch length, width and height should be dredged back to its original dimensions. At NYSDOT, ditches are mowed to control vegetation rather than mechanically cleaning ditches with heavy equipment because mowing causes less erosion of exposed soil and can result in improved water quality.(*1170*)
- In general, culverts and ditches are cleaned, repaired or replaced only during periods of low water flow and not during intense rainfall events
- Dredging should be conducted during low water periods and during dry weather, avoiding rainfall events.
- Evaluate and modify, where feasible and appropriate, existing ditch slopes to trap sediments, and support development of vegetation
- Use best management practices identified in the local Integrated Vegetation Management plan.

- All efforts should be made to retain existing vegetation, especially along the ditch slopes to maintain slope stability.
- Consider excavating only the first three quarters of the ditch and retaining vegetation in the remainder. WSDOT assessed routine highway ditch cleaning alternatives or service levels for water quality benefits, surveyed biofiltration swales to evaluate conditions promoting water quality benefits, and assessed restabilization and revegetation options for use after ditch cleaning and for restoring biofiltration swale vegetation. Of the options explored, the study found the greatest water quality benefits when the first three quarters of the ditch were excavated and vegetation was retained in the remainder. The ditch treated in this manner was capable of reducing TSS by approximately 40 percent, total phosphorus by about 50 percent, and total and dissolved Cu and Zn each by roughly 20 to 25 percent. Analysis of survey data also showed that biofiltration swales with broad side slopes, wide bases, and total storage volumes equivalent to 3 inches of runoff from the impervious drainage area consistently supported good vegetation cover and showed few signs of damage. For assisting grass growth, straw held in place with stapled jute mat had a clear advantage in effectiveness over the alternatives and a slight economy advantage over the coconut mat.(*1171*)
- Dispose of removed material above the bank line and not in any waterway or wetland. Recycle excavated material when feasible.
- Adequate siltation control measures should be in place before dredging operations begin. Use erosion control devices such as check dams, silt fences and other acceptable techniques, when the potential exists to have sediment or other materials enter a water of the State. Install check dams on steep slopes, as necessary, to slow water velocity reduce erosion and sedimentation. Consult with DOT Environmental Specialists if silt devices are inadequate to filter water prior to draining to watercourses.
- When feasible, begin dredge at fixed flow elevation points (i.e. culvert inlets/outlets, catch basin inlets, etc.).
- Cleaned ditches should be seeded and mulched at the end of each work day. Monitor daily for subsequent erosion until area is stable. Repair as necessary.
- Temporary conveyances should be completely removed as soon as the surrounding drainage area has been stabilized or at the completion of construction.
- The measure should be inspected after every storm and repairs made to the dike, flow channel and outlet, as necessary. Approximately once every week, whether a storm has occurred or not, the measure should be inspected and repairs made if needed. Damages caused by construction traffic or other activity must be repaired before the end of each working day.
- Check the channel lining, embankments, and bed for erosion and accumulating debris and sediment buildup. Remove debris and repair linings and embankments as required.
- If channelized flow is too strong for the surrounding environment, energy dissipaters may be needed. If vegetation or rock lined ditches reduces the ditch flow capacity, the road may be endangered. Native material curbs, or berms can be developed using a grader. Vegetating these berms will enhance the durability of these constructed features. Hardened curbs such as asphalt or concrete will require a construction crew and an

engineer. The softest approach to developing vegetated ditches is to not heel or pull the ditch with a grader, except when absolutely necessary. Roadside ditches should be large enough, and have adequate relief drain spacing, to carry runoff from moderate storms. Ditch gradient between 2 and 8 percent slopes are usually better performers. Slopes greater than 8 percent provide runoff waters with too much momentum and erosive force and will require more ditch relief. Slopes of less than 2 percent drain water too slowly, or not at all.

Evaluating Ditches and Culverts for Water Quality and Function

DOTs track the need to maintain and replace culverts before they contribute to flood damage on roads and bridges. To do so, many state DOTs rely on time-consuming manual systems to record information on inventory, condition, and work needs. Other agencies have no formal system in place and consequently find themselves reacting to immediate or impending problems, rather than proactively managing maintenance and replacement.

Culvert Management Systems

To help agencies manage their culvert inventories, condition assessments, and improvement programs, FHWA developed a computer-based "Culvert Management System" under the Local Technical Assistance Program (LTAP). The system provides an automated tool to facilitate the coordination of culvert maintenance and replacement operations on a system-wide basis. With the software, state DOTs can create an inventory of their culverts, assess them, and schedule repairs and replacements. It also helps agencies to develop maintenance plans and to estimate costs for installing, repairing, or replacing culverts. The system consists of five modules, which an agency can phase in individually. The inventory module enables the agency to record information about each culvert under its jurisdiction, such as size and location, while the condition module maintains a record of each culvert's condition. The schedule module helps the agency develop a culvert work plan for the year. The work needs module enables the agency to define maintenance and rehabilitation options, determine costs, and rank work by type and priority. With the work funding module, agencies can project culvert deterioration over time and develop long-term work programs.

Drainage Ditch Evaluation

NYSDOT has developed the following rating system for drainage ditches and maintenance: (*1172*)

- 4 - Sides well shaped, clean, properly graded, smooth transition to inverts of culverts or drainage structures, environmentally friendly particularly in sensitive areas
- 2- Slopes slightly oversteepened, minor erosion or material build-up around headwalls, end sections or structures, minor invert erosion, meets environmental guidelines
- 0 - Slopes significantly oversteepened, significant vegetation impacting flow, standing water, significant erosion or material build-up around headwalls, end sections or structures, significant invert erosion, or one or more violations of the Department's environmental guidelines.

Mn/DOT developed a Ditch Stabilization Matrix that identifies appropriate BMPs to stabilize different kinds and lengths of slopes and ditches:

Figure 18: Mn/DOT Ditch Stabilization Matrix with Recommended Treatment Methods

Erosion Control Method	Permissible Shear Lbs/ft2	Ditch Grade 1% - 2% Max. Ditch Length			2% - 4% Max. Ditch Length			4% - 6% Max. Ditch Length			6% - 9% Max. Ditch Length			9% - 12% Max. Ditch Length		
		300'	600'	>600	300'	600'	>600	300'	600'	>600	300'	600'	>600	300'	600'	>600
Permanent Seed w/ Cover Crop & Type 1 Mulch	0.6		S	C												
Sod Ditch Check w/ Seed & Mulch	-				S	C										
3889 Type 1 Ditch Check	-						SC									
3878 EC SOD	1.0						SC									
3885 Cat 3, 4 Blanket	1.5								SC							
Sod w/ 3883 EC Netting Type 2	1.5							S	C							
3889 Type 6 Ditch Check	-									SC						
3885 Cat 5 Blanket	2.0									SC						
3888 ESM Class 2	3.5										SC					
3888 ESM Class 3	5													SC		
3889 Type 7 Ditch Check	-													SC		
3888 ESM Class 4	6															SC
3601 Type III, IV Riprap	14															SC

Evaluation of Other Drainage Structures

NYSDOT has developed the following rating system for other drainage structures and maintenance: (*1173*)

Drainage Structures

- 4 - Clean and in very good structural condition, frames and grates in very good condition, no erosion or material build-up, environmentally compatible
- 2 - Some material present not affecting flow characteristics, some aging of structure or frame / grate – but not enough to pose structural problems, minimal scour or invert loss
- 0 - Significant material build-up or erosion impacting flow, significant structural loss, frame / grate separated or missing, undermining of frame / grate

Closed Drainage System

- 4 - Clean and in very good structural condition, inverts at structures in very good condition, no erosion or material build-up

- 2 - Some material present not affecting flow characteristics, some aging of pipe, end sections or headwalls – but not enough to pose structural problems, minimal scour or invert loss
- 0 – from structure

Litter and Debris

- 4 - No appreciable litter present within segment
- 2 - Small concentrations of litter or two or more pieces of large debris present
- 0 - Significant concentrations of litter or debris exceeding 5 large pieces

NYSDOT developed an inspection form for open channels, as seen in the Appendix that also includes space to identify needed actions, further comments, etc.

Drain and Culvert Maintenance for Water Quality and Fish Passage

Drain and culvert maintenance includes the maintenance of under drains, horizontal drains, down drains, gutters, overside drains, scuppers and deck drains. Drains are maintained to prevent flooding and allow unobstructed flow. Subtasks include vehicle operation, cleaning (backhoe or Vactor™ may be used) and stockpiling and disposal of removed material.

- Use water quality management practices to control potential pollutant sources such as disturbed soil, leaks and stockpiles create the possible pollutants of sediment, litter, fuel, hydraulic fluid and oil. Recommended environmental stewardship practices include: illicit connection/illicit discharge reporting and removal, scheduling and planning, illegal spill discharge control, vehicle and equipment fueling, vehicle and equipment maintenance, solid waste management, liquid waste management, concrete waste management, contaminated soil management, sanitary/septic waste management, sandbag or gravel bag barrier, straw bale barrier, fiber rolls, hydroseeding/handseeding, compaction, baseline stormwater drainage facilities inspection and cleaning and water conservation practices. (*1174*)
- Stenciling should be applied to urban drain inlets to discourage public dumping.
- Litter is a high priority pollutant in some receiving waters and is a pollutant listed on the CWA Section 303(d) lists for receiving waters in a few areas. Storm drain inlets that contain 12 inches or more of accumulated material should be cleaned.
- When Illicit Connection/Illicit Discharges are discovered, they should be referred to the District Maintenance or NPDES Stormwater Coordinator for initial investigation and reporting. Illegal dumping that may impact stormwater quality should be removed. All cleanup activities should be reported to the DOT or District Maintenance Stormwater Coordinator, as well as all illegal-dumping incidents found but not cleaned.

With regard to maintenance to ensure fish passage, post-construction evaluation of culvert improvements is important to assure the intended results are accomplished, and that mistakes are not repeated elsewhere. There are three parts to this evaluation: 1) Verify the culvert is installed in accordance with proper design and construction procedures. 2) Measure hydraulic conditions to assure that the stream meets these guidelines. 3) Perform biological assessment to confirm the hydraulic conditions are resulting in successful passage. Staff and resource agency biologists may assist in developing an evaluation plan to fit site-specific conditions and species. The goal is to generate feedback about which techniques are working well, and which require modification in the future.(*1175*)

Any physical structure will continue to serve its intended use only if it is properly maintained. Hence the following practices should be employed.

- Ensure timely inspection and removal of debris for culverts to continue to effectively move water, fish, sediment, and debris.
- Inspect all culverts should be inspected at least annually to assure proper functioning. Summary reports should be completed annually for each crossing evaluated. An annual report should be compiled for all stream crossings and submitted to the resource agencies. A less frequent reporting schedule may be agreed upon for proven stream crossings. Any stream crossing failures or deficiencies discovered should be reported in the annual cycle and corrected promptly addressed.

Evaluating and Ranking Slope Stability and Chronic Environmental Deficiencies

Washington State DOT Chronic Environmental Deficiencies (CED) Program & Rating to Prioritize Sites

Washington State (WSDOT)'s Unstable Slope Management System helps rate and prioritize problem slopes. WSDOT has also developed a Chronic Environmental Deficiencies (CED) Program with a rating form to prioritize sites. The agency performs detailed inventories of roadside problem areas and other routine roadside vegetation maintenance needs. Corrective action is implemented with secured funding.

WSDOT was the first agency in the United States to fully develop and implement an unstable slope management system (USMS), an internal WSDOT database and application designed for all participants in the unstable slope management process to view and enter data pertaining to their respective job functions. In addition, data from other WSDOT databases such as TARIS (traffic and accident data) can be downloaded automatically into the USMS database, while other information required by other WSDOT databases, such as PATS (Priority Array Tracking System) can be uploaded from the USMS database. WSDOT's system:

- Rationally evaluates all known unstable slopes along WSDOT highway facilities utilizing a numerical rating system for both soil and rock instabilities.
- Develops an unstable slope rank strategy, based on highway functional class that would address highway facilities with the greatest needs.
- Provides for early unstable slope project scoping, conceptual designs for mitigation, and project cost estimates that could be used for cost benefit analysis.
- Prioritizes the design and mitigation of unstable slope projects, statewide, based on the expected benefit.

10.12. Erosion and Sediment Control in Maintenance

Erosion and sediment control is a critical maintenance activity and should not only be considered on previous land-disturbing activities such as road construction, but also on any roadside land-disturbing activity, including slide or flood emergencies. Best management practices are available to effectively treat most yards, facilities, and roadside erosion and sediment problems.

Consequently, maintenance staff should become familiar with their DOT's Erosion and Sediment Control Manual. BMPs are available for perimeter, surface, slope, ditch, channel, and inlet and outlet protection, among others. Revegetation of disturbed or bare areas is the key component to long-term erosion and sediment control and should be used in most instances. Erosion and sediment control measures are used for all areas where maintenance activities involve clearing, grubbing, grading or excavating.

Information on environmental stewardship practice in erosion and sedimentation control and links to selection guidance, drawings, and implementation are included in the Design and Construction chapters; however, some basic environmental stewardship practices for erosion control in maintenance include the following:

- Use temporary vegetation to provide immediate ground cover until permanent landscaping is in place. It is desirable to re-seed and mulch any disturbed areas at the end of the day.
- Other "positive" erosion control measures (such as silt fence , check dam, etc.) should be installed prior to commencing work and left in place and maintained until the site is stabilized
- Areas should be re-vegetated with native seed mixes that require minimal care
- Temporary structural erosion control measures should be installed when cleaning culverts or cleaning ditches that discharge into streams, wetlands, lakes or ponds
- When cleaning ditches, temporary check dams should be used wherever they are necessary and placed so that the crest of the downhill dam is at the same elevation of the toe of the uphill dam.
- Check dams should be left in place until the ditch is re-vegetated.
- Temporary sediment traps should be placed at the inlet of a culvert that drains into a stream, wetland or other water body. Sediment traps should be constructed by excavating an additional 1/3 meter (one foot) below the ditch invert for a distance of six meters (20 feet).
- Temporary turbidity curtains should be placed around culvert outlets in low water velocity situations for additional protection at, or close to, very sensitive sites, such as drinking water supplies, angler parking areas, or swimming facilities. Turbidity curtains should only be installed parallel to the shoreline and should never be placed across streams.
- After the project site is stabilized, any accumulated sediment should be removed before removing check dams or turbidity curtains.
- To improve habitat and reduce erosion, consult with the environmental staff regarding incorporation of appropriate soil bioengineering practices, such as live willow cuttings/ stakes/posts and live willow wattles to stabilize disturbed and/or eroding stream banks.
- Sediment control structures should not be placed in streams
- The smallest practicable work zone is cleared to minimize erosion
- Length and steepness of slopes should be minimized. Place terraces, benches, or ditches at regular intervals on longer slopes.

- Maintain low runoff velocities in channels by lining with vegetation riprap, or using check dams at regular intervals, in addition to minimizing steepness and slow length.
- Trap sediment on-site. Many conventional BMPs are available, in addition to always evolving new ones.

DOT environmental staff, Roadside Managers, or Landscape Architects should be consulted for more detail or if problems arise. Links to existing erosion and sediment control resources and a brief overview of environmental stewardship practice related to erosion and sediment control is included under the section of that name in the Construction Chapter.

Evaluating and Ranking Roadside Erosion Control Problem Areas

PennState's Dirt & Gravel Roads Center System for Identifying and Ranking Erosion Control Problem Areas

Penn State University operates a Dirt & Gravel Roads Center with DOT support. The center has developed a system to identify and rank erosion control problem areas, based on the following criteria:

1. Ranking of road sediment in stream: None, Slight, Moderate, or Severe/Stream Encroachment.
2. Wet site conditions: Dry, Saturated Ditches, Roadside Springs, Flow in Ditches, Saturated Base.
3. Road surface material: Hard Gravel, Mixed Stone, Soft Stone/Dust, Stone/Dirt/Dust, and Severe Dust.
4. Road slope/grade: <10 percent, 10-30 percent, or >30 percent.
5. Road shape: Good, Fair, or Poor.
6. Distance to stream: >100 ft., 50-100 ft., <50 ft. crossing.
7. Slope to stream: <30 percent, 30-60 percent, >60 percent.
8. Outlet to stream: None, Near Stream, Directly into Stream.
9. Outlet bleeder stability: Stable, Moderate, Unstable.
10. Road ditch stability: Stable, Fair, Poor, Unstable.
11. Road bank stability: Stable, Fair, Poor, Unstable.
12. Average canopy cover: Moderate, Minimal, Heavy.

10.13. Recycling in Roadside Maintenance Operations

Use of Compost to Stabilize Steep Slopes and Prevent Erosion and Sediment Control

Research and field trials show that compost works effectively in stabilizing steep slopes, preventing erosion, and fostering germination. Composted organic material stimulates the chemical, physical, and biological characteristics of soil, adding texture and structure in a manner that resists erosion. Unlike many other erosion control best practices, compost can be left in place after construction as a soil amendment.

The absorbency and runoff control benefits of compost are particularly beneficial on steep slopes where the soil is too poor and nonabsorbent for vegetation to become established. Compost can absorb as much as the first 12.7 millimeters (0.5 inches) of a rainfall. Although hydroseeding (spraying a mixture of hay, straw, fiber mulch, water, fertilizer, agricultural lime, grass seed, and tackifier) helps control runoff as well, in some settings this mixture may not be as resistant to erosion as the compost method. Silt fences and straw bales are often used in conjunction with hydroseeding; however, compost berms are as good as or superior to silt fences or straw bales in filtering soil particles from stormwater and can allow more water to absorb into the soil. The compost mixture also stimulates the seeds to germinate more quickly and grow deep roots.

Compost has also proven beneficial to water quality. The EPA has characterized non-point source pollution as the leading cause of contamination in U.S. receiving waters and highways as a major contributor. (*1176*) In response to the issue, some DOTs have begun to pursue use of compost on highway embankments as a best practice in controlling pollutants in runoff from highways and a source of credit in meeting water quality requirements. Compost decreases pollutants by chemically binding substances, such as heavy metals and toxic organics (including hydrocarbons, pesticides, and herbicides), many of which are subsequently disposed of through bioremediation. As such, compost filters can be used to help clean stormwater discharge before it enters receiving waters. A Washington State DOT study on BMPs for stormwater runoff in confined spaces evaluated various filter media having potential for use in filtration vaults found that garden bark, peat moss, sand, and compost are the best filter media for treating stormwater runoff in vaults. These media have acceptable hydraulic properties to pass water through the filters and have good pollutant removal abilities.(*38*)

TTI conducted Research Study 0-1352, *Use of Compost and Shredded Brush on Rights-of-Way*, to determine for TxDOT the potential of compost and shredded brush to serve as erosion-control materials for use in highway rights-of-way. This effort was based on literature reviews and on field performance evaluations on 1:3 slopes and with up to 5-year rain events. The high performance of various compost test plots led TxDOT to include compost on the agency's Approved Material List for Standard Specification Item 169 - Soil Retention Blanket and to conclude the cost savings were likely. TTI reported that research groups in the U.S. and around the world have effectively demonstrated the use of compost as an erosion control measure. In various tests, compost has shown to provide a physical barrier between rainfall and the surface soil, dissipating the effect of impact energy and minimizing erosive forces. To maximize water quality benefits from compost utilization, the Center for Transportation Institute-Texas Transportation Institute, (TTI) of the Texas A&M University System, makes the following observations and recommendations for practitioners: (*1177*)

- High quality, mature compost will provide the most effective results. A low grade, immature or unstable compost can contribute to water contamination by leaching nutrients and/or heavy metals.
- Compost that is relatively dry (40 percent water content or less) effectively binds the elements and reduces leaching.
- A layer of compost can provide foot or vehicle access to slopes previously inaccessible as a result of mud created by heavy rains on clay soils. A layer of compost at the exit of a site will prevent mud from being tracked onto adjacent streets by vehicles leaving a construction site. Effective application thickness is an average of 7.6 cm.

- Application of compost with a moisture content of less than 25 percent will facilitate application and allow for better absorption of water during a storm event.
- A particle size of 19mm was most effective as an erosion control method and as a soil amendment. The larger pieces were less aesthetically acceptable for landscape purposes, and the finer grade was less effective as an erosion control method. Coarser grades are best for steeper slopes.
- Compost can be effectively used on slopes up to 70 percent (35 degrees)
- Extend compost cover for 0.61m to 0.92m above slope to reduce the velocity of flow or possibly construct a berm.
- Consider end use of area to determine which grade of compost will be best suited for the site. An area that will be landscaped may require a finer grade to avoid repeated application of finish grade compost for soil amendment.

The Federal Highway Administration's Eastern Federal Lands Highway Division (EFLHD) tested compost in a very steep environment on a landslide site along the Blue Ridge Parkway near Asheville, NC. To EFLHD's knowledge this project was the first time compost was applied to roadside terrain this steep; parts of the slope exceed a 45-degree angle and installers had to rappel down. EFLHD was operating under a number of other constraints in addition to very tight timeframe. Conventional equipment could not be used on such steep slopes and late May-early June was a sub-optimal season for establishing vegetation. Water quality and protection of artesian springs in the area were also priorities. EFLHD and the National Park Service wanted to establish a green, vegetated slope on the repaired section to prevent excessive runoff, and to prevent the introduction of noxious weeds through topsoil, straw, or hay. Partially installed compost withstood extremely heavy rainfall and shielded seeds during the following two months of drought until re-germination conditions improved. AASHTO's FP-96 Section 713.05 specifications for mature compost were modified to fit the site conditions and meet appropriate compost tests in accordance with USEPA and U.S. Composting Council requirements.(*1178*)

Figure 19: Compost Blanket on Steep Slope on Federal Highway Helped Restore Slide and Re-establish Vegetation Restoration Despite Severe Drought

Composting Deer Carcasses

The New York State DOT (NYSDOT) is addressing its obligation to remove dead animals from roadways and adjacent areas in an innovative and environmentally sound fashion by composting deer carcasses. In fiscal year 2001, NYSDOT responded to almost 25,000 deer mortalities. Notably high rates of deer/vehicle accidents occur in the lower Hudson Valley, where NYSDOT Region 8 reported approximately 8,000 dead deer in fiscal year 2000, even though the Region maintains only about 12 percent of the agency's centerline miles. These disposal challenges have been accompanied by a decrease in the number of rendering companies available to collect and dispose of the carcasses. With growing developmental pressures and more stringent environmental regulations, fewer deer can simply be disposed of in wooded areas. Deer picked up during weekend hours must be kept at a yard site until transfer to a landfill or other disposal option is possible. Multiple handling of the deer carcasses causes additional hours of labor and adds to the disposal cost of deer. Moreover, deer that are stored at a yard for more than 12 hours start decomposing, making rehandling highly unpleasant for workers.

NYSDOT examined farm practices of composting of livestock mortalities with woodchips or sawdust. While decomposition is slow via a typical pit burial, total body decomposition can be achieved by composting within a few months. The compost end product, once deemed safe, has potential re-use within the highway environment. NYSDOT and the NYSDEC developed the Guidelines and basic steps to achieve optimal results and ensure human health and environmental protection. This example is noted as the Deer Carcass Composting – Practice Guidelines in the Appendix.(*1179*)

Recycling and Reducing Waste/Emission

Herbicide reduction practices and examples are included in the vegetation management section. Reduced salt and sand usage practices and accomplishments are discussed in the section on Winter Operations.

Mass Highway's Pollution Prevention Program for Construction and Maintenance

For the past several years, Mass Highway has undertaken efforts to prevent pollution through conservation and reduction programs relating to construction projects as well as operation of maintenance facilities. Mass Highway maintains a number of pollution prevention initiatives relative to air, energy, water, and solid waste and toxics reduction.

Table 17: Mass Highway Pollution Prevention Initiatives by Media

Media	Initiatives
Air Pollution Prevention	Fleet inspections to ensure vehicle emissions compliance; garage location consolidations to reduce overall fume emissions; and installation of vapor recovery systems for underground storage tanks.
Energy Conservation	Installation of high efficiency lighting systems.
Sold Waste Source Reduction	Waste reductions have been realized through the expanded use of recycled and re-manufactured products including the construction of salt sheds composed of 50 percent recycled plastic aggregate.
Water Conservation and Pollution Prevention	Installation of vehicle washwater recycling units at several maintenance facilities.
Toxics Use Reduction	The Pollution Prevention Task Force has prepared technical evaluations of products and made recommendations for reduction of the following substances: petroleum-based hydraulic and lubricating oils; automotive parts cleaning solvents and associated cleaning systems; perchlorethylene cleaning solvent and miscellaneous automotive lube/cleaning products. In response to these recommendations, the Department: switched to non-chlorinated solvent brake cleaner; eliminated solvent parts cleaner tanks in some districts, and; reduced automotive fluid use through the leasing and out-servicing of fleet vehicles.

Mass Highway is continuing to identify, evaluate and implement pollution prevention initiatives. Pollution prevention opportunities and activities under current consideration include:

- Eliminating solvent parts cleaners statewide.
- Upgrading maintenance garages to include state-of-the-art automated oil dispensing and quick drain capabilities.
- Use of vegetable-based diesel fuels to reduce heavy equipment air emissions.
- Purchasing low volume high pressure washers for vehicle/equipment cleaning to reduce water use.
- Purchasing aqueous brake cleaning systems to eliminate all brake solvent use and eliminate asbestos dust hazards.
- Use of vegetable based hydraulic oil.
- Use of neutral pH, non-oil emulsifying vehicle degreasing/washing detergents to eliminate caustic detergents and improve effectiveness of oil/water separators.
- Identifying specific areas within a given project for experimental or full usage of new products comprised of solid waste materials.
- Developing specifications and special provisions for incorporating recycled materials into construction projects.
- Developing and tracking test applications of recycled products and materials to document product effectiveness relative to standards for highway performance and environmental acceptability.
- Investigating and implement economically viable opportunities to reuse and recycle solid and hazardous waste generated by routine operations such as waste oil, street sweepings, catch basin cleanings, tires, construction and demolition debris, special waste, scrap metal and wood waste.
- Active participation of the Research Needs Committee to identify potential programming and funding opportunities; provide input of needed material reuse and recycling research efforts and to keep up to date on new recycling and reuse technologies, regulations and activities successfully utilized by industry and other state transportation departments. working with state agencies and other organizations to develop training and educational workshops on the use of recycled materials.
- Actively participating with state and federal regulatory agencies on Beneficial Reuse policies.

Mass Highway also initiated a Pollution Prevention Task Force (PPTF) as part of the Environmental Management System Implementation Plan to reduce risk and improve the overall environmental quality at Department facilities through toxic use reduction. The PPTF is comprised of District HazMat Coordinators and other Environmental personnel who cooperate with District Operations personnel in leading pollution prevention efforts for maintenance facilities.

Mass Highway prepares an annual recycling report to meet the requirements of the Commonwealth of Massachusetts' 2000 Transportation Bond Bill (Chapter 235 of the Acts of 2000) and define Mass Highway's accomplishments in terms of recycling, environmentally preferable procurement, and pollution prevention; to discuss and promote ongoing projects; and to establish goals for the coming years. (*1180*) In 2000, Mass Highway recycled more than 15,000 tons of waste and used more than 111,000 tons of recycled materials in construction projects. The agency spent nearly $27 million on recycled-content and environmentally preferable materials and products, considered an economic boon for the state. In 2000, Mass Highway attained an overall recycling rate of 76 percent by recycling more than 15,000 tons of its own waste stream, a 10 percent increase over the previous year and more than double that accomplished by municipalities. Waste materials recycled include antifreeze, construction and demolition debris, street sweepings, and tires.

The majority of MHD's waste stream is composed of materials collected from the State's highways and stored at its depots. This includes everything from street sweepings, to construction and demolition debris (C&D), to tires. After being transported to MHD's depots these materials are segregated for future reuse, disposal, or recycling. Segregation ensures greater recyclability and less processing of these materials by reducing contamination. The most prevalent (and problematic) materials collected by MHD are street sweepings, C&D debris, and catch basin cleanings. Materials such as asphalt, brick, and concrete (ABC), and scrap metal have significant value and well-developed markets and are easier to recycle. In 2000, nearly 16,000 tons of waste materials including ABC, C&D, scrap metal, street sweepings, wood, and yard wastes & leaves were collected and stored at MHD depots. Close to 15,000 tons of these materials were recycled. Over 90 percent of the over 300 tons of automotive related waste products created at MHD depots is recycled. Office wastes created by MHD's six offices are typical and include paper, paper products, and toner cartridges. Mass Highway counted 15.75 tons of paper recycled, reaping energy savings of 161 million BTU's or emissions savings of 12 tons of carbon dioxide.

Mass Highway tracks agency performance by the percentage recycled in different waste type categories: (*1181*)

Table 18: Mass Highway Waste Material Disposal & Recycling Rates

Waste Type	Amount Disposed (Tons)	Amount Recycled (Tons)	Percentage Recycled
Automotive Wastes			
Antifreeze	0.00	3.24	100.0%
Batteries	0.00	2.00	100.0%
Filters	2.65	3.26	55.2%
Gasoline	0.48	1.69	77.9%
Oil	0.00	21.90	100.0%
Tires	0.00	259.07	100.0%
Other	27.85	5.08	15.4%
Containers			
Aluminum Cans	0.06	0.85	93.4%
Steel Drums	0.25	6.30	96.2%

Fixtures			
Alkaline Batteries	0.00	0.03	100.0%
Ballasts	0.00	0.26	100.0%
Flourescent Bulbs	0.00	1.20	100.0%
Surplus Paints	2.18	2.40	52.5%
Office Waste			
Cardboard	0.50	0.50	50.0%
Magazines & Newspapers	0.00	3.45	100.0%
Paper	6.35	15.75	71.3%
Toner Cartridges	0.00	0.56	100.0%
Operations Wastes			
Absorbents	1.40	0.00	0.0%
ABC Debris	0.00	1597.37	100.0%
Catchbasin Cleanings	650.00	0.00	0.0%
C&D Debris	497.24	2031.50	80.3%
Clean Wood	20.00	1028.57	98.1%
Scrap Metal	0.00	303.57	100.0%
Street Sweepings	100.00	9664.06	99.0%
Treated Wood	16.00	113.19	87.6%
Trash	3535.80		
Total	**4860.76**	**15065.80**	**75.6%**

10.14. Preserving Air Quality in Maintenance and Operations

Ozone Action Days

DOTs are beginning to partner with other state agencies and metropolitan regions to reduce ozone on red alert days and as part of larger partnership efforts. For example, New York State DOT partners with New York City and the New York Metropolitan Transportation Council to implement a coordinated regional clean air awareness program. Within the agency, NYSDOT works to reduce air quality effects from transportation by disseminating warnings of forecasted unhealthful ground level ozone conditions to a network of NYSDOT regional offices, local agencies, and interested parties. The warnings, along with recommended transportation actions to reduce emissions, are broadcasted to affected areas of the state. The information is transmitted electronically and by telephone and fax. Designated contacts at each receiving location then implement their action plans. New York agencies participating in this Ozone Action Days program deliver the alert information to the public through such means as variable message signs on highways, bridges, and tunnels; and the dissemination of the warnings to area employers and the media.(*1182*)

Flex-time programs

Some DOTs have implemented flex time programs to contribute to the alleviation of congestion, air pollution, and ozone formation. DOTs have also provided shuttle services at the noon hour to help workers avoid having to drive to lunch.

Delaying or Rescheduling Ground Maintenance

A number of DOTs, including Georgia, New Jersey, and New York State, are delaying or rescheduling ground maintenance activities that require gasoline powered equipment such as mowers, blowers, weed-eaters, chain saws, etc. In some cases use of off-road construction equipment is delayed until after 6 p.m. as well.

Restricting or Limiting Painting

Georgia DOT is exploring restricting and/or limiting indoor and outdoor painting on Action days until after 6 PM or not at all on these days. New Jersey DOT also defers spraying and painting on Ozone Action Days. (*1183*)

The Virginia DOT examined episodic limits on asphalt paving and traffic marking activities, in particular prohibiting road paving and traffic marking on ozone action days; however, the benefits from the possible control measures did not meet the NOx or VOC threshold necessary for implementation as a regional air quality control measure in Virginia.   Asphalt paving has been found to have *de minimis* emissions; however reductions in traffic marking have been implemented by Maryland DOT and Montgomery County on Ozone Action Days.(*1184*)

Regular Vehicle Maintenance and Tune-Ups

Most DOTs have programs to perform regular maintenance and tune-ups. Changing the oil and checking tire inflation can improve gas mileage, extend vehicle life, and reduce air pollution.

Wisconsin DOT operates a very effective inspection/maintenance (I/M) program. In 2002, WisDOT produced a report reviews the status of existing I/M programs in the United States and I/M research being performed by other states. The report also reviews the status of current I/M technology, including second generation onboard diagnostics (OBDII) testing, identification of liquid gasoline leakers, particulate/diesel emissions control program, remote sensing programs, toxic emission control programs, supplemental federal test procedure, and EPA activities related to I/M programs. The study concluded that additional research is needed to better define future I/M requirements. Key recommendations included the need for a malfunction indicator lamp response study, evaluation of stand-alone alternatives to centralized OBDII inspection, a determination on how to find vehicles with liquid leaks and other gross evaporative emission problems, and assessing the need for tailpipe tests on high mileage OBDII equipped vehicles. (*1185*)

Alternate Fuel Vehicles and Refuelling Stations

Some DOTs have been facilitating reduction in air pollution through the use of alternative fuel vehicles. The Colorado DOT has purchased electric bicycles for environmental staff at the District 6 office. Other DOTs and many municipalities have purchased cars and trucks powered by natural gas, hybrid, E85 (ethanol), and electricity.

The Central New York Regional Transportation Authority with the support of the United States Department of Transportation and the New York State Department of Transportation has been a leader in the testing and implementation of compressed natural gas as an alternative vehicle fuel. With a growing fleet of compressed natural gas busses, the agency needed a refueling station. Through interagency cooperation, public-private partnerships, and proactive public involvement, the team utilized Congestion Mitigation and Air Quality Improvement Program funding sources to build an indoor state-of-the-art compressed natural gas refueling facility. The project also included a public compressed natural gas fueling station, which has encouraged more widespread public and private vehicle fleet conversion to compressed natural gas in the greater Syracuse-Onondaga County area. The refueling station has provided many benefits to the surrounding communities by reducing air pollutants from mobile sources and has helped to improve the region's air quality by minimizing congestion and providing the added benefit of public transportation.(*1186*)

Night Refueling and "Don't Top off the Tank" Policies

To reduce release of gas fumes in the air, some DOTs have encouraged employees to stop short of a full tank to reduce pollution. Refueling at night can also prevent gas fumes from heating up and creating ozone. Georgia DOT is among those implementing this approach.(*1187*)

Truck Stop Electrification

The Congestion Mitigation and Air Quality (CMAQ) program supports improvements pertaining to operations. In 2003, FHWA provided issued expanded guidance and provided more information on the eligibility of truck stop electrification (TSE) and other idle-reduction measures under the CMAQ program. The guidance documents and other reference materials about the CMAQ program can be found online. The guidance notes that long-duration idling related to freight movement has become the norm for business operation at highway truck stops, airports, and at intermodal transfer points, emitting pollutants, consuming fuel, producing noise, and increasing maintenance costs. USDOT and EPA DOT and EPA have formed a partnership to work with State transportation and environmental agencies, and MPOs to accelerate the implementation of TSE projects on routes heavily traveled by long-haul trucks, to identify appropriate locations and assist in jointly funding projects. CMAQ funded TSE projects must occur in close proximity to and primarily benefit a nonattainment or maintenance area and be included in a conforming transportation plan and TIP. Further information on alternatives to idling can be found at the CMAQ website.

Atmospheric Dispersion of Deicing Salt Applied To Roads

The Illinois Department of Transportation funded a study to understand and describe the atmospheric transport of road salt in the form of sodium chloride (NaCl) applied to highways as a deicing material, focusing on interstates in the Chicago area. Results from chemical analysis of aerosol and snow samples are reported that show progress toward characterizing the road salt aerosol with respect to its size, mechanisms of emission, range of atmospheric transport, and mechanisms of deposition. Analysis of the preliminary data suggest: (*1188*)

- A large portion of the salt aerosol that becomes aerosolized is emitted after the road surface has been cleared of snow and ice.
- Approximately 90 percent of the airborne road salt is contained in aerosol particles of diameter larger than 2.5 micrometers (μm) or 10^{-4} inches.

- The salt deposition pattern near a treated roadway as determined by snow samples decreases consistently with distance from the road. Average deposition values for a single snow event were found here to yield an aerial deposition of 0.06 grams per square meter (0.6 pounds per acre) at 500 meters (1,640 feet) from the road. The corresponding value for the total deposition per length of roadway is 85 grams per meter or g/m (300 pounds per mile or lb/mi).

Based on evidence from aerosol and snow sampling, the most important emission process is erosion of dried salt material from the roadway followed by dry deposition of the aerosolized salt material. A predictive atmospheric loading model is scheduled for completion in the last half of 2004. No practices to minimize atmospheric deposition from deicing salt are being recommended based on research to date.(*1189*)

Open Burning

Open burning can produce hazardous contaminants, unreasonable smoky conditions, additional fire hazards, and unsafe driving conditions. In areas where open burning is regulated, such as cities, counties, state or federal lands (USFS-BLM), or where air quality standards are in effect, a burning permit is required and burning often will be allowed (if at all) only under very restrictive conditions.

Every attempt should be made to remove and dispose of flammable materials in approved locations such as landfills. Brush and small trees can be chipped and blown back on the right-of-way or hauled away and stored for later use as erosion control mulch. Brush mowing may be another alternative to consider, if practicable.

If it is determined that burning is the best or only suitable method of disposal, it should be done with all due caution, traffic control, and strict adherence to all applicable rules and regulations.

10.15. PAINTING OPERATION STORMWATER BMPS

Environmental stewardship practices for painting operations minimize exposure of paints and solvents to stormwater run-on and runoff. These Caltrans recommended practices safeguard against the accidental release of painting materials into storm drainage systems and natural watercourses.(*1190*)

Following these storage practices will reduce the exposure of paints and supplies to stormwater run-on and runoff at maintenance facilities:

- Where feasible, store paint materials in an area with a canopy or roof designed to direct runoff away from the storage area.
- Check for leaking or ruptured paint containers.

Careful transport of painting material to and from the work site helps to prevent accidental spills:

- Load and unload paint on level ground when using a forklift to minimize the chance of tip-overs and potential spills.
- Ensure that all paint pallets are securely fastened before moving.
- Secure the paint containers to the transport vehicle using approved methods such as ropes and straps.

- Transport paint and materials to and from work sites in containers with positive locking lids.
- Do not transfer or load paint over or near drain inlets, stormwater drainage systems, or watercourses.

Proper application practices inhibit paint chips and excess paint drift from being transported to storm drainage systems or watercourses by wind or other means. See the section on Bridge Painting for more detailed environmental stewardship practice.

- Monitor weather and wind direction to ensure that paint drift is minimized and does not enter drain inlets, stormwater drainage systems, or watercourses.
- If possible, use canvas or plastic tarps under the work area to capture excess paint or paint chips.
- To avoid spills, follow proper operational procedures for lane striping and paint applications.
- Ensure that the paint spray gun remains closed when not in use to prevent leaks.

Thorough cleanup and disposal practices ensure that paint-related hazardous materials are handled properly.

- Do not clean out the paint spray gun over the ground.
- Wipe up small paint spills immediately with rags. For larger spills, use dry absorbent material.
- Collect all excess material and paint wash solutions in appropriate containers. Secure all containers and transport to a Maintenance facility for proper disposal.
- Dispose of used absorbent and rags, and empty paint and solvent containers in appropriate containers at a Maintenance facility that has approved storage areas.
- Special procedures may be required when removing yellow stripes.
- Follow proper waste disposal procedures. Dispose of hazardous waste according to regulations. Contact the District Maintenance HazMat Manager or refer to the Maintenance Hazardous Waste Manual for more information and guidance.

10.16. Road Waste Management

DOT road maintenance activities generate large amounts of dirt, litter, or roadwaste debris from sweeping roadway surfaces, picking up litter, clearing vegetation, cleaning highway drainage systems, and clearing landslides from roadways. Roadwaste materials generally share the same contaminants of concern – bacteria, litter, sharps (glass, needles, etc.), chemicals from spills or illegal dumping, gasoline, oil, heavy metals.

In the past DOTs sometimes stockpiled or disposed much of this roadwaste at maintenance yards, back lots, or along highway right-of-way; however, these options are less viable with growing amounts of waste material, increasing highway traffic and pollution, less available land, and stricter environmental regulations. Managing DOT roadwaste using conventional methods calls for solid waste to go to landfills and liquid waste to sewage treatment plants. Just separating roadwaste into liquid and solid portions using conventional methodologies can be extremely difficult and expensive. Waste is often required to undergo expensive testing or sorting prior to disposal. Likewise disposal of all DOT solid waste in landfills can be impractical, inefficient and cost prohibitive. Landfills and sewerage hookups are not readily available for DOT roadwaste disposal in many areas.

Many roadwaste pollutants are easily detectable. Litter and trash in roadwaste piles can be detected visually. Many chemical pollutants can be detected as odd colors, stains, discoloration, or chemical smells. Other times pollutants can only be detected through chemical testing, or in the case of knowing oil or grease is present, it may still take laboratory testing to determine if levels are toxic. Heavy metals detection requires laboratory testing. Determining risk is key to knowing disposal options. If waste is full of trash, smells of oil and gasoline, it has a high toxic risk and reuse options are limited; hauling waste to a high-risk waste dump can be the quickest option. Trash may be able to be screened from medium risk waste and stored in an appropriate spot while toxic hydrocarbons (present from gasoline or oil contamination) break down. Later, such material may be appropriate for shoulder repair or patching holes under proper circumstances. Some roadwaste, such as landslide debris, has no (or low) toxic risk and can be used as clean fill. With clean waste, the main issue is finding an environmentally appropriate location for final placement where it will not erode or impact a wetland.(*1191*)

ODOT undertook a Roadwaste Research Project in conjunction with the Oregon Department of Environmental Quality and various agencies concerned with highway operations to identify more efficient and effective ways to manage roadwaste materials. The first phase was a literature review, which identified current roadwaste issues and problems across the country and summarized the most effective methods yet developed to manage this special waste stream. Phase 1 findings were documented in the report "Roadwaste: Issues and Options" (*1192*). The second phase of the project pursued some of the more promising roadwaste management methods identified in Phase 1, with implementation and testing in the field. ODOT worked with local highway agencies in the Portland area to develop methods that would efficiently reuse or dispose of roadwaste generated from local urban roads. Field trials were conducted to collect data on pollutant levels associated with various roadwastes and disposal methods. Phase 2 findings were documented in ODOT Roadwaste Field Trials.(*1193*) The Roadwaste Management Report summarized the findings of the research project and offered recommendations on how ODOT Districts can use this information to better manage roadwaste materials. The major findings of ODOT's Roadwaste Project can be summarized as follows:

- Roadwaste covers a broad range of materials with a broad range of environmental risks. Roadwaste pollutant levels reflect highway traffic counts and surrounding land uses. Levels of pollutants and trash found in roadwaste will vary widely.
- Some roadwaste is entirely free of contamination and can be managed as clean fill. Managing roadwaste efficiently and saving on disposal costs relies upon knowing when the waste is dirty, when it is clean, and when it is mildly contaminated. Roadwaste does not classify as a "hazardous waste" (except for the very rare spill or illegal dumping incident).
- Knowing the characteristics and volumes of the waste a District collects helps in the selection of management methods that most efficiently address actual environmental risk.
- Identifying and separating differing roadwastes allows more ready management while requiring less frequent analysis. District-level baseline waste characterizations help identify the most appropriate management methods to address actual risks.

- Roadwaste must be properly managed to address environmental risk. Storing low risk roadwastes separate from more contaminated or trashy waste makes reuse easier and will help control management costs. Ready reuse is available for some materials; other materials require simple treatment. More contaminated materials may require a significant investment in treatment or ongoing tracking unless a conservative management option is selected; e.g., disposal in a permitted landfill. Complying with waste recommendations when nonhazardous wastes are mixed with hazardous wastes costs additional maintenance dollars.
- Partnering with local agencies will save resources, and risks are minimal.
- Efficient management of DOT roadwaste will require District level planning.

ODOT's Roadwaste Management Flowchart offers a planning process that can be used to manage the roadwastes that ODOT collects and environmental risks associated with them. Finally, it presents specific waste treatment and disposal options and discusses sorting, reuse, and recycling options.(*1194*)

Stormwater System Residuals and "Vactor Waste:" Catch Basin, Sump and Line Cleanout

On average, vactor waste is the most contaminated type of roadwaste with the highest environmental risk. "Vactor waste" is so named after a brand of eductor truck commonly used to vacuum out catch basins, sumps and storm sewer lines. Certain factors generally increase the risk of toxic contamination. Generally, the more silts or fine particles present, the higher the chance of contamination. Dead-end sumps will be more contaminated than catch basins, since catch basins let a lot of fine material pass through them. The higher the traffic count or average daily traffic (ADT), the higher the contamination levels. Wastes from more frequently cleaned sumps (or catch basins) can be expected to be cleaner.

Because vactor waste contains water, there is an increased risk for runoff and ground infiltration. Infiltration of contaminated water through porous gravel, sand, and fractured bedrock may threaten groundwater. Without contact of oxygen and sunlight, contaminants do not readily degrade. The fine particles in vactor waste are easily suspended in runoff and can dramatically impact stream health – both immediately and in the long term. Fines can carry high levels of contaminants and themselves pose threats, e.g., clogging fish gills and burying spawning beds. This wastewater requires special management and cannot be returned to the storm drain system or disposed on land without a water quality permit from the state environmental agency or EPA.

Basic environmental practices for dealing with vactor waste are outlined in Appendix B of ODOT's report:

- Liquid fractions may not be disposed back into stormwater catch basins or collection systems that discharge to surface waters, wetlands, or the subsurface unless. Instead, these liquids should be disposed, after approval is obtained, to a sanitary sewer.
- Sanitary sewers may require placement of vactor truck decant water only into high flow sewers or only after 24 hours to settle out the suspended solids.
- Where sanitary sewers are not available, the DOT hazardous materials section may identify DOT-owned areas where public access is limited for field decanting of vactor solids or liquids under a state permit. Sites for land application of decant water should be

free of runoff concerns and able to hold petroleum contaminants in the top layer of soil to insure the best chance for treatment, with controls preventing public access. Overuse should be avoided to prevent build up of contaminants.

- Vactor solids tend to be more contaminated than liquids. Being harder to screen for trash and with less ready reuse options, vactor solids are a good candidate for disposal at a permitted landfill. An agreement to provide this material for use as landfill daily cover can substantially reduce disposal costs. All waste disposed at permitted landfills must be dry enough to pass the "paint filter test" and may face other requirements.
- Some local agencies have invested in dewatering facilities and may be open to partnering.

Vac waste from bridge culvert cleanout normally produces rock and trash and very little fine material. Bridge scuppers will capture only well-washed rock and gravels. Since these wastes pose no real risk, they do not need to be tested. Free from trash, they are ready for immediate reuse. Clean, well-washed rock in the maintenance of other stormwater facilities can also be reused. Other vactor cleanout waste in the District might have unique characteristics and deserve separate management under its own category.

Road and Roadside Dirt and Debris

Sweeper trucks remove dirt and debris from the highway system. Contaminant concentrations in sweepings are usually lower than those found in vactor waste, but even relatively clean sweepings can contain toxins and require careful management. The risks posed by these materials are similar to vactor wastes. Wastewater collected with wet road materials has many of the same concerns as vactor truck wastewater. Sweeper loads full of fallen leaves and other organic materials may be better managed by composting than by classic waste disposal.

The City of Portland separates street debris into heavy sand and light debris. Until 1988 sweeper debris was disposed of in general purpose landfills. By 1988 landfill space was diminishing and disposal rates jumped from $16.50 to $42.25 per ton. The rate is now $75 per ton. Sand, 20 percent of the volume but 80 percent of the weight of the debris, could be disposed of for free as cover materials. Separating sand from organic material saved the Bureau approximately $675,000 the first year.(*1195*)

Basic environmental practices for dealing with sweeping dirt and debris are outlined in Appendix B of ODOT's report:

- Screen regular sweepings, disposing trash and litter only at DEQ-permitted landfills.
- Store materials such that rainfall will not cause any runoff. (Contaminated runoff could impact other areas on site, wetlands, or surface waters.) Store sweepings to minimize the potential for site impacts from roadwaste contaminants. Storage on an impermeable surface with leachate collection and/or protection from rainfall is preferable. Tarps may be used for cover, or berms or retention ponds may be used to contain runoff.
- Winter road sand may be collected and reused once screened and sized. If sand washing is required to remove excess fines, minimize site impacts, collect the fine particles, and prevent runoff. (Pretreatment by settling or flocculation then permitted discharge to sanitary sewer is a sound practice).
- Most roadwaste is very poor fill, tending to have poor compaction ratings, and reduces in volume substantially as organic matter decomposes.

- Storage, processing and reuse of materials other than road sand and clean fill may require a state solid waste permit. Composting over 25 tons per year usually requires a site-specific permit.
- Screened materials collected from areas known to have low impacts from roadwaste contaminants may be screened for trash and used as poor grade fill in DOT-owned and controlled areas. During storage and processing, fines should not be allowed to become airborne.
- Sidecasting of minimally contaminated sweepings onto non-ditched shoulders can be appropriate if these roadsides are not adjacent to surface waters, wetlands, or stormwater management systems with discharge to surface waters, wetlands or the subsurface.

Winter Road Sand

Quick pick up of winter road sand on urban streets can reduce toxic pollutants and result in net direct cost savings. Many DOTs and local governments have road sweeping programs to reduce air and water pollution. Pollution reduction benefits have been quantified in a few cases. A 2002 WisDOT/FHWA/USGS study evaluated the effectiveness of an improved highway sweeping program using a high efficiency sweeper as a best management practice (BMP) for reducing pollutants in urban highway stormwater runoff, believed to be the most complete attempt to date to document the use of a high efficiency sweeper program on an urban freeway section. Based on data collected and analyzed during the study, it was calculated that a once per week freeway sweeping program using a high efficiency can be an effective stormwater runoff best management practice (BMP) for an urban freeway section. WisDOT subsequently developed guidelines for the purchase and use of high efficiency sweepers.(*1196*)

Road sand quickly removed from roads after a thaw may be ready for reuse as is, or it may require a screening step to remove trash and/or to drop out the more contaminated and less useful fines. The recycled sand replaces new product that would otherwise have to be purchased, and recycling results in less waste to manage. Use of anti-icing and de-icing agents may reduce the need for road sand application.

Ditching Spoils and Sediment Pond Cleanout

Contaminant levels in ditching spoils will vary widely, depending on cleaning methods, water flow, traffic count, and surrounding land use. ODOT found that spoils collected from ditches draining high ADT roads in urban areas had contaminant levels as high as those found in vactor wastes, while ditchings from some rural areas tested completely clean. More rarely, rural ditch material had tested at high levels for heavy oils or other contaminants. ODOT manages rural ditchings from low-ADT roads as clean fill in most cases.

Roadway sediment ponds detain roadway runoff, dropping out contaminated fines. The spill containment attributes of sediment ponds may require testing for a broader range of constituents. Limited contaminant data on ODOT Interstate 84 sediment cleanout showed levels similar to catch basin and sump waste, in very similar material.

Landscape Cuttings: Greenwaste

DOTs can collect high volumes of organic matter during road projects or as a result of slides. In the fall, leaves can accumulate on roadways and in right-of-ways. Taken together, waste organic materials are termed “greenwaste.” As buried organic matter can release toxic nitrates to groundwater, burial is not usually permitted. In addition, as vegetative matter decomposes it reduces significantly in volume, resulting in major settling issues on the ground surface – a problem shared to a lesser degree with sweepings and vactor wastes. Composting is the best alternative for clean greenwaste. Compost can be made on a district basis or hauled to a commercial composter if greenwaste volumes are low. See composting section.

Construction Site Soils and Slide Debris

Slide debris and construction site soils and slurries not impacted by road oils or heavy organic loads should be managed as clean fill. Greenwaste should be removed for composting. Care should be taken in storage and placement of these materials. In the Appendix is an example of generated waste from Oregon DOT.(*72*)

Disposal and Re-use Options

As transportation agencies, DOTs are required to accept long-term liability for the wastes it collects from highway maintenance. Only in cases such as a reported spill incident can the responsibility for waste management be placed on another party. Liability for environmental impacts from the wastes ODOT collects is unending; it is "cradle to grave." The challenge is to substantially limit risk and liability while not incurring undue cost. Reuse and disposal are the two major choices for managing roadwaste solids.

Re-use of Roadwaste

The key to reuse is viewing roadwaste as something of value rather than as something to discard – as a potential product rather than a waste, in which case stringent waste management regulations may not apply. Rather than paying tipping fees for disposal, the product is used to replace materials the DOT might otherwise need to purchase. Reuse also reduces the burden on expensive and difficult-to-site landfills. For a reuse option to work, it must protect human health and the environment while reducing total cost for managing the waste. Disposal of solid waste requires a permit. Only clean soil materials, weathered asphalt and concrete can be used as fill material without first obtaining a permit. Long-term storage, such as stockpiling, will be seen as disposal unless it can be shown to state and local environmental agencies that treatment or storage for eventual legitimate reuse is occurring. Routine screening for trash in loads may facilitate this.

Ready Reuse Options can include clean fill, winter road sand reuse, and managing gravel and rock. Besides screening for trash and keeping an eye out for impacts from spills and releases, no treatment or tracking of these clean materials is necessary. More specific reuse options may include: rock fall berms and noise barriers, use as soil amendment (freeway infields/median or agricultural use), poor grade utility trench fill, highway shoulder repair, and asphalt or cement or pre-fab concrete manufacture.

Untreated roadwaste has poor drainage characteristics and a poor compaction rating. Sweepings, vac wastes, etc. have a high organic component that will decompose, leading to settling, sinkholes and cracking. Thus untreated reuse of these materials is not recommended as construction site fill, or under roads or parking lots. High temperature thermal treatment, which burns off the organic materials along with the contaminants, can make fill options workable.

Berm or Noise Barrier Construction

Marginally contaminated roadwaste might be suitable for use as berm material. ODOT Region 1, District 2B, constructed a berm of roadwaste and landslide debris at the base of Rocky Butte in the City of Portland to prevent rock fall from reaching the I-205 freeway (Figure 13.1). Runoff from this area is contained and infiltrates into the ground through a level grassy area. There is no ready access for human contact. Sampling shows contaminant levels in the berm to be well below industrial cleanup thresholds. The berm and berm water runoff have been routinely sampled to assess contamination risks and to monitor the natural bio-degradation of petroleum contaminants.

Recommended practices:

- Remove trash. Solid waste rules require that trash be removed prior to legitimate reuse.
- Limit public access. Place barriers on ODOT-controlled property, so it is inaccessible to foot traffic.
- Contain or treat stormwater runoff. Monitor for pollutants to insure they do not escape into runoff or into accessible areas of the property.
- Limit contaminant levels to below state industrial cleanup thresholds.
- Mixture with uncontaminated materials will reduce contaminant concentration. Roadwaste testing below the industrial cleanup standard might be mixed with clean fill or clean slide debris to reduce site contamination risks. Clean material can also be used to cap and contain material with low but significant contaminant concentrations. Any mixture of clean materials with contaminated materials, however, runs the risk of creating more contaminated materials.
- Plant and/or mulch berms. Limit erosion and control dust.
- Encourage biological treatment of contaminants with open air and plantings. You may also choose plants to enhance on-site phytoremediation.

The risk associated with using roadwaste for berms is low to moderate. With restricted public contact and controlled stormwater runoff, risk is dependent on contaminant concentration, site and soil characteristics, and future site use. Long-term tracking and monitoring of reuse sites is appropriate. DOT regional environmental representatives or a specialist from the state environmental agency can help assess proper placement and long term management of these berms.

Use as Soil Amendment

Use of roadwaste as soil amendment reduces costs substantially, and can even offset costs of purchasing new product. Risk can be effectively controlled by choice in placement. Most roadwaste has decent drainage characteristics, plentiful nutrients, and good water retention, with a good mix of particle sizes appropriate as an effective growing media. After the usual screening for trash, limited use of roadwaste as a soil amendment may be quite feasible if placement of contaminated material is carefully considered. Washington DOT (WSDOT) mixes vac waste with wood chips for an effective growing medium and uses it in freeway infields and medians. The wood, serving to improve the growing media, also fixes metals and petroleum compounds.

Recommended practices include the following:

- To pursue reuse of roadwaste as a soil amendment, it is necessary to know the characteristics of the material. Placement of a product that would result in surface concentrations above industrial cleanup levels would prevent reuse.
- When allowing reuse of untreated roadwaste on land out of DOT control, a contract with the landowner is recommended, limiting placement to cropland, with a significant setback from any water conveyance, state water, or wetland. A simple site review by qualified staff is recommended. Any material released should be at most only marginally contaminated, i.e. having a baseline waste characterization below industrial cleanup standards.
- Place the product where risk of exposure is very low and risk of transport is minimized. With runoff issues controlled during placement and good vegetative cover, the problem becomes long-term tracking. Drying the vac sludge is not essential, as plantings do require moisture.
- Track placement and conduct regular tests to track contaminants.
- Take care to place the waste mixture over existing soil or clay, not over quickly draining sand or gravels.
- Simple treatment by aeration has been observed to substantially reduce petroleum concentrations. The expected reduction of simple compounds prior to reuse will limit risk of transport. Heavier and harder-to-treat compounds are less mobile. To encourage further aeration and reduce chance for movement to the subsurface, placement should be limited to within two feet of ground surface. In addition, limit placement to areas with little or no chance of human exposure.

Poor Grade Utility Trench Fill

Massachusetts allows use of sweepings as poor grade utility fill. They term it “poor grade fill” because it has a poor compaction rating, quickly loses volume, has poor drainage characteristics for use as fill, and is marginally contaminated. Still, use as fill over utility lines is workable and can be protective. Mass Highway does note that the trench must be mounded up to allow for a substantial volume reduction in the fill material; otherwise, the utility line will start to look like a shallow ditch and will accumulate runoff. Mass Highway does not allow reuse of catch basin vac waste as fill, judging it to be too contaminated. Given the known problems with use of roadwaste under paved surfaces, placement is only recommended under open ground. What makes this option work well is that the material is not placed in concentration, so overall site impacts are not likely.

Limited reuse as poor grade utility fill away from ready human contact should not present significant risks.

- The use should be limited to commercial or industrial properties and agency-controlled, limited access areas.
- An uncontaminated soil trench cap can further limit potential exposure. Tracking placement of materials below industrial cleanup levels or on ODOT-controlled, limited access areas should not be necessary.
- With a baseline contamination level established for vac waste, a DOT may be able to reuse waste as poor grade utility fill.

- Be careful to not stockpile roadwaste for reuses that may never materialize; this reuse may be more appropriate for public works agencies with greater need for utility trench fill.
- Screening for trash will likely be required prior to reuse.

Highway Shoulder Repair

As sweepings or vactor waste can substantially reduce in volume with time, use of these materials as highway shoulder fill can result in soft shoulder problems in the future. Furthermore, since most highway shoulders drop off into ditches, water quality issues may also limit reuse of sweepings and vactor waste in many locations. Potential for public access is another issue limiting use of more highly contaminated materials. It is important to limit material used for highway shoulder repair to relatively clean materials with good compaction ratings.

Asphalt, Cement or Pre-fab Concrete Manufacture

Asphalt and cement manufacturers can use fines or sand-sized feedstock from a variety of sources though materials with any significant organic matter content must be avoided. Asphalt plants need dry materials free of trash and they can use petroleum-contaminated soils. Cement manufacturers process their feedstock in a kiln, creating sand-sized particles for cement production. Cement kilns operate at extremely high temperatures; any organic matter present burns and as such adds fuel to the fire, which can create serious upset conditions if not anticipated. Cement kilns need to know the percent of organic matter present in their feedstock. Cement manufacturers often specify that vactor waste be free of oversized materials and debris, and tested for the eight TCLP metals to insure they are not accepting hazardous waste. Each manufacturer will impose its own conditions on acceptance.

Consistent supply of consistent material is key. Water content, trash content, organic matter content, particle size, and amounts are all important factors. As a supplier, the District/Region must be able to deliver product to meet the manufacturer's schedule. Collection schedules and capacity to safely store roadwaste materials that will go for reuse should be considered. Sweepings that have "cooked out" (i.e. composted) might make better asphalt feedstock, and might supply a more consistent organic matter percentage for cement production. Testing requirements might be waived after a District can show a consistent product.

Although it takes planning and effort to get roadwaste into a manufacturing process, it can pay off. Using more contaminated and problematic material (which poses higher disposal or management costs) as feedstock can yield substantial savings. The basic issue of consistency should be pursued in developing good partnership opportunities and long-term business arrangements. Transportation costs should be factored into any plans for use as feedstock, and hauling distance could limit the applicability of some business opportunities. Still, shipment to distant manufacturers could potentially be more cost effective than disposal. DOTs positions as large purchasers of asphalt and concrete can put them in a good negotiating position to have their roadwaste reused. Materials contracts might reasonably specify that a minimum percentage of acceptable roadwaste materials be used as feedstock in cement kilns.

The high temperatures in cement kilns destroy the PAHs and TPH fractions and virtually eliminate the risk otherwise inherent in the material. Heavy metals are bound into the cement and are unlikely to pose a concern at the concentrations present. Heavy metals do have the potential to be a concern in the disposal of cement mixer wash-out water; however, cement manufacturers currently use many other materials with higher metals concentrations as feedstock. PAHs do not pose a risk in asphalt, and asphalt uses petroleum as a binder in any case. Heavy metals content in waste asphalt should not prove to be a significant concern.

Treatment Options

Treatment is more cost-effective than disposal if the treatment costs (testing, hauling, managing, permits, treating, and tracking) are less than or equal to the disposal expenses plus the cost of buying the product new.

Composting

Composting can use a variety of materials as feedstock. Composting leaves and grass on a district level ("greenwaste") can bring savings over hauling the material to a commercial composter, especially if the compost can be used to replace purchased growing media. For efficient composting, some brush may require chipping, and thick, woody wastes may require tub grinding. Reuse of wood chips and making wood available for home use may also be workable. Washington DOT recycles their vactor sludge into a growing media by mixing it with wood chips.

Composting of non-greenwaste materials is also possible. The City of Portland has been composting greenwaste and sweepings for several years and has encountered good success. Removing trash and sharps (hypodermic needles and glass) is a problem encountered with composting sweepings. Cigarette butts are prevalent and particularly hard to screen out. Great Western Sweepings in Tualatin, Oregon, has worked out a dual screening system that ODOT found to work well.

Roadwaste does not need the turning that normal compost does, since it has a much lower oxygen demand. Treatment studies have also shown that petroleum compounds can bind with organic matter. Woody waste and compost can fix both metals and carcinogenic PAHs, preventing them from escaping into the surrounding environment.

Permits may be required for compost operations of a certain size (exceeding 25 tons of input per year in Oregon). ODOT has found there are benefits to obtaining a permit: DEQ can help solve site stormwater issues and provide you with technical assistance to ensure a good product. You will need to know how to avoid hot spot fires and also how to not end up with a stinking mess. The City of Portland study mentioned above may result in a better understanding of risks associated with composting. The use of composted material on lands outside of ODOT control is not recommended except for designated farm use (see Use as Soil Amendment). Although composting requires significant time and expense, the challenges are manageable and, in the right areas, the results will be well worth the effort.

Thermal Treatment

Thermal treatment is often used to destroy the gasoline and diesel petroleum fractions in soil collected from underground storage tank cleanups. Gas and diesel can be removed at relatively low temperatures. However, the gasoline and diesel fractions do not pose the most significant risk for management of common roadwastes. The low-temperature thermal desorption technology used by mobile soil burners does not destroy the major risks—carcinogenic PAHs and heavy metals. High-temperature thermal remediation (exceeding 650° F) appears to volatilize a significant portion of the CPAHs, substantially reducing the concentrations of the most significant contaminant. Volatilized contaminants not immediately destroyed are burned off at temperatures above 1,200° F in an afterburner.

The City of Portland takes their vac waste to TPST's high-temperature thermal desorption facility in North Portland. Prior to thermal desorption, the material is screened for trash. Water content needs to be 30 percent or less; this can be achieved by mixing with other batches. Treatment of CPAH-contaminated batches has shown that this technology can remove these compounds. Heated pile technology is expected to work as long as the material can effectively be stacked with the heating pipes.

High-temperature thermal treatment normally results in a sterile product, with all of the organic contaminants and vegetative matter destroyed. The compaction rating of the product is sufficient for use as construction fill. With no organic materials, there is nothing to degrade. The material is no longer suited for use as a growing medium though.

Testing for TCLP heavy metals may be required; facilities generally cannot accept roadwaste with a contaminant level so high that it qualifies as a hazardous waste. Minimal level of trash content may be allowable.

The City of Portland has netted $15 per ton cost savings over using Metro area landfills by using this approach. Little to no environmental risk is expected from reuse of roadwaste that has undergone high-temperature thermal treatment if adequate treatment standards are maintained.

Passive Bioremediation (*Simple Aeration*)

Bioremediation allows natural microorganisms to break down contaminants. Some micro-organisms can eat petroleum, using it for energy, and release carbon dioxide and water. Bioremediation cannot be used to "treat out" heavy metals, though metals may be rendered less mobile. "Passive bioremediation" means the microbes already present do their work, without steps taken to enhance their activity. In cleanup parlance, this is often termed "natural attenuation." Roadwaste piles left alone to naturally bio-remediate have had little or no detectable total petroleum hydrocarbons (TPH) in as little as six months.

Reducing diesel and heavy oil fractions does not eliminate the major risks associated with physical contact with roadwaste. The heavy metals and most of the CPAHs are still present. They are tightly bound into the material, however, and not readily transported to groundwater or surface water. In reducing TPH concentrations substantially, the most mobile and highest concentration contaminants are removed from the equation, making placement away from ready access much more workable. Uses for passive bioremediation include preparation for direct reuse (e.g. in noise barriers or rock fall berms), reduction of active decomposition and preparation for landfilling in a roadwaste landfill. Permits may be required by the state regulatory agency for passive bioremediation sites and technical assistance may be available. Care should be taken to make sure requirements address actual risks. Breakdown of organic matter releases organic acids, reducing pH. Lower pH environments can mobilize heavy metals. The same process can happen with composting roadwaste. Care should also be taken to minimize, control, monitor and/or treat stormwater runoff from all storage and treatment areas.

Active Bioremediation

Active bioremediation enhances the effects seen in passive bioremediation by adding nutrients to help feed the microbes, surfactants that release bound contaminants, and chemicals that help break down complex chemicals or that provide chemical sources of oxygen. Peroxides can break down complex carbon chains, in some cases making them more ready food for existing microbe populations, as well as introducing needed oxygen. Such techniques have mainly been used in treating petroleum-contaminated soils from underground storage tank cleanup sites. These lighter petroleum compounds are not a concern in roadwaste. The nutrients and microbe populations in roadwaste are usually quite capable of dealing with the normal petroleum fraction (see Passive Bioremediation, above). Thus, using a product designed to break down gas and diesel fractions as a roadwaste treatment technology can be a waste of time and money.

The microbes found in roadwaste are of hardy varieties. Some of the specialized microorganisms introduced to treat complex carbon compounds do not compete well with natural microbes. Special conditions may be required, including the presence of special nutrients or chemicals to enhance or kick-start biological activity; a certain temperature range perhaps found only during special times of the year; or a tight pH soil acidity range. Liming agents and other pH adjusters can be used to create an environment better suited to the microbes you are using. Nutrients may be needed.

Overall, active bioremediation is considered an expensive option practical for only a small percentage of roadwaste. Placement of treated materials depends on the success in reducing CPAH concentrations. Of course, heavy metals will not be removed. If heavy metals are present in high concentrations, they could limit potential reuse and may make landfilling a more practical option. Active bioremediation of roadwaste should focus on destruction of the CPAHs. Several samples should be run through a lab after treatment to establish that the treatment was successful.

Phytoremediation

Phytoremediation involves using plants to treat contaminants. Certain plant species have been identified that are good at removing or destroying certain types of contaminants. For the heavy metals in roadwaste, planting a variety of grass that is known for its high uptake of lead could result in a crop of grass high in lead content. The grass could either be disposed or, if high enough in lead content, be sent to a smelter to recover the lead. Lead values as high as one percent by weight have been observed in grass, as rich as in some commercial ores.

While metals are a risk driver, carcinogenic PAHs are the main risk driver. Besides CPAHs in roadwaste, roadsides in high-traffic roadway corridors may increase in CPAHs over time due to the incomplete combustion of petroleum fuels. Mulberry bushes have been shown to break down CPAHs in the rhyzosphere (the biologically active root zone). Using plantings could be valuable both in treating roadwaste contaminants and as cover crops for roadwaste reuse sites. Using the right plants can also provide a defense against the build-up of CPAHs expected along high traffic corridors. Since roadway maintenance practices require planting cover crops, consider selecting cover crops that will reduce contaminant levels and act as a defense against future contamination.

Soil Washing

Soil washing removes contaminants from problem soils by rinsing; however, heavy hydrocarbons are adsorbed onto the surface of particles and will not readily dissolve into water. The goal is removal of the more highly contaminated fine particles from roadwaste, leaving the larger particle size fractions ready for reuse. (The wastewater would then need to be treated and the contaminated fines managed conservatively.) It may be possible to find a way to release all the contaminants into the rinsate, leaving clean dirt and contaminated water, which could be treated separately.

Removing fines creates a secondary problem: effectively managing the wastewater. Besides evaporating the water in large ponds, there is no simple technology to de-water the lighter suspended fines.

An aggressive surfactant may be able to break the bonds holding the contaminants to the roadwaste. However, these soaps or chemical agents themselves can be a problem. Lowering the pH of a roadwaste slurry could dissolve heavy metals into solution. Then the water could be chemically treated, flocculating out the metals. This would be an intensive process, however, and would not address the main risk driver (CPAHs). Thus acid release approaches do not appear workable. Removal of the liquid without entraining fines is difficult.

Field trials on this treatment method have not been conducted, so it is not known how applicable soil washing is for roadwaste management. Surfactant may be available that would release heavy petroleum compounds and metals into solution for removal and recovery and would not pose environmental harm in the resultant product. In theory soil washing could remove heavy metals and petroleum contaminants, leaving benign materials; however, there are too many variables to provide an overall evaluation of risk. The wastewater must be managed carefully, requiring a sealed system. Products resulting from any new treatment process would require laboratory tests to evaluate risk.

Disposal Options

Disposal in a permitted, municipal solid waste landfill is expected to virtually eliminate any future liability, a significant advantage. Most landfills cannot accept liquids or wetter sediments though. Costs for disposal at permitted landfills can vary widely.

Siting and obtaining a permit for a publicly-owned roadwaste landfill may be a better option if volumes are high and a good site is available. It is recommended that a roadwaste landfill be lined to prevent ready release of contaminants. Sharing costs and sharing liabilities with other government agencies is reasonable.

It is important to reconsider past practices. Disposal of roadwaste that does not classify as clean fill should not go to unlined construction and demolition (C&D) landfill. Many former sand or gravel pits operating as clean fill landfills are accepting roadwaste. The porous matrix of sand and gravel and the ready access to the water table at these sites makes them inappropriate for use as roadwaste landfills. Some sites have virtually injected contaminants into the subsurface by placing roadwaste in direct contact with the groundwater table. Problems in other states with old, unlined fills, are leading them to clear their roadwaste out of burial sites. Washington DOT is conducting site assessments and characterizing stockpiles of roadwaste, examining the potential for harm.

Permitted solid waste landfills are a sound, traditional waste management alternative and serve as a good option for small amounts of more highly contaminated wastes. Landfills are permitted to accept wastes within specified toxicity parameters and manage those risks well. Trash must be landfilled or recycled. Landfilling avoids costly laboratory tests and oversight. Tipping fees can be costly in some areas, though. Operating at high volumes, costs of disposal at permitted roadwaste landfills are likely to be much lower than regular solid waste tipping fees. Testing normal roadwaste prior to placement in a permitted solid waste landfill is not necessary and should be avoided if the District has a screening process in place to identify suspect loads.

10.17. Spoil Disposal or Placement of Inert Fill

NYSDOT and the New Brunswick, Canada, DOT outline the following practices for disposal of spoil or excavated material.(*1197*)(*1198*)

- Employees should not allow inert fill to erode or wash into a wetland or classified body of water. Spoil material should not be disposed of within 30 meters (legally 100 feet) of wetlands, within 15 meters (50 feet) of stream bank or within the floodway, whichever is greater, or in floodplains. Wetlands or streams may not be altered or filled without first obtaining permits from appropriate regulatory agencies. Consult with DOT environmental staff if such a permit is needed.
- Spoil material is not disposed of on forest preserve lands or on prime agricultural land.
- Spoil material is not disposed of in the vicinity of historic resources or archeological sites.
- Disposal areas should be located carefully, taking into consideration of the siting constraints. Disposal areas should not be located so as to block natural drainage. Disposal areas should be located no closer than 100 feet from a watercourse and where runoff from the disposal area cannot enter a watercourse or cause siltation of the watercourse. Additional setback requirements may apply in protected watersheds and designated groundwater protection areas, or may be warranted by site-specific conditions.
- Spoil material is not disposed of in visually-sensitive areas or in other environmentally-sensitive areas.
- Spoil material is not disposed of outside ROW, unless appropriate permits are in place.
- Spoil areas are graded and shaped to blend with the landscape and then re-seeded and mulched to prevent erosion.
- Spoil material is placed in an upland area (away from streams or wetlands), and then seed and mulch the spoil pile.
- Approved areas for filling should be marked by stakes or other markings, and appropriate erosion and sedimentation controls should be used. Filled areas should be graded and stabilized by seeding and/or other appropriate methods when filling is complete. Interim or seasonal stabilization should be used if filling occurs over an extended period.
- Fill that has been contaminated with oil, gasoline or other chemicals should not be used. Sediment from ditches and culverts does not need to be tested unless it smells like fuel, solvents, or sewage, or is mixed with roadside trash. Any material suspected of contamination should be reported promptly.
- Established fishing pools should never be filled in.
- Contractors should obtain permission from the property owners on whose land they wish to place disposal areas.
- Maintenance facility managers should prevent erosion of the fill slopes at their facilities and ensure erosion and sediment controls are properly implemented and maintained.

10.18. MAINTENANCE OF SOILS

Maintenance activities can greatly affect soil structure in a positive or negative way. A solid plant cover is the best defense against erosion and invasive species. Routine maintenance activities can help build the soil to support vigorous plant growth.(*1199*)

- Plants suffer from nutrient deficiencies in the soil. Contact the Landscape Architect for recommendations before amending soil. The Landscape Architect can provide information on appropriate fertilizers or soil amendments.
- Allow organic matter to remain on the ground where it will not jeopardize safety or visual quality. Logs and brushpiles enrich the soil and provide habitat while decomposing. Such decomposition can reduce the need for additional fertilization or soil amendments and reduce maintenance expenditures.
- Fresh wood chips can use up available nitrogen and affect plant growth. To avoid this problem, spread wood chips thinly over a large area or add nitrogen to aid in decomposition.
- Avoid driving vehicles or operating equipment on saturated soil and in vegetated areas.
- Reseed, cover, or mulch bare soils as soon as possible when they have been exposed by maintenance activities or errant vehicles.

With regard to control of soil tracked by equipment onto pavement or other inappropriate areas:

- Substantially visible sediment should be swept or vacuumed from the maintenance activity site.
- If not mixed with debris or trash, consider incorporating the removed sediment back into the maintenance activity site.
- Washing and rinsing of equipment should be performed in designated areas and the resulting runoff shall not be discharged to the storm drain system.

10.19. EMERGENCY ACTIONS

All emergency actions in or adjacent to streams, wetlands, lakes, ponds or other water bodies, or historic resources require some form of environmental review and notification to regulatory agencies and thus should be coordinated through DOT environmental specialists or landscape architects. To qualify as an emergency, the damage or threat to bridges, roads or other transportation facilities must present an immediate threat to life, health, property or natural resources and must be the result of a single event, not long-term neglect. Agency notification should include:

- Description of the proposed action.
- Location map and plan of the proposed project.
- Reasons why the situation is an emergency.

In addition, many emergency projects require authorization from the U.S. Army Corps of Engineers or the U.S. Fish and Wildlife Service and must be coordinated appropriately. For large-scale disasters, batches of emergency projects may be approved with a single authorization, at the discretion of the regulatory agencies. In addition, the following environmental stewardship practices should be employed: (*1200*)(*1201*)

- All emergency work should be performed to cause the least modification, disturbance, or damage to the course or bed of a stream and its banks, or any adjacent wetlands. Avoid additional impacts to wetlands or streams where possible and repair any damage to fishery or water resources caused by DOT Maintenance responses to the emergency. Remedial actions for emergencies include bioengineering and fish friendly designs, where practicable for stability and safety.
- No equipment should be operated in the water unless it has been approved by the state permitting agency.
- Identify and plan for slide debris disposal sites as part of local disposal plans. Appropriate sites for long and short-term material disposal should be identified and cleared for any potential wetland or sensitive species impact and mapped.
- When conducting emergency work, all general and special permit conditions must be followed, and if significant project modifications occur during construction, these changes should be coordinated with the environmental specialist and/or the permitting agencies.
- Provide quick response and first inspection, and notify appropriate resource staff in a timely manner.
- Provide, if possible, adequate erosion control or bank stabilization necessary to keep material from entering watercourses.

10.20. Field Review of Roadside Maintenance Operations

Caltrans Maintenance Activity Pollution Prevention Program

Caltrans developed a pilot program for review and improvement of roadside maintenance operations, which was ultimately expanded to a full-scale inspection program called the Maintenance Activity Pollution Prevention Program (MAPPP). Program practices include the following:

- Evaluate stormwater Best Management Practices (BMPs) in the field.
- Identify potential improvements.
- Provide a feedback mechanism for work crews.
- Conduct general stormwater training, activity-specific training for work crews, and reviews of specific guidance, expectations, and documentation.
- Develop a documentation method that could be applied consistently statewide.

WSDOT's Maintenance Accountability Process and Environmental Factors

WSDOT has developed a Maintenance Accountability Process (MAP) tool to measure and communicate the outcomes of maintenance activities and to link strategic planning, the budget, and maintenance service delivery. Twice a year, field inspections are made of randomly selected sections of highway. The results are measured, recorded and compared to the MAP criteria to determine the level of service (LOS) delivered.

For example, WSDOT's roadsides are maintained to fulfill highway objectives in four functional categories: operational, environmental, visual and auxiliary. The Operational category includes those functions that provide safe and multi-use roadsides. The Environmental category includes those functions that protect and enhance natural and built surroundings. Visual functions promote a positive quality of life and are integral to the other functions. Auxiliary functions are those that supplement the transportation system, such as safety rest areas. The primary elements of roadside maintenance include, vegetation management, litter control and maintenance of safety rest areas.

Results are summarized annually, such as in the September 2003 Field Data Collection Manual, which includes the following A (blue) through F (red, none) grades for drainage maintenance and slope repair and roadside vegetation management.

Group - 2 Drainage Maintenance and Slope Repair															
2A1 Maintain Ditches					✓			⊙							
2A2 Maintain Culverts								✓		⊙					
2A3 Maintain Catch Basins and Inlets					✓		⊙								
2A4 Maintain Detention/Retention Basins								✓⊙							
2A5 Slope Repair				✓			⊙								
Group - 3 Roadside and Vegetation Management															
3A1 Litter Pickup										✓	⊙				
3A2 Noxious Weed Control		✓			⊙										
3A3 Nuisance Vegetation Control			✓			⊙									
3A4 Control of Vegetation Obstructions						✓		⊙							
3A5 Landscape Maintenance								✓	⊙						

Further details about the methodology of measurement in these areas follow:

Drainage Ditches

Units of Measure: Total linear feet of ditch, per 0.10 mile section; total linear feet of filled ditch, per 0.10 mile section.

Threshold: Count as deficient all ditches which are 50% or more full.

Methodology: Measure all ditches within the section and record the total linear feet of ditches. Measure and record the linear feet of ditch that is 50% or more full of sediment or other material.

For purposes of this survey, to be considered a ditch the structure must be designed and constructed to carry water – not a natural swale, or must be maintained as a ditch by Maintenance.

Comments: Streams adjacent to the roadway are not considered ditches. Standing water (tidal or non-tidal) in ditches is not a deficiency. Vegetation growing in the ditch is not a deficiency. Ditches designed solely to capture rock fall shall not be considered a ditch for this survey.(*1202*)

Culverts

Unit of Measure: Total number of culverts, per 0.10 mile section. Total number of culverts greater than or equal to 50% filled or otherwise deficient, per 0.10 mile section.

Threshold: Count as deficient if:

- Any portion of the culvert is 50% or more filled with sediment or debris, or
- Any end is significantly crushed or deformed, or

- The volume of the inflow or outflow is reduced 50% or more by obstructions such as rocks, vegetation, or woody debris, or
- The pipe is separated 1” or more, or damaged in a way that the function of the culvert is causing significant damage to the roadway prism or adjacent drainage channel.

Methodology: Count and record all culverts within the section. Count and record any culvert that is 50% or greater filled or otherwise deficient. Evaluate only those culverts that cross state highways or county roads at their intersection with state highways. Do not count culverts under private access roads.

Comments: Vegetation obscuring the end of a culvert is not a deficiency unless it obstructs the flow of water. Standing water (tidal or non-tidal) in ditches is not a deficiency. Culverts designed to be half filled with gravel for fish habitat should not be rated as deficient.(*1203*)

Catch Basins / Inlets

Inlet Pipe, Outlet Pipe, Flow Line, Elevation, Catch Basin or Grate Inlet, Grate Ground Elevation, Silt Storage, Capacity Varies

Units of Measure: Total number of catch basins and drain inlets, per 0.10 mile section; total number of catch basins and drain inlets that are deficient.

Threshold: Count as deficient any catch basin or drain inlet that has:

- 50% or more of the inlet grate blocked with debris, or
- The catch basin has sediment buildup that reaches or exceeds the flow line elevation of the outlet pipe.

Methodology: Count and record the total number of catch basins and drain inlets in the section. Count and record the number of catch basins and drain inlets blocked by debris or catch basins filled with sediment.

Comments: Both catch basins and drain inlets are rated for blockage of the inlet grate. Only catch basins are rated for sediment build-up. A flashlight and/or probe may be needed to determine if the structure is a catch basin (i.e., has silt storage capacity) and whether it is deficient.(*1204*)

Slope Failures

Unit of Measure: Total number of slope failures, per 0.10 mile section.

Threshold: Only count as deficient a slide or erosion that is at the time of the inspection:

- Jeopardizing the structural integrity of the shoulder or traveled lane(s), or
- Blocking the shoulder or traveled lane(s), or blocking the ditch, or
- Jeopardizing the structural integrity of guardrail or traffic signs.

Traffic may move slower through the area or lanes may be reduced, causing intermittent stoppages. Erosion or slides not meeting the thresholds above shall not be considered deficient.

Methodology: Determine and record the total number of slope failures found within the survey section. Both fill and cut slopes can be affected.(*1205*)

Comments: Chronic or ongoing slope failures that do not meet the criteria listed above at the time of the survey are not to be counted as failures. Edge drop-off is not considered a slope failure.(*1206*)

Noxious Weeds - Weed Infestation

Units of Measure: Total square feet of infestation, per 0.10 mile section.

Threshold: Presence of noxious weeds on the roadside.

Methodology: Survey the roadside and determine the presence of any noxious weeds. Measure the square feet of the infestation; the total square feet of infestation should not exceed the total square feet of roadside.

Comments: Identifying noxious weeds can be difficult and is best done by a person trained in weed identification. For assistance in identifying noxious weeds consultation with the area roadside or spray crew is recommended.(*1207*)

Nuisance Vegetation - Weed Infestation

Units of Measure: Total square feet of infestation, per 0.10 mile section.

Threshold: Presence of nuisance vegetation on the roadside.

Methodology: Survey the roadside and determine the presence of any nuisance vegetation. Measure the square feet of the infestation; the total square feet of infestation should not exceed the total square feet of roadside.

Comments: Identifying nuisance vegetation can be difficult and is best done by a person trained in weed identification. For assistance in identifying nuisance weeds consultation with the area roadside or spray crew is recommended.(*1208*)

Vegetation Obstruction

Unit of Measure: Total number of vegetation obstructions per 0.10 mile section.

Threshold: Vegetation blocking sight distance to guide or regulatory signs, or intersections as seen from the driver's perspective.

Methodology: Measure and record total number of instances where vegetation obstructs sight distance to signs or intersections. For example, if a survey site has two blocked signs and one blocked intersection the surveyor shall record 3 vegetation obstructions on the survey form.

Comments: For the purpose of judging adequate site distance for this survey, signs and intersections should be visible from distances of:

- Freeways 800 feet min.
- Rural roads 500 feet min.
- Urban roads 200 feet min.(*1209*)

Litter

Unit of Measure: Total number of litter counted, per 0.10 mile section.

Threshold: Objects approximately 4 inches in any dimension or larger.

Methodology: Observe and record all litter 4 inches and greater.(*1210*)

CHAPTER 11: APPENDIX

11.1. FLORIDA DOT ENVIRONMENTAL POLICY

Example 16: Florida DOT Environmental Policy

It is the policy of the Florida Department of Transportation to help preserve and enhance Florida's natural, physical, cultural and social environment as we develop, implement, and maintain transportation facilities and services. In carrying out this policy, the Department will:

- Balance quality engineering and aesthetic design principles with consideration of environmental and economic aspects of the transportation program.
- Utilize methods to preserve, enhance, and protect trees and other vegetation as valuable natural resources consistent with ecosystem management principles, local community values and established safety practices.
- Take into account the effects of transportation improvements on prehistoric and historic cultural resources in all phases of Department activity and avoid, minimize, or mitigate for such impacts as applicable.
- Cooperate in the State's Greenways Program of land acquisition and management through identification and prioritization of important habitat connections. Where alternative mitigation strategies permit, the Department will support land acquisition activities to help achieve this ecological infrastructure. Consideration of habitat connectivity and wildlife crossings will be included on existing facilities as well as in the development of planned projects.
- Consider, in all functional activities, environmental factors such as noise, air quality, stormwater runoff, water quality, wetlands, wildlife and habitat, and hazardous materials in order to preserve and enhance the state's environmental quality.
- Maximize the use of recycled materials in highway construction.
- Cooperate in the State's program to control the spread of invasive exotic plants.
- Consider social consequences resulting from transportation actions to ensure that impacts to the human environment are identified and fully considered equally with impacts related to the natural and physical environments.
- Be sensitive to community values and needs utilizing an open decision-making process, which strives to accommodate community concerns, where feasible, and facilitate problem solving in a collaborative manner.
- Utilize proactive public involvement that is responsive to agencies, citizens and groups in addressing environmental issues and developing transportation plans, programs and policies.

11.2. KENTUCKY TRANSPORTATION CABINET ENVIRONMENTAL POLICY

Example 17: Kentucky Transportation Cabinet Environmental Policy

The Kentucky Transportation Cabinet will use practical means and measures to provide an environmentally sound, fiscally responsible, safe and efficient transportation system which promotes conditions under which people and nature can exist in productive harmony while providing for economic growth and enhancing the quality of life for present and future generations of Kentuckians.

The principles and responsibilities of the above policy statement which we are incorporating into the culture and fabric of our organization and daily activities are as follows:

Stewardship
We will strive to protect, conserve, restore, and enhance the natural and human environment, while we plan, design, construct, and maintain facilities that meet transportation needs.

Leadership
We will promote development, sharing and the integration of sensitive and innovative environmental practices and technologies into planning, design, construction, and maintenance activities to encourage personnel to value and take pride in their environmental leadership roles.

Partnership
We will seek stewardship opportunities to cooperatively partner with the public, federal and state resource agencies to identify shared visions, missions, and goals which will result in new consensus building processes, new methods and protocols, and new design and environmental technologies to be applied on mutually beneficial undertakings.

Practice
We will employ Context Sensitive Solutions to ensure that our planning, design, construction, and maintenance activities reflect community and environmental values as determined through proactive involvement with the public, resource agencies, and other stakeholders.

Commitment
Our Cabinet is committed to a culture that embraces environmental leadership with an unwavering focus on protecting the environment through stewardship and our devotion to satisfy the public, resource agencies, and other stakeholders as the primary measure of success in carrying out our mission.

By working with the public, resource agencies and other stakeholders to integrate environmental stewardship into our daily activities, the Cabinet is responding to the wishes and needs of its customers, the values it holds foremost as public servants while acting in the spirit of environmental law. It is the right thing to do for transportation and the human and natural environment.

11.3. MAINE DOT ENVIRONMENTAL POLICY

Example 18: Maine DOT Environmental Policy

It is the Vision of the Maine Department of Transportation that we "...will create and maintain a safe, efficient, and economical transportation system that is cost effective, energy efficient, environmentally sound and responsive to the diverse needs and values of the people of Maine and the Nation." In accomplishing this, we recognize that the Department's actions can, and often do, impact environmental resources. We understand that the public expects us to deliver our services and products in a way that protects and enhances environmental resources. We appreciate that these resources are the basis of our quality of life and have tremendous economic and social value.

It is therefore the policy of the Maine Department of Transportation that we continuously evaluate our actions for their impacts upon environmental resources and that we conduct our activities so as to avoid and minimize those impacts. It is our desire to deliver safe and efficient transportation systems and to protect and enhance environmental resources. It is not a question of either one or the other. It is a matter of delivering both.

To accomplish this, the Department will:

- Develop and utilize an Integrated Transportation Decision-making process (ITD) regarding transportation projects that incorporate environmental considerations from the earliest planning state through construction and maintenance;
- Evaluate areas that need improvement regarding protection of the environment and implement the changes necessary to make those improvements;
- Conduct a review of our organizational structure and culture regarding environmental responsibilities and make the changes necessary to strengthen that structure and to change the culture where appropriate;
- Partner with Federal and State environmental agencies to identify and collaborate on reaching goals of mutual interest; and
- Make environmental protection part of every employee's job expectations.

As Commissioner, I am personally committed to making this policy work. It is what the public expects of us, it is an investment in our future, and it is simply the right thing to do. I will hold each employee accountable for his/her part of the Department's commitment to the protection and enhancement of Maine's environmental resources as we carry out our Transportation responsibilities.

11.4. North Carolina DOT Environmental Stewardship Policy

Example 19: North Carolina DOT Environmental Stewardship Policy

The mission of the North Carolina Department of Transportation is to provide an integrated transportation system that enhances the state's well being. Our goal is to provide a safe and well-maintained transportation system that meets the needs of our customers and supports the development of sustainable, vibrant communities. In so doing, we are committed to planning, designing, constructing, maintaining and managing an interconnected transportation system while striving to preserve and enhance our natural and cultural resources.

Environmental stewardship encompasses these responsibilities and is reflected in our day-to-day operations by:

- Safeguarding the public's health by conducting our business in an environmentally responsible manner.
- Demonstrating our care for and commitment to the environment.
- Recognizing that our customers expect us to provide mobility and a quality of life that includes the protection of the natural resources and the cultural and social values of their community.
- Each employee is responsible for incorporating these principles of safety, environmental stewardship and customer focus into their daily activities.

11.5. PennDOT's Green Plan Policy Statement

Example 20: PennDOT's Green Plan Policy Statement

As a direct result of our commitment to assuring adequate, safe and efficient intermodal transportation facilities and services at reasonable cost to the citizens of the Commonwealth of Pennsylvania, the Department of Transportation will play a leading role in the administration of environmental responsibility. The Department will demonstrate this leadership by committing to the following principles relative to the planning, design, construction, operation and maintenance of Pennsylvania's balanced intermodal transportation system.

Principle 1
Plan, design, build, operate and maintain a statewide transportation system that protects the environment, prevents pollution and uses resources efficiently.

Principle 2
Contribute to economic vitality and quality of life by applying sound environmental management practices which address the requirements of the public, users, carriers, industry and labor.

Principle 3
Comply with applicable environmental legislation and regulations.

Principle 4
Establish a program of review and continual improvement of environmental performance which accounts for technical and economic developments, scientific understanding, and significant environmental impacts.

Principle 5
Establish relevant and measurable objectives which endeavor to improve environmental performance and provide the means to gauge progress.

Principle 6
Ensure employees understand those principles as well as their priority, and are furnished with the means to fulfill them.

These principles are essential elements for the management of the Department as we enter the 21st century. As part of a fully integrated environmental management system, these principles should be incorporated into the policies, programs and practices of all Department of Transportation organizations

11.6. Washington State DOT Environmental Policy

Example 21: Washington State DOT Environmental Policy

The Department of Transportation acknowledges the state's vital interests in protecting and preserving natural resources and other environmental assets and its citizens' health and safety. These interests must be integrated with other vital interests committed to the Department, including the cost-effective delivery and operation of transportation systems and services that meet public needs.

The Department shall conduct all its affairs in accordance with the dictates of sound environmental protection practices, including pollution prevention wherever reasonably possible. The Department shall also avoid, minimize and appropriately mitigate adverse environmental impacts. These undertakings extend to the construction, maintenance and operation of its systems and facilities. Legal obligations in these matters are established by applicable laws and regulations; this Policy Statement is not intended to create further or additional legally-enforceable requirements.

- To support the performance of the Department's responsibilities and undertakings, as Secretary of Transportation, I hereby commit the Department:
- To implement and maintain an environmental management system that embraces all the Department's program functions;
- To establish, maintain and make available to the public appropriate performance indicators of the Department's exercise of its environmental stewardship and to consistently review these indicators as a basis to improve the Department's performance;
- To comply with all environmental laws and regulations applicable to our business and activities;
- To assure that employees of the Department receive training appropriate to their functions concerning the Department's environmental responsibilities;
- To communicate to contractors, designers, consultants and other participants in the Department's work the management practices and compliance requirements established to further the aims of this Policy Statement;
- To encourage employees and all other citizens to communicate with the Department about ways to increase the effectiveness of Department's practices supporting its mission of environmental stewardship;
- To make every reasonable effort to also protect the cultural and historic resources of the state.
- Each employee of the Department is charged to exercise his or her responsibility on behalf of the Department to assure that the intentions of the Policy Statement are diligently carried out.

11.7. New South Wales Roads and Traffic Authority Environmental Policy

Example 22: New South Wales Roads and Traffic Authority Environmental Policy

The RTA manages road related transport infrastructure and provides safe and efficient access to the road network for the people of NSW. The RTA will demonstrate due diligence in the provision of its services, manage its work activities in a manner that is consistent with the principles of ecologically sustainable development, and will deliver continuous improvement in environmental performance through:

- Developing and implementing an environmental management system.
- Reviewing the environmental effects of our activities and setting appropriate environmental improvement objectives.
- Integrating environmental duty of care into business planning and day to day activities.
- At a minimum, conducting all our operations, whether carried out by or on behalf of the RTA, in accordance with relevant legislation and government policy and agreements.
- Minimizing pollution and environmental impacts as a result of RTA activities.

- Promoting the efficient use, reuse and recycling of resources, and the minimization of waste.
- Involving the community in planning and implementation decisions.
- Including environmental considerations in all aspects of strategic planning of our road and traffic management.
- Providing our employees with the skills, awareness and leadership to achieve the RTA's environmental responsibilities.
- Monitoring, reviewing and reporting publicly on the environmental performance of the organization.

11.8. TEXAS ENVIRONMENTAL COMMITMENT CHECKLIST

Table 19: Texas Environmental Commitment Checklist

	TxDOT ENVIRONMENTAL COMMITMENT CHECKLIST For Construction, Maintenance and Facilities Projects		
PROJECT:		**DATE:**	
CSJ:		**DEQC:**	
HIGHWAY:		*Name*	
Stormwater Pollution Prevention			
Required Information and Documentation			
Does the construction site have a Stormwater Permit?	Yes ☐	No ☐ *	N/A ☐
Is a notice posted in a publicly accessible location near where construction is actively underway (and moved as necessary)?	Yes ☐	No ☐ *	N/A ☐
Does the notice contain the following information:			
The permit number or a copy of the NOI?	Yes ☐	No ☐ *	N/A ☐
The name and telephone number of a local contact person?	Yes ☐	No ☐ *	N/A ☐
A brief description of the project?	Yes ☐	No ☐ *	N/A ☐
Location of SW3P (Job site or other location).	Yes ☐	No ☐ *	
Is there a copy of the Construction General Permit in the SW3P? (a copy of the Federal Register is sufficient)	Yes ☐	No ☐ *	N/A ☐
Is there a copy of a Delegation of Authority Letter authorizing the inspector to sign inspection reports in the SW3P file?	Yes ☐	No ☐ *	N/A ☐
Is the SW3P retained on-site at the facility that generates the stormwater? (If no, where is it located ____)?	Yes ☐	No ☐ *	N/A ☐
Is the SW3P updated and documented in the plans as necessary to remain consistent with any changes in design, construction, operation, or maintenance applicable to protecting surface water resources in sediment and erosion site plans or site permits, or stormwater management site plans or site permits approved by State, Tribal or Local Officials for which	Yes ☐	No ☐ *	N/A ☐

the permittee receives notice?			
Is the description of construction and waste materials expected to be stored on-site updated?	Yes ☐	No ☐ *	N/A ☐
Are the following records maintained and available for inspection, or included in the SW3P?			
Dates when major grading activities occur?	Yes ☐	No ☐ *	N/A ☐
Dates when construction activities temporarily or permanently cease on a portion of the site?	Yes ☐	No ☐ *	N/A ☐
Dates when stabilization measures are initiated?	Yes ☐	No ☐ *	N/A ☐
Did stabilization occur within 14 days at locations where soil disturbing activities have ceased or will cease for at least 21 days or were temporary measures installed?	Yes ☐	No ☐ *	N/A ☐
General Conditions			
Are Best Management Practices (BMPs) being utilized?	Yes ☐	No ☐ *	N/A ☐
Are silt fences, buffer strips, or equivalent sediment controls at a minimum used for all side-slope and down-slope boundaries of the construction area?	Yes ☐	No ☐ *	N/A ☐
Controls & Measures			
Have erosion and sediment controls been designed to retain sediment on-site to the extent practical during the construction phase?	Yes ☐	No ☐ *	N/A ☐
Were control measures, in accordance with manufacturer specifications and good engineering practices:			
Properly selected?	Yes ☐	No ☐ *	N/A ☐
Properly installed?	Yes ☐	No ☐ *	N/A ☐
Properly maintained?	Yes ☐	No ☐ *	N/A ☐
In effective operating conditions?	Yes ☐	No ☐ *	N/A ☐
Are controls in place to minimize:			
Dust generation?	Yes ☐	No ☐ *	N/A ☐
Off-site vehicle tracking of sediments?	Yes ☐	No ☐ *	N/A ☐
Are off-site accumulations of sediment removed at a frequency sufficient to minimize off-site impacts? (sediment near off-site inlets, etc)	Yes ☐	No ☐ *	N/A ☐
Is sediment removed from the sediment traps or sediment ponds when design capacity is reduced by 50 percent?	Yes ☐	No ☐ *	N/A ☐
Are litter, construction debris, and construction chemicals exposed to stormwater prevented from becoming a pollutant source from stormwater discharges? (e.g., screening outfalls, picked up daily)	Yes ☐	No ☐ *	N/A ☐
Are solid materials including building materials being discharged?	Yes ☐*	No ☐	N/A

(except those authorized by a permit issued under section 404 of the CWA)			☐
Were velocity dissipation devices (i.e. rock filter dams, holding ponds, etc) placed at discharge locations and along the length of any outfall channel to provide a non-erosive flow velocity from the structure to the water course?	Yes ☐	No ☐ *	N/A ☐
Inspections			
Were the inspections performed at least once every 14 calendar days and within 24 hours of the end of a 0.5 inch or more rain event (or once every 30 days in areas with less than an average 20 inches of rainfall per year)? (*Note: some projects may require more frequent inspections, refer to the plans*).	Yes ☐	No ☐ *	N/A ☐
Did the inspector check the following:			
Disturbed areas of the construction site that have not been stabilized?	Yes ☐	No ☐ *	N/A ☐
Areas used for storage of materials that are exposed to precipitation?	Yes ☐	No ☐ *	N/A ☐
Structural control measures?	Yes ☐	No ☐ *	N/A ☐
Locations where vehicles enter or exit the site?	Yes ☐	No ☐ *	N/A ☐
Based on the inspection, are the SW3P Sheet and SW3P Layouts modified within 7 calendar days following the inspection?	Yes ☐	No ☐ *	N/A ☐
Is it documented and available for inspection?	Yes ☐	No ☐ *	N/A ☐
Based on the inspection, are controls and measures modified or added before the next anticipated storm event (or as soon as practicable)?	Yes ☐	No ☐ *	N/A ☐
Did the inspection Summary Report include:			
The name of the inspector?	Yes ☐	No ☐ *	N/A ☐
The date(s) of the inspection?	Yes ☐	No ☐ *	N/A ☐
Measures/area inspected?	Yes ☐	No ☐ *	N/A ☐
Actions needed/taken as a result of the inspection?	Yes ☐	No ☐ *	N/A ☐
Signature of inspector with certification statement?	Yes ☐	No ☐ *	N/A ☐
Inspector properly delegated in writing to EPA?	Yes ☐	No ☐ *	N/A ☐
Water Resources Compliance			
USAC Permits			
US Army Corps of Engineers (USACE) Permits: Does the project have a USACE (Section 10 or Section 404) permit?	Yes ☐	No ☐	N/A ☐
If yes, is a copy of the permit kept onsite (in the form of Nationwide Permit text	Yes ☐	No ☐	N/A

and/or a letter or other documents from the USACE)?		*	☐
Are any Project Specific Locations, on or off Right-of-Way, that are *directly related to the USACE permit* addressed in the permit or Corps letters to the contractor (for off ROW PSLs)?	Yes ☐	No ☐ *	N/A ☐
Has clearance been obtained for any changes in design or construction methods in the areas covered by the permit?	Yes ☐	No ☐ *	N/A ☐
Does the project meet all conditions listed in the permit?	Yes ☐	No ☐	N/A ☐
Is a copy of the completed Section 401 Water Quality Certification Tier I checklist (or other specific Section 401 requirements) attached to the permit?	Yes ☐	No ☐ *	N/A ☐
Does the project have the BMPs installed as designated in the Tier I checklist or as otherwise specified?	Yes ☐	No ☐ *	N/A ☐
Are the BMPs working effectively? (If not, immediately bring the problem to the attention of the project engineer)	Yes ☐	No ☐ *	N/A ☐
Are there wetlands on the project site?	Yes ☐	No ☐	N/A ☐
Are wetlands that are required to be preserved by the USACE permit being effectively protected?	Yes ☐	No ☐ *	N/A ☐
Other Water Requirements			
Does the project require an Edwards Aquifer Protection Plan (for central Texas counties Kinney, Uvalde, Medina, Bexar, Comal, Hays, Travis, & Williamson only)	Yes ☐	No ☐	N/A ☐
If yes, is a copy of the Water Abatement Plan kept on-site?	Yes ☐	No ☐ *	N/A ☐
Are all appropriate conditions affecting construction being met?	Yes ☐	No ☐ *	N/A ☐
Does the project have a US Coast Guard Section 9 permit?	Yes ☐	No ☐	N/A ☐
If yes, is a copy of the permit kept onsite?	Yes ☐	No ☐ *	N/A ☐
Are all appropriate conditions affecting construction being met?	Yes ☐	No ☐ *	N/A ☐
Does the Project fall under the requirement of the Texas Coastal Management Plan?	Yes ☐	No ☐ *	N/A ☐
If yes, are all appropriate conditions affecting construction being met?	Yes ☐	No ☐ *	N/A ☐
Other Environmental Requirements			
Vegetation Management			
Are there any mitigation issues involving vegetation impacts?	Yes ☐	No ☐	N/A ☐
Is the ROW to be used for mitigation?	Yes ☐	No ☐	N/A ☐
Is there any vegetation that requires fencing, or other protection, to preserve it from damage	Yes ☐	No ☐	N/A

or removal?			☐
Are there any vegetative management issues within the project?	Yes ☐	No ☐	N/A ☐
Has project been coordinated with district environmental staff before removal of trees/shrubs within proposed ROW?	Yes ☐	No ☐ *	N/A ☐
Has project been coordinated with district environmental staff to salvage native plants in project area?	Yes ☐	No ☐ *	N/A ☐
Invasive species addressed as required?	Yes ☐	No ☐ *	N/A ☐
Is revegetation/landscaping with native grasses and shrubs in accordance with project plans?	Yes ☐	No ☐ *	N/A ☐
Are recycled plant trimmings to be used as mulch and to reduce runoff?	Yes ☐	No ☐ *	N/A ☐
Is any stockpiled organic layer of soil from existing wetlands to be used on mitigation site?	Yes ☐	No ☐ *	N/A ☐
Are the wetlands to be preserved already delineated?	Yes ☐	No ☐ *	N/A ☐
Noise			
Are there any noise level concerns within the project?	Yes ☐	No ☐	N/A ☐
Minimized construction noise:			
In residential areas	Yes ☐	No ☐ *	N/A ☐
In sensitive receptors in area.	Yes ☐	No ☐ *	N/A ☐
Historical and Archeological			
Are there any historical or archeological issues in the PS&E?	Yes ☐	No ☐	N/A ☐
Archeological survey to be conducted during/after ROW purchase. Parcel #_____	Yes ☐	No ☐	N/A ☐
Are there any archeological surveys needed to be done on outstanding parcels? Parcel #________.	Yes ☐	No ☐	N/A ☐
Are there any archaeological sites that must be avoided until mitigation is complete and THC concurs no additional work is required prior to construction?	Yes ☐	No ☐	N/A ☐
Are there any designated avoidance areas?	Yes ☐	No ☐	N/A ☐
If yes, are they delineated such that they are not disturbed? (If disturbed, notify project engineer immediately)	Yes ☐	No ☐ *	N/A ☐
Are there any historical elements to be salvaged or protected? (i.e. bridge plaques or historic bridge rail)	Yes ☐	No ☐	N/A ☐
If any archeological evidence were discovered during the course of construction (bones, burnt rock, flint, pottery), were the TxDOT Emergency Discovery Guidelines followed?	Yes ☐	No ☐	N/A ☐

Change Orders			
Has the district environmental staff reviewed all draft change orders to determine whether an environmental analysis and/or resource agency coordination is necessary?	Yes ☐	No ☐ *	N/A ☐
If any environmental analyses are required, has it received clearance?	Yes ☐	No ☐ *	N/A ☐
Federal Listed and Proposed Threatened and Endangered Species, Critical Habitat, State Listed Species, and Candidate Species			
Are there any listed species, etc., within project limits?	Yes ☐*	No ☐	N/A ☐
Is there designated critical habitat in the project area?	Yes ☐*	No ☐	N/A ☐
Was there consultation with the U. S. Fish and Wildlife Service and/or National Marine Fisheries Service for the project?	Yes ☐	No ☐	N/A ☐
If yes to any of the above 3, are there any commitments or requirements for on-site mitigation for endangered species?	Yes ☐	No ☐	N/A ☐
Are they being done properly?	Yes ☐	No ☐	N/A ☐
Are there any species/wildlife commitments for scheduling the construction activities for the project?	Yes ☐	No ☐	N/A ☐
If yes, are they complied with?	Yes ☐	No ☐	N/A ☐
Are there any requirements for species monitoring during construction?	Yes ☐	No ☐	N/A ☐
If yes, are they complied with?	Yes ☐	No ☐	N/A ☐
Are there any commitments for state listed species within the limits of the project?	Yes ☐	No ☐	N/A ☐
Does the inspector have a current list of species on the “watch list” for the project?	Yes ☐	No ☐ *	N/A ☐
Are pictures and descriptions that help identify these species available on the project?	Yes ☐	No ☐ *	N/A ☐
Have any of the species been spotted on the project site during construction?	Yes ☐*	No ☐	N/A ☐
Do TxDOT and Contractor staff know what they do if they see a listed species on-site?	Yes ☐	No ☐	N/A ☐
Essential Fish Habitat			
Is there any essential fish habitat within project limits?	Yes ☐*	No ☐	N/A ☐
Is there designated essential fish habitat in the project area?	Yes ☐*	No ☐	N/A ☐
Was there consultation with the U. S. Fish and Wildlife Service and/or National Marine Fisheries Service for the project?	Yes ☐	No ☐	N/A ☐
If yes to any of the above, are there any commitments or requirements for on-site mitigation for essential fish habitat?	Yes ☐	No ☐	N/A ☐

If so, are they being done properly?	Yes ☐	No ☐	N/A ☐
Are there any essential fish habitat commitments for scheduling the construction activities for the project?	Yes ☐	No ☐	N/A ☐
If yes, are they complied with?	Yes ☐	No ☐	N/A ☐
Natural Habitat Commitments			
Are there any commitments for natural habitat mitigation in the right-of-way other than vegetation management issues?	Yes ☐	No ☐	N/A ☐
Are the mitigation commitments stated in the project plans?	Yes ☐	No ☐	N/A ☐
Migratory Birds			
Are there any concerns that migratory birds are nesting within project limits?	Yes ☐*	No ☐	N/A ☐
Have migratory birds or nests been noticed on the project in such a situation that a 'take' of the birds might occur?	Yes ☐*	No ☐	N/A ☐
If a migratory bird 'take' might occur, has coordination with the resource agencies cleared the action?	Yes ☐	No ☐	N/A ☐
Hazardous Materials			
Are there any hazardous materials on the site or are there plans to use any hazardous materials during construction?	Yes ☐*	No ☐	N/A ☐
Is there evidence of hazardous materials not identified in the PS&E? (for example underground storage tanks, containers, spills)	Yes ☐*	No ☐	N/A ☐
If yes, immediately contact the Area Engineer.			

11.9. MAINE DOT ENVIRONMENTAL AND SAFETY AUDITING POLICY AND PROCEDURE

Example 23: Maine DOT Environmental and Safety Auditing Policy and Procedure

OBJECTIVE

This policy establishes a procedure to implement an effective environmental auditing program in the Bureau of Maintenance & Operations (M&O), including an auditing plan, auditing program, and auditor training. M&O's goal is to maintain a safe workplace, protect the environment, and have no violations in conducting regulated activities. M&O's objective is to close all non-conformances within time limits set by management at the time audit findings are reviewed. Other important benefits of auditing are cross-training, increased awareness of environmental requirements among its staff, and continuous improvement.

M&O recognizes that environmental and safety auditing is necessary to reduce the risk of noncompliance, and to provide assurance that regulations, Department requirements, policies and procedures are being followed. M&O's environmental auditing program will focus on prioritizing compliance issues, managing environmental risks, improving operations, reducing costs, and verifying the effectiveness of management systems that will ensure compliance. M&O will identify and prioritize audit issues, develop annual audit plans, and develop standard audit protocols or methods.

APPLICABILITY
This policy is applicable to all MDOT maintenance divisions, including Highway Maintenance, Motor Transport Services (MTS), Bridge Maintenance and Traffic Engineering.

TARGET AUDIENCE
This policy will be distributed to M&O supervisory personnel in Highway, MTS, Bridge, and Traffic Engineering, and other affected units of MDOT, including but not limited to: Director, Bureau of Maintenance and Operations; Director, Motor Transport Services; MDOT Division Managers/Engineers; Assistant Division Engineers; Safety Coordinators; Superintendents, Managers, and Supervisors. This policy will also be distributed to: Director, Environmental Office (ENV); Manager, Water Resources and Hazardous Waste, OES.

RESPONSIBILITY

- It is the responsibility of the Division Manager/Engineer to implement actions that will ensure compliance with laws and regulations and MDOT's environmental policies and procedures.
- The M&O Director will charter a standing Environmental Management Committee to oversee the implementation of the audit program. The Environmental Management Committee's responsibilities will include, but not be limited to the following:
    - Approve an annual environmental auditing plan for M&O
    - Approve (and revise as needed) environmental audit procedures for M&O
    - Receive reports of audit findings and communicate specific findings to appropriate levels of management
    - Monitor implementation of corrective actions from audits
    - Annually evaluate the audit program (and develop evaluation criteria and methodology)
    - Recommend resolution of any appeals of Corrective Action Reports to the Bureau Director

It is the M&O Director's responsibility to prepare the annual audit plan and to manage the implementation of the audit plan in accordance with this procedure, including the appointment and training of qualified auditors to serve on audit teams. It is the responsibility of the M&O Director to follow up with Division Managers to ensure that all corrective actions are completed or resolved in a timely manner.

It is the responsibility of all employees to be familiar with the Department's environmental policies and procedures that affect their work, as documented in MDOT's Environmental Policy and Procedures Manual.

It is the responsibility of the audit team leaders to plan and schedule audits according to the predefined scopes and purpose in conjunction with Division Managers/Engineers.

REQUIREMENTS
Audit Team. Auditors will be qualified by training and experience, and will follow generally accepted guidelines as described in ISO 14010, 14011 and 14012. Auditors must be approved by the M&O Director based on experience, training, and education. M&O will conduct its auditing program with advice as necessary from Legal Services, and will employ a team approach including members of ENV, M&O management, and M&O staff. M&O will use internal Department staff to perform audits when possible, provided that the auditors' duties and responsibilities are independent of the area and activities being audited and that auditors have proper training and experience. Outside auditors will be used when necessary to ensure independence, and when specific expertise and experience are required.

Audit Preparation/Planning. The Director of M&O, with advice from ENV and Legal Service, will define a "regulatory framework" of laws and regulations that apply to M&O. This framework will be used to prioritize risks, and to develop the annual audit plan. The Director of M&O will prepare annually a two or three year audit plan which will include, at a minimum, the following elements: 1) Identification of high priority environmental compliance risks; 2) Areas and activities to be audited, including; compliance with regulations and internal policies and procedures, the required frequency of the audits, and the expected dates during the upcoming cycle; 3) Audit team to conduct each audit, including the team leader; and 4) Information about the planned scope and general methodology of each audit.

Audit Execution

- The Division Manager/Engineer of the area to be audited should be notified of the audit at least 45 days prior to the audit. The notification will include a definition of the audit scope, topics, and protocols, as well as a pre-audit questionnaire (if appropriate).
- At least two weeks prior to the audit, the audit team leader will provide to the Division Manager/Engineer a proposed schedule for the audit, which will include meeting times and a list of personnel who will be interviewed or otherwise must be present for the audit. At this time, certain documents may be requested by the audit team leader to help prepare for the audit. One week prior to the audit, a final audit schedule will be agreed upon between the audit team leader and the Division Manager/Engineer.
- The audit team will prepare, in advance, the audit methodology to be used, including checklists, worksheets, interview questions, and protocols.
- The audit team will conduct an Opening Meeting with the Division Manager/Engineer and local management employees from the area being audited. The purpose of this meeting will be to review the audit scope, methods, logistics, reporting requirements, Corrective Action Request forms, and follow-up requirements, including an appeals process.
- The audit team will use accepted methods (*e.g.*, ISO or ASQ) to collect objective, verifiable evidence pertaining to the environmental aspects that are the subject of the audit. This evidence will include, but not be limited to observation, measurement, photographs, document review, interviews, testing, or inspection.
- Audit findings, including any non-conformances, will be recorded in writing, and may be entered into an audit tracking software program. Corrective Action Request (CAR) forms (example attached) will be completed prior to the closing meeting by the audit team member. Each CAR will be signed by a local management representative, who will be given a copy.
- The audit team may hold interim meetings daily with local management to address questions or issues that arise during the audit, or to revise the schedule as needed.
- The audit team will conduct a Closing Meeting with local management at the completion of the audit to review a summary of the findings before departing the area being audited. This meeting will include a discussion of each CAR, and the requirements for Corrective Action plans, including any appeals of CARs.

Audit Reporting and Corrective Action Follow-up

- A written audit report will be prepared by the audit team within two weeks of the audit. Copies of the audit report will be forwarded to the M&O Director and the Division Manager/Engineer of the area that was audited. Report distribution will be limited to individuals specified by the M&O Director.
- Within two weeks of receiving the audit report, the Division Manager/Engineer will submit to the M&O Bureau Director, a Corrective Action Plan, which will identify specific corrective actions, resources required, persons responsible for completion, any CAR appeals, and target completion dates.
- Completion of the corrective actions in the Corrective Action Plan will be monitored by the Environmental Management Committee on a bimonthly basis. Completed actions will be deleted from the Corrective Action Plan when evidence of completion is provided.
- If necessary, the audit team may be asked by the Environmental Management Committee to conduct a follow-up review of corrective actions to ensure effective implementation.
- Any environmental policies or procedures that are revised as a result of the auditing process will be done so according to the Environmental Procedure Development procedure.

COMMUNICATION AND TRAINING

All environmental auditors, including outside contractors, will be trained on the contents of this procedure and Environmental Management Systems auditing standards (e.g., ISO 14010, 14011, and 14012) prior to conducting any audits.

The M&O Director will communicate to all M&O employees a general statement regarding the scope and purpose of environmental auditing at M&O, either in environmental awareness training or through other written or verbal communication, such as by memorandum or in Department or M&O newsletters.

EVALUATION

The Environmental Management Committee will conduct an annual evaluation of M&O's environmental audit program. A written report will be provided to the Chief Engineer summarizing the findings of the environmental audit program evaluation.

Table 20: Mass Highway Compliance Tracking Roles and Responsibilities

Role	Responsibility
Deputy Chief Engineer Environmental	Assumes ultimate responsibility to ensure proper tracking of compliance matters at the facilities.
DMEs	Responsible for ensuring that compliance matters are properly identified and corrected by District Personnel.
Supervisor of HazMat/HazWaste Unit	Responsible for ensuring those out-of-compliance matters are addressed as quickly as possible and that issues that cannot be corrected within 14 calendar days are properly reported to the Clean State Database. Requests compliance tracking data from the District HazMat Coordinators and the Audit Program Coordinator.
DHCs	Perform regular inspections that ensure the compliance matters are properly addressed at the facilities. Ensure proper review of weekly inspection reports submitted by the CSIII/Area Supervisors and or the CSII/Facility Foreman.
Audit Program Coordinator	Maintains a record of all Self-audits including the Corrective Action Reports and the Clean State Matters Reports. Upon request by the Supervisor of the HazMat/HazWaste Unit will produce a record of all compliance issues identified by the Self —Audit Program.

11.10. MAINE DOT CORRECTIVE ACTION REQUEST FORM

Figure 20: Maine DOT Corrective Action Request Form

Location: ___________________________ Number: __________________

Originator: __________________________ Date: ___________ Time: ____

Type:

 Internal Audit Consultant Outside Inspector/Auditor External Complaint

 Internal Complaint Other ________________________________

Entered by: ________________________________ Date: ______________ Phone:_____________

Process or activity where problem is noted: Relevant standard/procedure/instruction: ____

Condition found: Acknowledged by: ____ Date:________________

Corrective Action Plan: Target Date for Completion: ____________   Approved by: ____ Date:___________________

Maine Department of Transportation, Bureau of Maintenance and Operations **3/1999**

11.11. MASS HIGHWAY COMPLIANCE TRACKING METHODS

Example 24: Mass Highway Compliance Tracking Procedure for Facilities

Facility Inspections

Facility inspections are performed by Mass Highway personnel on a quarterly, bi-monthly or monthly schedule based upon the operations conducted at each facility. Facility personnel perform weekly inspections of facilities equipped with Hazardous Waste accumulation areas.

A facility designated for vehicle or heavy equipment repair will be inspected monthly whereas a seasonal snow and ice facility is inspected quarterly. These regular inspections permit Mass Highway to gather compliance information on a more frequent basis as compared to the self-audits. The results of these inspections are transmitted to the District Maintenance Engineer who facilitates the correction of any out-of-compliance issues. Corrections are coordinated between the DME the CS III, Facility Foreman and the DHC. The results of these inspections and the documented corrections are maintained at the District headquarters. The respective District HazMat Coordinator reports compliance matters that cannot be corrected within 14 days of identification to the Supervisor of the HazMat/HazWaste Unit. The Supervisor instructs the Mass Highway Clean State Database Coordinator to enter the matter into the database with a schedule for correction. Progress made on correcting the compliance matter is reported to the Clean State Database on a quarterly basis.

Routine Facility Observations
Mass Highway personnel are expected to keep facilities neat and generally adhere to good housekeeping practices. Furthermore, facility personnel are expected to report issues that may pose a potential compliance issue to their supervisor. Examples of potential issues that should be reported include but are not limited to the identification of dumping of materials in non-designated areas, missing spill equipment, spills and/or dripping fluids from containers and/or equipment.

Correcting Out-of Compliance Issues
Out-of Compliance situations that have been identified by way of Inspection, Self-Audit and/or Due Diligence must be corrected as soon as possible. Simple corrections such as replacing a label or closing a container should be made upon discovery. Corrections such as replacing broken or missing equipment, equipment repairs, and waste disposal should be made in a matter of days. Efforts should be made to resolve corrections requiring the use of outside contractors within 14 days of identification.

Tracking Compliance Matters
The Supervisor of HazMat\HazWaste Unit receives regular updates from the District HazMat Coordinators that identify any needed compliance corrections at the Facilities. This information is gathered from the regular facility inspections. The District HazMat Coordinators also maintain a log of compliance issues that require Environmental Section intervention. All issues that cannot be corrected within the 14 calendar period will be entered into the Clean State Database. Out-of-compliance issues from self-audits are tracked with the Audit Program Coordinator using the Corrective Action Report and the Clean State Matter Report. All issues that have not been corrected are entered into the clean state database.

Compliance Tracking Roles and Responsibilities
A summary of the roles and responsibilities for the Compliance Tracking Component is provided below.

11.12. MASS HIGHWAY COMPLIANCE TRACKING ROLES AND RESPONSIBILITIES

Table 21: Mass Highway Compliance Tracking Roles and Responsibilities

Role	Responsibility
Deputy Chief Engineer Environmental	Assumes ultimate responsibility to ensure proper tracking of compliance matters at the facilities.
DMEs	Responsible for ensuring that compliance matters are properly identified and corrected by District Personnel.
Supervisor of HazMat/HazWaste Unit	Responsible for ensuring those out-of-compliance matters are addressed as quickly as possible and that issues that cannot be corrected within 14 calendar days are properly reported to the Clean State Database. Requests compliance tracking data from the District HazMat Coordinators and the Audit Program Coordinator.
DHCs	Perform regular inspections that ensure the compliance matters are properly addressed at the facilities. Ensure proper review of weekly inspection reports submitted by the CSIII/Area Supervisors and or the CSII/Facility Foreman.
Audit Program Coordinator	Maintains a record of all Self-audits including the Corrective Action Reports and the Clean State Matters Reports. Upon request by the Supervisor of the HazMat/HazWaste Unit will produce a record of all compliance issues identified by the Self —Audit Program.

.

11.13. MASS HIGHWAY SELF-AUDIT PROCEDURE

Example 25: Mass Highway Self-Audit Procedure

This section presents an overview of the procedures and roles and responsibilities for conduct of Mass Highway Self-Audits. The actual Mass Highway Self-Audit Protocol Handbook is available for a detailed discussion of the procedures and roles and responsibilities. The procedures discussed below generally involve five Mass Highway staff members; the Audit Coordinator, the Lead Auditor, District Maintenance Engineer, the Facility Forman and the District HazMat Coordinator. There are three Phases to a Mass Highway Self-Audit; the Pre-audit Preparation, the Audit Site Visit and the Post Audit Phase. The process is described below.

Pre-audit Preparation. The Audit Coordinator prepares a schedule for facility audits. Once the schedule has been prepared, the Audit Coordinator will designate a DHC as the District Lead Auditor. The Lead Auditor will be a DHC from a District other than the one being audited. The Lead Auditors are provided with facility and District contact information needed to complete the self-audit notifications, site visit, and follow up reporting. The Lead Auditor will notify the DHC and DME in the District of the scheduled audit at least two weeks in advance of the audit. The DHC and DME will ensure pre audit questionnaires are completed, Facility foremen are contacted, and that facility records are made available at the time of the audit.

Audit Site Visit. The Lead Auditor will conduct a pre-audit briefing with facility personnel to 1) inform facility personnel of the purpose of the audit; 2) inform facility personnel of their audit responsibilities and required participation in the audit; and 3) answer any preliminary questions the facility personnel may have regarding the audit. After the briefing, the Lead Auditor conducts a facility walkthrough, recording any environmental compliance findings in field notes and facility plans. The Lead Auditor also performs a record review of applicable compliance documents, such as manifests and environmental permits. During the walkthrough and records review, the Lead Auditor completes the Audit Protocol Checklist. Findings that may be immediately corrected should be completed during the walkthrough and documented by the auditor. The Lead Auditor then conducts exit briefings and submits the draft findings list to the Facility Foreman at the completion of each audit. The list is provided so facility personnel may initiate corrective actions in advance of receiving a Corrective Action Report (CAR).

Post Audit Phase. Following the audit site visit, the Lead Auditor prepares a CAR, which summarizes the audit findings. An electronic version is forwarded to the Audit Coordinator and the DME. Upon receipt of the CAR, the DME coordinates with the facility foreman to ensure facility personnel conduct the necessary corrective actions. DHCs are responsible for correcting or managing corrective actions that fall outside operational responsibility of the Facility Foreman or DME.

The Facility Foreman ensures that the corrective actions have been completed and documents corrective actions in the space provided on the CAR. The completed CAR is forwarded to the Lead Auditor for review and confirms that the completed actions adequately address the findings on the CAR. The completed CAR is forwarded to the Audit Coordinator along with a memo that summarizes the completed self-audit.

For each unresolved regulatory finding, the Lead Auditor completes a Clean State Matter Report (CSMR). If a completed CAR has not been received within 14 days of the audit a CSMR is completed for all regulatory findings identified on the original CAR. Within two days of receiving the completed CAR, the Lead Auditor forwards all audit field notes, checklists, completed CAR, and CSMRs to the Audit Coordinator for archiving in the Environmental Section's Self-Audit Program files. The Audit Coordinator will enter all unresolved regulatory findings documented on the CSMRs into the EOEA's Clean State Database.

The Audit Coordinator provides the audit findings to the DHC. The DHC will complete and transmit to the Audit Coordinator and DME a Corrective Action Plan (CAP) for each unresolved regulatory finding on the completed CAR. The DHC will provide quarterly CAP progress reports to the Audit Coordinator until the CAP has been completely resolved. The Audit Coordinator will enter the updates into the Clean State database. Once a CAP has been completely resolved, the Audit Coordinator will complete and submit a request for de-listing of a regulatory finding from the EOEA's Clean State Coordinator and the Clean State database.

A summary of the timelines described in the preceding sections for conducting Self-Audits and audit follow-up activities is provided below.

Activity	Responsible Person	Timeline

Assign Audit Team and Lead Auditor	Audit Coordinator	According to Annual Schedule
Notify DHC, DME, and Facility foreman of impending Self-Audit	Lead Auditor	At least two weeks before audit site visit date
Complete and submit CAR to DHC, DME, and Foreman	Lead Auditor	Within two days after audit site visit.
Complete and submit CAR and CCAR to Lead Auditor	Foreman/DHC	Within 14 days of the date the audit was conducted
Complete audit summary memo and CSMRs and submit to Audit Coordinator	Lead Auditor	Within 1 week after receipt of CCAR or within 2 days of CCAR due date
Enter audit results into Clean State database and submit final CAR to DHC	Audit Coordinator	Within 2 weeks after receipt of CCAR from Lead Auditor
Complete Corrective Action Plan	DHC	Within 21 days after receipt of final CCAR from Audit Coordinator
Complete CAP Progress Reports	DHC	Quarterly — ongoing until Final CAP Completion Report issued
Update of Clean State database	Audit Coordinator	Quarterly — ongoing until Final CAP Completion Report issued

Mass Highway has a thorough system for performing environmental audits of maintenance facilities. This system and accompanying tools will be discussed in greater detail in the Facilities section. Checklist items cover hazardous waste, solid waste, water quality and natural resources, as follows, and include space to note comments and needed corrective actions:

11.14. Mass Highway Facility Self-Audit Checklist

Example 26: Mass Highway Facility Self-Audit Checklist

Hazardous Waste

1. Are all containers closed?
2. Are all containers labeled?
3. Is the waste compatible with the container and/or its liner?
4. Are containers holding ignitable or reactive wastes located at least 50 feet from the property line?
5. Is the accumulation area delineated?
6. Is the accumulation area posted with a sign?
7. Is secondary containment provided?
8. Is sand contained within a containment area?
9. Is salt contained indoors?
10. Are hazardous materials stored in appropriate locations?
11. Are hazardous materials stored in proper containers?
12. Are all hazardous material containers closed and labeled?
13. Are MDSS and right-to-know information prominently posted?
14. Are hazardous materials stored near floor drains?

15. Are all compressed gas cylinders properly sorted (labeled, capped, chained, or in rack)?
16. Are there any leaking vehicles/equipment present?
17. Are materials other than hazardous waste present in accumulation areas?
18. Is hazardous waste present outside the accumulation area?
19. If present, are satellite accumulation area requirements being met?
20. Are emergency contacts posted?
21. Does the facility have a supply of spill absorbents available?
22. Are weekly inspections being performed?
23. Are accumulation volume limits exceeded for the generator status?
24. For SQGS only: are hazardous wastes being stored for longer than 180 days?
25. Are all self-transporting two part receipts on file?

Solid Waste

1. Are bulk solid wastes stored in designated storage bins or segregated by type?
2. Are dumpsters and trash cans free of hazardous wastes, regulated recyclables, and universal wastes?
3. Is the facility free of litter?
4. Is solid waste accumulated in a natural resource area? (*refer to facility plan*)
5. Are there any decommissioned/ abandoned vehicles or equipment present?
6. Underground/aboveground storage tanks
7. Is there any evidence of spillage around tank fill ports or dispensing pumps?
8. Are required tank permits/registrations clearly posted at the facility?
9. For outdoor aboveground petroleum storage tanks: is secondary containment provided?
10. For aboveground storage tanks (including propane and calcium chloride tanks): are the tanks clearly placarded or labeled with their contents and NFPA ratings?
11. Are weekly stage ii vapor recovery inspections being performed?

Water Quality

1. Are garage floor drains clear of debris or obstructions and functioning properly?
2. Do floor drain sumps/troughs require sediment removal?
3. Is there evidence of oil or hazardous materials entering a floor drain or catch basin?
4. For wastewater recycling systems: are the systems functioning properly?
5. For wastewater tight tanks or recycling systems: does the tank or system need to be pumped?
6. Record current volume in tank or system.
7. Is there evidence of sand or sediment entering any catch basins or other drainage structures at the facility?
8. Is the oil/water separator functioning properly

Natural Resources

1. Are there any regulated wetland resource areas or waterways on or adjacent to the facility? (i.e. vegetated wetlands, banks, floodplains, land under water, and the riverfront area) *note: refer to the facility plan for confirmation.*
2. Are there activities occurring which are resulting in direct impacts to a wetland resource area or waterway? *Note: direct impacts include filling, excavating, dumping, or altering.*

3. Are there activities occurring which are resulting in indirect impacts to a wetland resource area or waterway? *Note: indirect impacts include erosion, sedimentation, or siltation.*
4. Are there activities occurring within the buffer zone that are resulting in direct or indirect impacts to any vegetated wetland or bank to a waterway?

11.15. MASS HIGHWAY ENVIRONMENTAL ROLES & RESPONSIBILITIES

Example 27: Mass Highway Environmental Roles & Responsibilities

Commissioner
The Commissioner is responsible for ensuring that Mass Highway's EMS is integrated as a fundamental part of daily operations and is supported by all managerial and supervisory levels of the Department. In doing so, the Commissioner's Office ensures the EMS is consistent with the Department's overall Mission Statement, Goals and Objectives; the facilitation of agreements with other Massachusetts State Departments including the Department of Environmental Protection; adequate EMS related funding and staff levels as recommended by the Chief Engineer.

Chief Engineer
The Chief Engineer ensures that the needs for staffing and resources for the sustainability of this EMS are defined and communicated to the Commissioner and that environmental policies and programs are effectively implemented and communicated by senior management. The Chief Engineer also ensures that the EMS is reviewed on a regular basis and that practical measures are implemented to improve its effectiveness.

Administrative Services Division
The Administrative Services Division provides Mass Highway EMS support in areas of Budget, Training, Safety, Information Technology Systems (ITS), and Personnel. A summary of the roles and responsibilities for the Administrative Services Division is provided below.

Projects Division
The Projects Division is responsible for ensuring that environmental laws and regulations are considered and properly addressed during the design phase of projects at Mass Highway facilities and directly supports all components of the Environmental Management System. The Projects Division consists of the following Sections; Bridge, Highway Design, Highway Administration, Right-of-way, Project Management and, Environmental. The Section primarily responsible for stewardship of the EMS is the Environmental Section.

Environmental Section
The Environmental Section provides expertise in interpretation of environmental regulations, compliance program development and implementation, compliance budget analysis, compliance inspection and reporting and environmental SOP/policy review and development. The Environmental Section supports the EMS with defined roles and responsibilities to maintain environmental compliance at facilities. Below is a summary of general Environmental Section roles and responsibilities. Specific roles and responsibilities are provided in the descriptions of the individual EMS components of this manual.

11.16. MASS HIGHWAY ENVIRONMENTAL SECTION EMS ROLES AND RESPONSIBILITIES

Table 22: Mass Highway Environmental Section EMS Roles and Responsibilities

Role	Responsibility
Deputy Chief Engineer Environmental	Responsible for managing the Sections roles and responsibilities relative to this EMS; ensures that the EMS review is conducted and continual improvements are made within the Division.
Supervisor of HazMat /HazWaste Unit	Serves as the steward for the EMS. Responsible for the accuracy of the manual and its specific components including funding, Emergency Preparedness, Environmental Requirements, SOPs, Facility Handbook, Training, Compliance Tracking and, Self-Auditing, and EMS Review. Coordinates and facilitates programs including Hazardous

	Waste, Wetlands, Hazardous Materials, Tanks, Water Quality, Solid Waste, and Massachusetts Contingency Plan. Assigns tasks to Section personnel to ensure compliance with State and Federal regulations. Maintains current Environmental Requirements List; arranges quarterly meetings with regulatory agencies; assists the Deputy Chief Engineer Environmental with EMS review process.
Audit Coordinator	Ensures that the Self -Audit Program functions in accordance with the Mass Highway Self Audit Protocol. Performs regular review of the program and recommends modifications in accordance with changes in Mass Highway's operations at Facilities.
Training Coordinator	Administers Environmental Training Program by maintaining a current list of required training and notifies respective staff of upcoming training. Coordinates submittal of training registration documentation. Maintains training records for Environmental Section.
EMS Task Force	Participates in the annual EMS Review and evaluation process.
Supervisor of Wetlands and Water Quality	Manages NOI and RDA process; obtains and tracks Order of Conditions; file Completeness Reports; oversees Departments compliance with stormwater regulations. Ensures corrective actions are implemented to comply with the Massachusetts Wetland Regulations and Administrative Consent Orders.
District HazMat Coordinators	Play key roles in implementation of EMS component programs including Requirements, Self-Audits/Inspections, Emergency Preparedness, Environmental Training, and SOP programs. May arrange for inspection of systems (septic systems, holding tanks, oil/water separators, and vehicle wash recycling systems). May arrange for disposal of wastewater; forward water usage reports to Supervisor of HazMat/HazWaste Unit; ensures that monitoring wells are inspected, permits/as-built plans are kept at facilities, compliance with permit-specific requirements, inspects for presence of appropriate backflow prevention devices on drinking water sources/cross connections; conducts regular inspections of facilities, assists in obtaining Material Safety Data Sheets, assists in identification of unknown roadside materials; prepares Tier II Reports; manage MCP consultant contracts and provide MCP technical assistance; assists Supervisor of HazMat HazWaste Unit with on-site observation of contractor work; sign MCP submittal certifications; maintain hazardous waste generator registration and manifest files; arrange/notify when waste disposal is required; arrange for removal of unknown/roadside wastes; develop and conduct annual environmental awareness training; review options for street sweeping disposal; conduct facility audits.
Boston HazMat Staff	Play key roles in implementation of EMS components including Environmental Requirements, Environmental Training, and SOPs. Manage contracts and timelines to support compliance with environmental requirement, EMS support programs and administrative consent orders; submit reports that track compliance progress to DEP and EPA. Track the status and provide guidance on permit renewal and assist as needed to ensure Mass Highway remains in compliance with applicable permits. Manage MCP consultant contracts; assist supervisor of HazMat/HazWaste Unit with MGL ch. 21E and the MCP tank permitting; manage Stage II Vapor Recovery forms/documentation; assist with NOI and RDA process.

Right-of-way Section

The Right-of-way (the Section) is responsible for ensuring that properties being considered for purchase by Mass Highway for use as facilities receive proper real estate assessment for the identification of environmental compliance liabilities. The Section is also responsible for ensuring that facility properties receive canvassing by Mass Highway Environmental staff prior to disposition.

Operations Division

The Operations Division is responsible for the implementation of the EMS to ensure that Districts/facilities receive proper personnel and contract support to ensure compliance with environmental regulations, Mass Highway SOPs and policies and, Administrative Consent Orders. The Operations Division is responsible for ensuring that all permits are secured for construction and improvement activities at the depot facilities and that copies of all permits are forwarded to the Projects Division/Environmental section. This applies to existing Units within Operations: Highway Maintenance, and Traffic Engineering and Operations. For the purpose of the EMS, Operations pays particular attention to current facility operations, proposed facility improvements and, lease agreements involving Mass Highway facilities. Operations staff ensures that the EMS is properly implemented at maintenance buildings and Draw Bridges. A summary of roles and responsibilities for the Operations Division staff is presented below.

11.17. MASS HIGHWAY OPERATIONS DIVISION EMS ROLES AND RESPONSIBILITIES

Table 23: Mass Highway Operations Division EMS Roles and Responsibilities

Role	Responsibility
Deputy Chief Engineer Operations	Ensures that the EMS review is conducted and continual improvements are made within the Division to ensure compliance with the EMS related to facility operations.
Operations Engineer	Ensures proper support of the EMS from the Highway Maintenance Unit (Snow and Ice, Communications, Structure Maintenance, Facilities); Equipment and Materials (Central Stockroom in Franklin, Heavy Equipment maintenance, repair, storage and auctions, Truck and Car fleet, Medford Sign Shop, Paint Crew (long Lines), Fuel Management; Traffic Engineering and Operations; ITS Programs (HOV Lane). Obtains and ensures compliance with applicable permits for Operation's facilities. Responsible for implementation of the EMS and environmental compliance for Line Painting operations including cleaning of painting equipment without releasing cleaning residuals into the environment and ensures proper storage of any hazardous material and/ or wastes. Ensures that the foreman of each paint crew coordinates environmental related activities with the respective Facility Foreman to ensure environmental compliance.
	Provides contract support and guidance to Unit and District maintenance personnel in such a manner that supports compliance with the EMS. The ensures that personnel are aware of Mass Highway Environmental Standard Operating Procedures, Policies, Administrative Consent Orders and environmental regulatory requirements. Ensures that facility project designs include proper environmental permitting in accordance with Federal and state regulations. Ensures that provisions are included for the operation of completed designs in accordance with issued environmental permits.

Construction Division

The Construction Division is responsible for ensuring that environmental laws and regulations are considered and properly addressed during construction of projects on Mass Highway facilities.

Research and Materials Testing Laboratory

The Research and Materials Testing Laboratory is responsible for ensuring that the laboratory is operated in accordance with federal and state regulations and Mass Highway's SOPs in support of Mass Highway's EMS.

EMS Task Force

The EMS Task Force is composed of representatives of Offices, Divisions, Districts, and Sections. The Task Force provides input to the Annual EMS Review and Evaluation Process.

Districts

The Districts are responsible for the implementation of the EMS at District facilities and to ensure that operations at facilities are in compliance with environmental regulations and Mass Highway SOPs. A summary of District EMS roles and responsibilities for facility compliance is provided below.

11.18. Mass Highway District EMS Roles and Responsibilities

Table 24: Mass Highway District EMS Roles and Responsibilities

Role	Responsibility
District Highway Director	The District Highway Director is responsible for being familiar with and overseeing the implementation of the provisions of the EMS such that the District's roles and responsibilities are carried out in such a manner so as to maintain environmental compliance.
District Maintenance Engineer	The District Maintenance Engineer (DME) must maintain an awareness of the EMS and is responsible for coordinating facility maintenance activities in accordance the procedures of the EMS Manual. This includes ensuring that facility personnel are allotted sufficient time to perform house keeping tasks that support environmental compliance and notifying appropriate Mass Highway personnel of an emergency situation at facilities in accordance with Mass Highway' s Emergency Response Plan (ERP) and Spill Prevention Control and Countermeasure (SPCC) Plans at specific facilities. Obtains and ensures compliance with all applicable permits for District facilities.
Contract Specialist III's/Area Supervisor	The Contract Specialist III/Area Supervisor (CS III/AS) ensures that: all personnel within the Area receive yearly Annual Environmental Awareness Training; facility inspections are conducted and that corrective actions are completed as required; EMS and Environmental Program documentation (generated by Facility Foreman and personnel) such as regular inspection checklists, Stage II Vapor recovery system checklists, Hazardous Waste area inspections checklists and oil/water separator inspection reports are forwarded to the District Maintenance Engineer. Responsibilities also include: review and submittal of the facility inspection reports/self-audit findings to the DME and initiating corrections as required; scheduling work as needed at facilities to maintain compliance including: septic system pump-outs, septic system inspections, vehicle washing recycling system maintenance and holding tank and oil/water separator pump-outs. The CS III/AS is also the designated Primary Emergency Coordinator as defined by Mass Highway's Emergency Response Spill Plan.
Contract Specialist II's/Facility Foreman	The Contract Specialist II/ Facility Foreman (CSII/FF) is responsible for ensuring that all operational activities that impact environmental compliance at District Facilities are conducted in accordance with the EMS and specifically with the provisions of the Facility Environmental Handbook. This includes maintaining proper areas for material and hazardous waste storage; using the emergency response call down procedures; adhering to guidelines presented in the Annual Environmental Awareness Training; staying current with the Environmental Standard Operating Procedures and being familiar with the location of wetlands, buffer zones and other areas of environmental concern.
Facility Personnel	The Facility Personnel are responsible for keeping work areas clean and materials and wastes stored properly, performing inspections on the Hazardous Material and Hazardous Waste storage areas, maintaining labels on material and waste containers, reporting spills of hazardous materials from machinery and heavy equipment and, attending annual refresher training related to environmental compliance.
Director of Equipment and Materials	Provides for EMS compliance at the Central Stockroom relative to proper hazardous material storage, appropriate HazMat labeling/signage, and proper management of Material Safety Data Sheets. Purchases materials that support EMS such as absorbents (pads, booms, Speedi-dri) spill kits for distribution to District stockrooms, and maintains an effort to purchase environmentally preferred products whenever practical. Ensures an adequate supply of fuel equipment such as nozzles and hoses that comply with the Department's current fueling system. Provides for the support of the Department fuel management system; perform testing, inspection and reporting of storage tanks and monitors storage

	tank leak detection systems. Ensures that decommissioned vehicles are stored in a manner that supports compliance with the Departments SOPs, and this EMS.

11.19. Mass Highway Training Expectations By Role

Table 25: Mass Highway Training Expectations By Role

Training	Regulation and Requirement	Participants	Delivery
Hazardous Waste Awareness Training	310 CMR 30.351(9)(g) Employees having responsibility for handling/managing hazardous waste at SQG facilities must be properly trained so they know how to perform their duties and so that hazardous waste handling practices and emergency procedures are performed properly and in compliance with all applicable requirements. Employees are provided initial training to a competency level with refresher training as necessary.	District Structures Maintenance Engineer, CSIII/Area Foreman, HOV Facility Personnel, CSII/Facility Foremen, Facility Personnel District HazMat Coordinators	Training provided during annual Environmental Awareness Training by DHCs
Universal Waste Training	310 CMR 30.1035 Employees having the responsibility for handling or managing universal waste shall be informed of the proper handling and emergency procedures appropriate to the types of universal waste handled at the facility. Employees are provided initial training to a competency level with refresher training as necessary.	District Structures Maintenance Engineer, CSIII/Area Foreman, HOV Facility Personnel, CSII/ Facility Foremen, Facility Personnel, District HazMat Coordinators.	Training provided during annual Environmental Awareness Training by DHCs
Department of Transportation General Awareness, Manifest, and Safety Training Programs	49 CFR 172.704(a) 310 CMR 30.409 Each hazmat employee shall be provided 1) general awareness training designed to provide familiarity with the requirements of this subchapter, and to enable the employee to recognize and identify hazardous materials consistent with OSHA Hazard Communication Standard (29 CFR 1910.1200). OSHA or EPA training may be used to satisfy the requirements of 49 CFR 172.704(a) to avoid duplication of training efforts; 2) function specific training concerning the requirements of the DOT hazardous waste regulations specific to the function the employee performs; 3) safety training concerning emergency response information, measures for protection from the hazards associated with hazardous materials, and methods and procedures for avoiding accidents. Employees are provided initial training to a competency level with refresher training every 3 years thereafter.	District HazMat Coordinators, CSII/Facility Foreman	Training coordinated by Environmental Division and conducted through a consultant contract

Stage II Vapor Recovery System Inspection Training	310 CMR 7.24 Persons performing Stage II systems weekly inspections must be trained to inspect equipment including, but not limited to, nozzle boots and splash/vapor guards, hoses, hose retractors, coaxial adapters, dry breaks, fill caps, vapor recovery caps, spill containment boxes and drain valves. Employees are provided initial training to a competency level with refresher training as necessary.	CSIII, Foremen, Laborers	Training is provided by the DHCs.
Spill Prevention Control and Countermeasure (SPCC)	40 CFR 112.7(e)(10) (iii) Employees shall be trained in the use of the SPCC, applicable pollution control laws and the operation and maintenance of equipment to prevent the discharges of oil. Employees are provided initial training to a competency level with annual refresher training.	Employees having a role in the SPCC plan for a facility	Training provided during annual Environmental Awareness Training by DHCs

Roles and responsibilities accompanying the training program are as follows:

11.20. Mass Highway Environmental Training Program Roles and Responsibilities

Table 26: Mass Highway Environmental Training Program Roles and Responsibilities

Role	Responsibility
Deputy Chief Engineer Environmental	Assumes ultimate responsibility for managing the Environmental Training Program
Operations Engineer, Maintenance Engineer, District Maintenance Engineer	Responsible for ensuring appropriate personnel attend environmental training programs relative to their roles and responsibilities within the EMS and maintaining training attendance records for Boston Operations staff assigned to Central Stockroom in Franklin, Paint Crews stationed in Deerfield, Reading, and Bridgewater Facilities.
DMEs	Responsible for ensuring appropriate personnel attend environmental training programs relative to their roles and responsibilities within the EMS and maintaining training attendance records for District Operations staff.
Projects Division Training Coordinator	Responsible for developing an annual budget for submission to Administrative Services, coordinating the training schedule, ensuring contracts are in place for training consultant services and conducting the annual review of the training program in accordance with the EMS.
Supervisor of HazMat\HazWaste Unit	Responsible for the approval of training program content revisions.
DHCs	The DHCs develop and deliver the Annual Facility Environmental Awareness Training program and initial SPCC training within their District and participate in the annual review of the environmental training program.
Environmental Staff	Environmental staff annually reviews the environmental training programs to determine if regulatory or operational changes necessitate revisions to the program. Share training

	materials over the MHD intranet.
EMS Task Force (Admin, Ops, Project, & Construction Divs.)	Provides comment and guidance to the Environmental Section, Safety Unit and Incident Response Unit relative to the feasibility and content of environmental training programs.
Safety Unit	Develops and presents the Right-to-Know Training.
Administrative Services	Identifies environmental training budgetary needs as part of the operations budget, communicates the availability of funding to the Environmental Section, and maintains training documentation for the Department.
ITS	Posts PowerPoint presentations onto the Mass Highway intranet.

11.21. PennDOT District 10 SEMP Responsibility Table

Table 27: PennDOT District 10 Strategic Environmental Management Program Responsibility Table

Working Title	**Responsibility Statement (refer to Section 6. of the Job Description)**
District Engineer	**Directs activities to fulfill the maintenance environmental requirements described or referenced in the District's Strategic Environmental Management Program (SEMP) Manual for Sound Environmental Practices. This direction of activities includes efforts to ensure that, within the fiscal constraints imposed through the Department's budgetary processes, resources are made available to fulfill the District's SEMP commitments and objectives. As a member of the District's Strategic Management Committee (SMC) performs the activities to fulfill the requirements identified for members of the SMC in the District's SEMP Development and Implementation Manual.** **Directs activities to fulfill the District's SEMP-related business plan objectives.** **Attends environmental training identified for this Working Title and for members of the SMC in the District's SEMP Manual for Sound Environmental Practices.**
ADE Maintenance	**Plans, organizes, and directs activities to fulfill the maintenance environmental requirements described in the Maintenance, MORIS, and Bridge Maintenance Manuals, and identified for this Working Title in the District's Strategic Environmental Management Program (SEMP) Manual for Sound Environmental Practices. This planning, organization, and direction of activities includes efforts to ensure that, within the fiscal constraints imposed through the Department's budgetary processes, resources are made available to fulfill the District's SEMP commitments and objectives. As a member of the District's Strategic Management Committee (SMC) performs the activities to fulfill the requirements identified for members of the SMC in the District's SEMP Development and Implementation Manual. Also fulfills the environmental management requirements designated for this title in environmental training programs.** **Implements the SEMP-related maintenance unit business plan objectives designated for this title. Supports the efforts of other managers and employees to implement the SEMP-related maintenance unit business plan objectives.** **Attends environmental training identified for this Working Title and for members of the SMC in the District's SEMP Manual for Sound Environmental Practices.**
County	**Manages, plans, and organizes county roads maintenance activities to fulfill the environmental management requirements identified in the Maintenance, MORIS,**

Maintenance Manager	**and Bridge Maintenance Manuals and designated for this title in the District's Strategic Environmental Management Program (SEMP) Manual for Sound Environmental Practices. This management, planning, and organization of activities includes efforts to ensure that, within the fiscal constraints imposed through the Department's budgetary processes, resources are made available to fulfill the District's SEMP commitments and objectives. Receives new information for or revisions to the District's SEMP Manual for Sound Environmental Practices from the District SEMP Process Owner, incorporates this information in each county and stockpile copy of the District's SEMP Manual for Sound Environmental Practices, and implements the new or revised SEMP procedures, processes, or tools. Also fulfills the environmental management requirements designated for this title in environmental training programs.** **Implements the SEMP-related maintenance unit business plan objectives designated for this title. Supports the efforts of other managers and employees to implement the SEMP-related maintenance unit business plan objectives.** **Attends environmental training designated for this title in the District's SEMP Manual for Sound Environmental Practices.**
Transportation Equip. Operator B **Transportation Equip. Operator A** **Temp. Equip. Op.A** **Hwy Maint. Worker** **Hwy. Sign Worker** **Carpenter** Mason	**Implements the environmental protection requirements of maintenance work activities performed by the employee. Also fulfills the environmental management requirements designated for this title in environmental training programs.** **Recognizing that everyone is involved in the District's and County's actions to demonstrate sound environmental practices, each employee fulfills the maintenance unit business plan objectives related to the Strategic Environmental Management Program (SEMP). Also, supports the efforts of other employees to meet these objectives.** **Attends environmental training designated for this position in the District's *SEMP Manual for Sound Environmental Practices*.**

Table from PennDOT District 10's Strategic Environmental Management Program Manual

11.22. PennDOT District 10 SEMP Training Table

Figure 21: PennDOT District 10 Strategic Environmental Management Program Training Table

	Working Title	Environmental Awareness	Stockpile/Facilities Academy	Stockpile/Facilities Refresher	E&S Control	E&S Control Refresher	Winter Services	Spring Maintenance Meeting	Fall Maintenance Meeting	New Employee Orientation Prog.	First Responder/Incident Response
		Training Programs									
County Maintenance Unit	County Maintenance Manager	×	×	×	×	×	×	×	×	×	×
	Assistant Maintenance Manager	×	×	×	×	×	×	×	×	×	×
	Highway Foreman I, II, and III	×	×	×	×	×	×	×	×	×	×
	Transportation Equipment Operator B	×	×	×	×	×	×	×	×	×	×
	Transportation Equipment Operator A	×	×	×	×	×	×	×	×	×	×
	Temporary Equipment Operator A	×	×	×	×	×	×	×	×	×	×
	Highway Maintenance Worker	×	×	×	×	×		×	×	×	×
	Highway Sign Worker	×	×	×	×	×		×	×	×	×
	Carpenter	×	×	×	×	×		×	×	×	×
	Mason	×	×	×	×	×		×	×	×	×
	County Equipment Manager	×	×	×	×	×	×	×	×	×	×
	Mechanic Supervisor	×	×	×	×	×		×	×	×	×
	Automotive Mechanic	×	×	×	×	×		×	×	×	×
	Equipment Body Repairer Painter	×	×	×	×	×		×	×	×	×
	Maintenance Repairman	×	×	×	×	×		×	×	×	×
	Tradesman Helper	×	×	×	×	×		×	×	×	×
	Semi-skilled Laborer	×	×	×	×	×		×	×	×	×
	Welder	×	×	×	×	×		×	×	×	×
	Diesel Mechanic	×	×	×	×	×		×	×	×	×
	Custodian	×	×	×	×	×		×	×	×	×
	County Roadway Programs Coordinator	×	×	×	×	×	×	×	×	×	×
	Chief Clerk	×						×	×	×	
	Roadway Programs Technician (RPT)	×						×	×	×	
	Radio Operator	×							×	×	
	Stock Clerk	×						×	×	×	
	Accounting Assistant	×								×	
	Purchasing Agent	×						×	×	×	
	Clerical Staff	×								×	

Table from PennDOT District 10's Strategic Environmental Management Program Manual

11.23. NYSDOT CONSTRUCTION/ENVIRONMENTAL TRAINING SCHEDULE

Table 28: NYSDOT Construction Environmental Sample Training Schedule

Region	Topic(s)	Presenter(s)	Audience (#)	Date(s)
1a.	Environmental and Landscape Permits, Issues and Practices - SEQR, Wetlands, SPDES, ECOPAC, Tree Preservation, Landscaping Enhancements	D. Hitt, D. Goetke, M. Manosh, R. Ambuske, D. Graves, C. Schleede	EICs	1/28/03
2a.	General Environmental Awareness, West Nile, SPDES, Waste Areas	E. Warner, E. Frantz, DEC	Winter Construction Meeting (80)	3/12/03
3a.	Erosion and Sediment Control, Tank Removal, Haz Waste, Asbestos, ECOPAC, SPDES, Waste Areas, Lead Paint (7.5 hrs)	R. Steele, C. Anderson, H. Koslowsky	Construction Staff and Contractors(25)	2/10/03 3/10/03 4/10/03 4/25/03
3b.	Erosion and Sediment Control, SPDES, Waste Areas (1 hr)	R. Steele	Contractors (50)	3/14/03
3c.	Haz Waste (1 hr)	R. Steele, M. Brophy	Bainbridge Residency (20)	3/18/03
3d.	Hazcom for NYSDOT (1 hr)	R. Steele		March
4a.	Disposal of Surplus Material-BMPs (1 hr)	T. Martin	AGC/DOT Conference (50)	12/11/02
4b.	Disposal of Surplus Material-BMPs (1 hr)	T. Martin	MEC/CEC Statewide Meeting (60)	1/17/03
4c.	Disposal of Surplus Material-BMPs (1 hr)	T. Martin	New EIC Training (40)	2/7/03
4d.	SPDES, Section 209 (1 hr)	T. Martin	EIC/Field Staff Winter Training (100)	2/26/03
4e.	Solid and Haz Waste Regs (30 min)	T. Martin	LAB/EAB Conference(25	3/6/03
4f.	Haz Waste Manifests (45 min)	T. Martin	EIC/Field Staff Winter Training (55)	3/13/03
5a.	Environmental Ethic, Wetlands, Streams, Water Quality, MBTA, Erosion and Sediment Control, Cultural resources, Asbestos, Noise, Air Quality, Trees & Planting, Curb, Ramps,	Shepherd, NYSDEC, Wheeler, Jones, Kluck,	Construction Inspectors School (75)	2/10/03 2/18/03 2/28/03

	Pedestrians	Christner, Tackley		
5b.	Same as above with emphasis on E&SC and Contractor Responsibilities	J. Shepherd	Contractor (20)	2/27/03
5c.	Same	J. Shepherd	EIC Annual Training (55)	3/13/03
6	SPDES Phase 2 Construction Permit (At So. Tier Reg Planning Board Conference)	T. Markel, NYSDEC	Town Highway Superintendent	4/10/03
8a-c	Erosion and Sediment Control, SPDES, 209 Revisions (2 hr)	J. Ayers, J. Fogietta	EICs and Inspectors(100	1/28, 29 & 30/03
8d-g	Erosion and Sediment Control (1 hr)	J. Ayers, S. Davis	Residency Maintenance Staff (110)	2/24-27
10	Environmental Awareness, SPDES, Erosion and Sediment Control, etc	L. Star	EIC Annual Mtg (45)	2/4/03

11.24. PennDOT Stockpile Quality Assurance Responsibilities

Example 28: PennDOT Stockpile Quality Assurance Responsibilities

Foremen

- Decide when walkaround best fits his/her schedule for the week (1 required per/week)
- Discuss his vision with all crew members
- If feasible, select one or two crew members to join him
- Check all items on payroll checklist and documents
- Check any other noticeable deficiencies and records in payroll remarks section
- Address any safety problems immediately if possible
- Report any safety problems unable to be addressed immediately to ACM
- Take care of any deficiencies he is able to during walkaround
- Finish walkaround and reports to his planned activity for that day
- Charge stockpile code for time spent doing inspection

Crew members

- Participate in walkaround with foreman and helps him/her address any deficiencies
- Get first hand knowledge what stockpile deficiencies are being looked for
- Get clear idea of what his role is when it comes to stockpile maintenance
- Carry what he/she has learned to other crew members throughout our organization

Assistant County Maintenance Manager

- Ensures that foreman is completing his weekly stockpile walkaround
- Addresses any stockpile safety needs foreman is unable to complete immediately

- Supports foreman when planning to address stockpile deficiencies
- Ensures county manager receives periodic progress reports

County Maintenance Manager

- Addresses any decision assistant county manager is unable to make
- Supports all levels and encourages everyone's participation to reach a common goal and vision

11.25. PennDOT 15-Minute Stockpile Walkaround

Example 29: PennDOT 15-Minute Stockpile Walkaround Checklist

1. Are all salt & mixed materials stored under a permanently roofed building ?
2. Is the salt loaded properly (at the front & sides of the storage structures)?
3. Have all visible signs of salt trailing away from the storage area been cleaned up?
4. Is water directed away from the entrances of the salt storage buildings?
5. Are all stored materials grouped together in separate areas with proper signs posted?
6. Are all drums & containers properly labeled & stored?
7. Are all compressed gas cylinders stored properly?
8. Do above ground storage tanks have proper containment?
9. Are confiscated or abandoned vehicles stored properly on the site (on paved pad)?
10. Is the equipment wash facility operating properly?
11. Are oil/water separators properly maintained?
12. Is there a stormwater management system in place & is it functioning properly?
13. Is the PPC Plan on site & updated within the past year?
14. Is the landscaping neatly maintained?
15. Are all required signs properly posted?
16. Have all necessary permits been updated & displayed?
17. Are all gates, locks & fences in place & in good repair?
18. Are all shingles in place on roofed structures?
19. Are all buildings & structures completely intact & damage free?
20. Are all of the buildings completely free of pigeons & other animals?
21. Do all buildings have proper identification signs & presentable paint jobs?
22. Are gutters & downspouts clear, free flowing, damage free & direct water away from buildings?
23. Have all fire extinguishers been identified by signs, inspected, and charged?
24. Is the safety station properly equipped?
25. Are the exhaust systems operating properly?
26. Are the proper clean sanitary facilities provided?
27. Is the site clear of trash & litter?
28. Are all of the lighting systems working properly?
29. Are all of the lightning rods & electrical systems damage free & working properly?
30. Are the truck heater outlets installed properly & operating with cords used or stored properly?

31. Has the emergency generator been tested in the last seven days?

11.26. PennDOT Stockpile Snapshot

Example 30: PennDOT Stockpile Snapshot

1. All salt and salt premix materials stored inside a roofed structure?
2. Is the area around the entrance and inside the salt building water free?
3. Are there visible signs of salt trailing away from the salt building?
4. Are all buildings and structures completely intact and damage-free?
5. Are shingles missing from the roof of the salt building?
6. Are gutters and downspouts functioning properly and damage free?
7. Is there proper secondary containment of above ground storage tanks?
8. Do all buildings have proper ID signs and presentable paint jobs?
9. Is premix covered or under roof?
10. Is the site clean and litter free?
11. Are all gates, locks and fences completely intact? If no one is present are they locked?
12. Are all materials and entrance properly signed?
13. Is the landscaping properly maintained?

11.27. PennDOT Maintenance Stockpile Activity Protocol

Example 31: PennDOT Maintenance Stockpile Activity Protocol

MAINTENANCE STOCKPILE ACTIVITY PROTOCOL					
Maintenace Activity	Facility Component	Protocol for Specified Tasks			
		Task	Timeframe	Responsible Person	Reference
GENERAL AND PREVENTIVE	ROOF	INSPECT	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	ROOF	REPAIR	AS NEEDED	ACM	County Br. Crew/Contractor
	GUTTERS & DOWNSPOUTS	INSPECT	SEMI-ANNUALY (APRIL & OCTOBER)	FOREMAN	Visual/ Foreman Checklist
	GUTTERS & DOWNSPOUTS	REPAIR	AS NEEDED	ACM	Contractor/ Br. Crew
	WINDOWS	INSPECT	ANNUALLY	FOREMAN	Visual/ Foreman Checklist

	WINDOWS	REPAIR	AS NEEDED	ACM	Contractor
	LOCKS	INSPECT	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	LOCKS	REPAIR	AS NEEDED	ACM	Contract/Br. Crew/Crew
	DOORS	INSPECT	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	DOORS	REPAIR	AS NEEDED	ACM	Contract/Br. Crew/Crew
	OVERHEAD DOORS	SAFETY INSPECTION	ANNUALLY	EQ MANAGER OR CONTRACTOR	Visual/ Manufactures Specifications
	OVERHEAD DOORS	LUBRICATE	ANNUALLY		
	OVERHEAD DOORS	PAINT	AS NEEDED		
	OVERHEAD DOORS	REPAIR	AS NEEDED	EQ MANAGER	Contract/Bridge Crew/ Painter
	SIGNS	INSPECT	ANNUALLY	FOREMAN/CREW	Visual/QA/Foreman Checklist
	SIGNS	REPAIR/ REPLACE	AS NEEDED	FOREMAN	Sign Crew
	LUMINAIRES	INSPECT	SEMI-ANNUALY (APRIL & OCTOBER)	FOREMAN/CREW	Visual/QA/Foreman Checklist
	LUMINAIRES	REPAIR	AS NEEDED	ACM/FOREMAN	Contract/Crew
	FIRE EXTINGUISHER	INSPECT	SEMI-ANNUALY (APRIL & OCTOBER)	FOREMAN	Visual/QA/Foreman Checklist
	FIRE EXTINGUISHER	RECHARGE	AS NEEDED	ACM	Contractor
	PAVED AREAS(PARKING, PADS)	INSPECT SEALING	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	PAVED AREAS(PARKING, PADS)	REPAIR	AS NEEDED	ACM	Seal Crew

MAINTENANCE STOCKPILE ACTIVITY PROTOCOL					
Maintenace Activity	Facility Component	Protocol for Specified Tasks			
		Task	Timeframe	Responsible Person	Reference

GENERAL AND PREVENTIVE	PAVED AREAS(PARKING, PADS)	INSPECT	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	PAVED AREAS(PARKING, PADS)	REPAIR	AS NEEDED	ACM	Paving Crew/Contract
	PAVED AREAS(PARKING, PADS)	CONDUCT SWEEPING AND FLUSHING	AS NEEDED	FOREMAN	Visual/QA/Foreman Checklist/Crew
	PAVED AREAS(PARKING, PADS)	CONDUCT SWEEPING AND FLUSHING	AS NEEDED	FOREMAN	Crew
	NON PAVED AREAS	INSPECT GRADING & SHAPING	SEMI-ANNUALY (APRIL & OCTOBER)	FOREMAN	Visual/ QA/ Foreman Checklist
	NON PAVED AREAS	REPAIR GRADING	SEMI-ANNUALY (APRIL & OCTOBER)	FOREMAN	Crew
	NON PAVED AREAS	DUST CONTROL	AS NEEDED	FOREMAN	Visual/QA/Foreman Checklist
	NON PAVED AREAS	APPLY DUST CONTROL	AS NEEDED	ACM	Specialized Crew
	BUILDING EXTERIOR	INSPECT PAINTING	ANNUALLY	FOREMAN/ACM	Visual/QA/Foreman Checklist
	BUILDING EXTERIOR	REPAIR	AS NEEDED	ACM	Contract/Crew
	BUILDING EXTERIOR	INSPECT PAINTING	ANNUALLY	FOREMAN/ACM	Visual/QA/Foreman Checklist
	BUILDING EXTERIOR	REPAIR	AS NEEDED	ACM	Contract/Crew
HOUSEKEEPING	INTERIOR OF FACILITY	GENERAL CLEANING & SWEEPING	DAILY	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	INTERIOR OF FACILITY	GENERAL CLEANING & SWEEPING	DAILY	FOREMAN/ CREW	Crew
	INTERIOR OF FACILITY	PROPER STORAGE FLAMABLES	DAILY	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	INTERIOR OF FACILITY	PROPER STORAGE FLAMABLES	DAILY	FOREMAN/ CREW	Crew
	EXTERIOR OF FACILITY	PICK UP LITTER	DAILY	FOREMAN/ CREW	Visual
	EXTERIOR OF FACILITY	PICK UP LITTER	DAILY	FOREMAN/ CREW	Crew

	EXTERIOR OF FACILITY	PROPER ENTRANCE SIGNING	AS NEEDED	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	EXTERIOR OF FACILITY	PROPER ENTRANCE SIGNING	AS NEEDED	FOREMAN/ CREW	Crew
	EXTERIOR OF FACILITY	GATE LOCKED	DAILY	FOREMAN/ CREW	Visual
	EXTERIOR OF FACILITY	LOCK THE GATE	DAILY	FOREMAN/ CREW	Crew

MAINTENANCE STOCKPILE ACTIVITY PROTOCOL

Maintenace Activity	Facility Component	Protocol for Specified Tasks			
		Task	Timeframe	Responsible Person	Reference
HOUSEKEEPING	EXTERIOR OF FACILITY	FENCING	ANNUALLY	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	EXTERIOR OF FACILITY	REPAIR	AS NEEDED	ACM	Contract/Crew
	EXTERIOR OF FACILITY	PILES MARKED	DAILY	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	EXTERIOR OF FACILITY	MARK PILES	DAILY	FOREMAN/ CREW	Crew
	EXTERIOR OF FACILITY	SPILLS CLEANED UP	DAILY	FOREMAN/ CREW	Visual
	EXTERIOR OF FACILITY	CLEAN UP SPILLS	DAILY	FOREMAN/ CREW	Crew
	STORAGE AREA PIPE	SIGNED & NEAT	DAILY	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	STORAGE AREA PIPE	SIGNED & NEAT	DAILY	FOREMAN/ CREW	Crew
	STORAGE SHED	NEAT & SPILL KIT	DAILY	FOREMAN/ CREW	Visual/QA/Foreman Checklist
	STORAGE SHED	NEAT & SPILL KIT	DAILY	FOREMAN/ CREW	Foreman/ Store room
	STORAGE SHED	CONDITION/ APPEARANCE	INSPECT	FOREMAN/ ACM	Visual/QA/Foreman Checklist
	STORAGE SHED	REPAIR/ REPLACE	AS NEEDED	ACM	Contractor/ Br. Crew
LANDSCAPING	FLAG POLE	INSPECT	DAILY	EQ. MANAGER	Visual/QA/Foreman Checklist
	FLAG POLE	REPAIR	AS NEEDED	EQ. MANAGER	Welder
	FLAGS	INSPECT	DAILY	EQ. MANAGER	Visual/QA/Foreman Checklist
	FLAGS	REPLACE	AS NEEDED	EQ. MANAGER	Purchasing Agent
	GROUNDS & VEGATATION	MOWING	AS NEEDED	FOREMAN/ACM	Visual/QA/Foreman Checklist

	GROUNDS & VEGATATION	MOWING	AS NEEDED	FOREMAN/ACM	Roadside Crew/ Crew
	GROUNDS & VEGATATION	VEGATATION CONTROL/ WEED EATING	AS NEEDED	FOREMAN/ACM	Visual/QA/Foreman Checklist
	GROUNDS & VEGATATION	VEGATATION CONTROL/ WEED EATING	AS NEEDED	FOREMAN/ACM	Roadside Crew/ Crew
	GROUNDS & VEGATATION	HERBICIDE/ VEGATATION CONTROL	AS NEEDED	FOREMAN/ACM	Visual/QA/Foreman Checklist
	GROUNDS & VEGATATION	HERBICIDE/ VEGATATION CONTROL	AS NEEDED	FOREMAN/ACM	Roadside Crew/ Crew
	GROUNDS & VEGATATION	INSPECT PLANTING BEDS	ANNUALLY	FOREMAN/ACM	Visual/QA/Foreman Checklist
	GROUNDS & VEGATATION	INSPECT PLANTING BEDS	ANNUALLY	FOREMAN/ACM	Roadside Crew/ Crew
	GROUNDS & VEGATATION	MULCH	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	GROUNDS & VEGATATION	MULCH	ANNUALLY	FOREMAN	Roadside Crew/ Crew

MAINTENANCE STOCKPILE ACTIVITY PROTOCOL

Maintenace Activity	Facility Component	Protocol for Specified Tasks			
		Task	Timeframe	Responsible Person	Reference
LANDSCAPING	TREES/ SHRUBS	INSPECT	APRIL & OCTOBER	FOREMAN/ACM	Visual/QA/Foreman Checklist
	TREES/ SHRUBS	TRIM & SHAPE	AS NEEDED	FOREMAN	Roadside Crew/ Crew
DRAINAGE	INLETS & PIPES	INSPECT	QUARTERLY	FOREMAN/ACM	Visual/QA/Foreman Checklist
	INLETS & PIPES	CLEAN	AS NEEDED	ACM	Roadside Crew/ Crew
	SEDIMENTATION DEVICES	INSPECT	QUARTERLY	FOREMAN/ACM	Visual/QA/Foreman Checklist
	SEDIMENTATION DEVICES	CLEAN	AS NEEDED	FOREMAN	Crew
	DITCHES & SWALES	INSPECT	APRIL & OCTOBER	FOREMAN/ACM	Visual/QA/Foreman Checklist
	DITCHES & SWALES	CLEAN	AS NEEDED	FOREMAN	Crew
	OIL/WATER SEPARATOR	INSPECT	SEMI ANNUALLY	EQ. MANAGER	Visual/QA/Foreman Checklist
	OIL/WATER SEPARATOR	CLEAN	AS NEEDED	EQ. MANAGER	Contractor/ Crew

UTILITIES	ELECTRICAL	INSPECT TRUCK RAIL	APRIL & OCTOBER	FOREMAN	Visual/QA/Foreman Checklist
	ELECTRICAL	REPAIR	AS NEEDED	ACM	Contractor
	ELECTRICAL	INSPECT FACILITY	ANNUALLY	EQ. MANAGER	Visual/QA/Foreman Checklist
	ELECTRICAL	REPAIR	AS NEEDED	EQ. MANAGER	Contractor
	EMERGENCY GENERATOR	INSPECT	MONTHLY	EQ. MANAGER	Policy
	EMERGENCY GENERATOR	REPAIR	AS NEEDED	EQ. MANAGER	Vendor/ Shop
	WATER WELLS	SAMPLING	APRIL & OCTOBER	EQ. MANAGER	State Reg's
	WATER WELLS	SERVICE & TREATMENT	AS NEEDED	EQ. MANAGER	Contractor
	STAGING BLDG. HEATER	INSPECT	ANNUALLY	FOREMAN	Visual/QA/Foreman Checklist
	STAGING BLDG. HEATER	REPAIR	AS NEEDED	ACM	Contractor
UNDER GROUND TANKS	REGISTERED	INSPECT	APRIL & OCTOBER	EQ. MANAGER	Pub 23
	REGISTERED	SERVICE	AS NEEDED	EQ. MANAGER	Tank Contractor/ Contractor
ABOVE GROUND TANKS	HEATED TANKS	INSPECT	APRIL & OCTOBER	SEAL COAT FOREMAN	Pub 23
	HEATED TANKS	SERVICE	AS NEEDED	ACM/ EQ MANAGER	Garage-Contractor-Crew
	CALCIUM TANKS	INSPECT	APRIL & OCTOBER	FOREMAN/ACM	Visual/QA/Foreman Checklist
	CALCIUM TANKS	SERVICE	AS NEEDED	ACM	Garage-Contractor-Crew
	CONTAINMENT AREA	INSPECT	MONTHLY	FOREMAN/ACM	Visual/QA/Foreman Checklist
	CONTAINMENT AREA	LITTER/WEEDS/WATER	MONTHLY	FOREMAN/CREW	Foreman/ Crew

MAINTENANCE STOCKPILE ACTIVITY PROTOCOL

Maintenace Activity	Facility Component	Protocol for Specified Tasks			
		Task	Timeframe	Responsible Person	Reference
RECORD KEEPING	PPC PLAN	UPDATE	ANNUALLY	CMM / RPC	Policy
(see appendix A)	PPC EMERGENCY PLAN	CONDUCT	ANNUALLY	CEM / FOREMAN	Policy

	SEMP MANUAL	UPDATE	AS NEEDED	PROCESS OWNER CMM / CHIEF CLERK RPC / FOREMAN	Process Map
	STOCKPILE INSPECTION	WEEKLY WALK AROUND	WEEKLY	FOREMAN / CREW	Process Map
	STOCKPILE CHECKLIST	CHECKLIST	QUARTERLY	FOREMAN	Pub 23 / Process Map
	STOCKPILE SNAPSHOT	QA	AS COMPLETED	DIST./COUNTY PERSONNEL	Process Map
	STOCKPILE QA	QA	MAY THROUGH SEPTEMBER	ENVIRONMENTAL PLANNER/ RPS	Process Map
(see appendix A)	HAZARD / ENVIRONMENTAL ID FORM	FORM	AS NEEDED	ANYONE	Process Map
(see appendix A)	STOCKPILE WEEKLY WALK AROUND	QA	WEEKLY	FOREMAN / CREW	Process Map

11.28. PennDOT Post-Storm Salt Management Tracking Responsibilities

Example 32: PennDOT Post-Storm Salt Management Tracking Responsibilities

District Management / County Management Teams

- Analyze last years winter data and revise application charts
- Update winter training plan
- Revise tracking sheets to improve application rates
- Update target application rates by snow lane miles by truck.
- Update charts to collect actual results
- Train Equipment Operators on application rates and prepare presentation to all employees

Every Equipment Operator, after every Snow Event

- Completes tracking forms
- Turns into Foreman after every shift

Assistant Manager

- Checks application rate and discuss variance if any with Foreman after every storm
- Prepares summary for stockpile

County Foreman

- Check application rate and discuss variance if any with Operators after every storm using prepared summary for stockpile

County Coordinator

- Collected summary of stockpile
- Makes County summary

- Sends copy to District
- Completes County CSI results after every storm external and internal

PennDOT District

- Develop scorecards of all counties by stockpile average rate
- Completes and sends report back to County
- Distributes reports to stockpiles

11.29. Risk, Compliance Issues, and Management Examples for Highway-Generated Waste - Oregon DOT

Table 29: Risk, Compliance Issues, and Management Examples for Highway-Generated Waste - Oregon DOT

Waste	Toxicity/Risk	Compliance issues	Management Examples
Vactor Waste • Catchment Cleanout • Sediment Ponds • Bridge Culverts	High (in urban areas). Typically the most contaminated roadwaste. Hydrocarbons and metals are common. Historical pollutants can be present. Low to High Depending on factors such as ADT, land-use, maintenance schedules, etc. Low (if content of silt or fine soils is low).	Vactor waste must be separated into liquids and solids prior to disposal. Each waste must be disposed of separately. Many waste disposal rules apply. ODOT Environmental and DEQ can offer guidance. Even free of toxins, litter, and trash, vactor waste requires proper placing and erosion control.	• Develop alternative disposal options such as bioremediation or composting. • Pursue alternative decanting techniques (retrofit sewerage manholes for liquid field disposal, treat vactor slurries with flocculent, etc.). • Partner with other agencies and share waste disposal facilities. • Construct ODOT decant facilities that separate vactor waste into liquids and solids. Landfill solids and dispose liquids to sewer.
Sweepings • Winter Sand	Low to High Litter and sharps will be obvious. Hydrocarbons and metals are a concern. Urban sweepings usually test high in toxin levels. Low (with quick pick up). Less time on roadway reduces litter and toxins.	Similar to vactor solids in risk and environmental concerns. Testing may be needed to determine toxin levels. Litter and trash must be disposed of at permitted waste facilities.	• Test, characterize, and sort for reuse. • Develop re-use options: compost, shoulder repair, fill, concrete, etc. (remove trash by screening). • Develop and permit disposal sites (partnering). • Thermal treatment (incinerator). • Landfill.
Ditching Spoils	Low to Medium Generally risk is low but urban ditchings have tested positive for toxins (hydrocarbons, metals, historical pollutants, chemical dumping, etc).	Storage sites must be suitable (protect wetlands and streams). Clean soil is a pollutant if it is not contained (erosion control).	• Use as fill material in appropriate locations. • Partner in give-away programs if material is suitable (agriculture, construction, etc.). • Develop and permit disposal sites.

Landscape Cuttings	Low Nitrogen, bacteria, and other pollutants associated with the break down of organic material can be considered toxic pollutants.	Landscape debris must be disposed at permitted facilities. Composting is allowed but may require a permit. Odor, vector control, and public perception are concerns.	• Keep landscape debris separate from other waste and dispose appropriately. • Composting. • Burning (only allowed at limited locations). • Chipping/Mulching.
Construction Soils and Slide Debris	Low Toxins can sometimes be a concern (fuel spills, septic waste, excessive vegetation, etc.)	Similar to Ditching Spoils in risks and concerns. Storage sites must be suitable. Material must be contained.	• Use as fill or construction material if appropriate (rock fall or sound berms, general fill, etc.). • Develop give-away programs with partners. • Develop and permit disposal sites.

11.30. NYSDOT-DEC Deer Carcass Composting – Practice Guidelines

Example 33: NYSDOT-DEC Deer Carcass Composting – Practice Guidelines

1. Choose a well-drained site with minimal slope, at least 200 feet from water courses or other hydrologically sensitive landscape features including streams and wetlands. Separation distances should be 500 feet from a residence and 200 feet from a property line. Siting should also consider prevailing winds and aesthetic impacts on neighbors.

2. Composting bin or windrow should be placed on a hard surface made of paved asphalt, concrete, or compacted millings. The pad needs to provide a good working surface in all weather conditions and protection of ground water. Sufficient amounts of amendments should be added to piles to minimize the movement of liquids (blood, etc.) from the carcasses. Any liquid that leaves the pad must be absorbed in woodchips or other acceptable materials and must be kept away from sensitive areas (streams etc.).

3. Prepare a foundation layer of wood chips or recycled deer compost in the bottom of the windrow or bin before adding carcasses. This initial layer should be 18-24 inches deep. Sufficient quantities of woodchips and/or finished compost must be at the site before any carcasses arrive to ensure the piles can be formed in a timely manner.

4. Place deer carcasses back to back in a single layer on the foundation leaving at least 6 inches between the carcasses and the bin walls. Completely surround and cover the carcasses with at least 6 inches of damp wood chips or recycled deer compost. If there are not sufficient carcasses for a full layer, cover the edges of the available carcasses with at least 6 inches of wood chips or recycled deer compost and begin adding carcasses at that point as they become available. Never leave any part of a carcass exposed even if extra wood chips or recycled deer compost must be added.

5. Continue this layering procedure until a windrow or bin is full. The last layer used to cap the bin should be 24 inches of wood chips or recycled deer compost. This layer should curtail odors and dissuade scavengers. Do not stack windrows/bins over 6 feet high. A temperature rise in the compost pile to 125 degrees F or higher indicates that the process is working.

6. Allow the pile to remain idle for several months. The pile can be broken down sooner, if the carcasses are clearly fully degraded. The internal temperature of the pile should be 120F to 150F during the active composting phase. For pathogen reduction, it must be shown that the carcass achieved a temperature of 131/F or greater for three consecutive days. The temperature probe used must be able to record temperatures in the areas of the pile where the carcasses are located.

7. Once the material is fully composted, it can be reused in starting new compost piles or used within a highway right-of-way with appropriate setbacks. DEC approval will be required for uses outside of the compost area.

FACILITY REQUIREMENTS

- Suitable site allowing for setbacks
- Hard surface made of asphalt, concrete or compacted millings for compost windrow OR

- Compost bins on asphalt, concrete or compacted millings work pads
- Sufficient supply of wood chips
- Provisions for monitoring temperatures within the compost pile. (Thermocouple probe, thermister probe or similar device may be used.)
- Rubber gloves and face masks
- Loader
- Water
- Before composting, contact the DOT Maintenance Environmental Coordinator (MEC).

FACILITY CONTROLS

The compost piles will be segregated from other facility operations, utilities, farming activities and main traffic areas. A sign designating the compost pile as such will be clearly visible at each compost area. The sign may state "Deer Carcass Compost."

All workers at the assigned locations should be made aware of the compost windrow or bin. Safety instructions will be given via classroom or field setting.

PERSONNEL TRAINING

The Highway Maintenance Supervisor assigned to the yard where the composting facility is located will inform all yard employees of the composting facility. All yard employees will be made aware of safety precautions required.

Employees working with the compost will be informed of the Operations and Maintenance procedures described herein.

LOADING PROCEDURES

Deer typically get collected by manually lifting the carcass into the back of a pick-up truck. While the first carcasses may be added to the fresh compost pile manually, any subsequent additions should be added via heavy equipment, such as a loader. It is allowable to park the pick-up truck as close as possible to the compost pile and manually place the carcass from the truck to the pile, as long as workers will not have to step onto the compost pile. Woodchips should be added via heavy equipment or off a pick-up truck. As it may be challenging to place the deer back to back with heavy equipment, the boards on one side of the bins should be removable to make loading and unloading the bins easier.

HANDLING INSTRUCTIONS

Handling of the compost pile will be accomplished via heavy equipment.

Handling of the compost should be performed in a manner that would prevent dispersion of the compost material on the ground and prevent dispersion of compost particles in the air.

COMPOST MANAGEMENT

A carcass may be added to the compost pile as ordered by the Resident Engineer. In general, any deer collected from the roadside may be added to the composting facility as long as it does not show any overt signs of disease. A deer that appears emaciated or showed untypical behavior prior to becoming killed should not be added to the compost pile as it may be diseased. Emaciated deer should be reported to NYSDEC Wildlife Pathology Unit in Albany (Phone number 518/478-3032) for testing.

Through the trial composting effort, DOT will be able to determine how many deer carcasses each compost bin/windrow can handle within a given time frame. Potentially, each composting bin could handle up to 30 carcasses per composting effort, depending on the size of the work pad. Compost windrows, extended lengthwise, would be able to accommodate more carcasses. Each composting bin/windrow can accept up to three layers of carcasses to a maximum height of 6 feet.

The first layer should consist of 18-24” of woodchips, followed by a layer of carcasses. Carcasses should be placed back to back. This arrangement aids in achieving higher composting temperatures. The carcasses should be covered by 6” of woodchips. Repeat this process until three layers are complete. Finish top layer with 24” of woodchips. For windrows, repeat this process in 10-15 foot long sections, adding on to the existing windrow.

The moisture content of the pile contributes to proper composting temperatures. The moisture content of the wood chips or recycled deer compost added to the mix should be about 60 percent, which is the point where a handful of the material will just begin to stay together when squeezed (wear rubber gloves if it is compost!).

- The wood chips or recycled deer compost should have the proper moisture content before adding it to the bin/windrow. It is difficult to uniformly add water to the mix in the composter.
- If the material falls apart after being squeezed, it is too dry. Water should be sprinkled and mixed into the wood chips.
- If free water drips from the squeezed material, or if a film of free water is left on the hand, the material is too wet. The material should be spread to air dry or mixed with drier material to lower the moisture content before adding to the compost mix.
- If a compost pile does not properly heat, it is probably too wet or too dry or was filled improperly.

RECORDKEEPING

Compost monitoring and record keeping is necessary in order to document proper functioning of the compost pile. If dysfunction is evident, steps can be taken to correct poor conditions. Compost monitoring will let DOT learn more about the composting process and create optimal composting conditions in the future.

- Any deer composting activities must be approved by NYSDEC.
- Record the number of carcasses added to the pile along with date.
- Temperatures within the compost pile will be monitored and recorded once a day. A sample data log sheet is attached for use. See Temperature Monitoring section.
- Odors should be recorded daily. Indicate whether there are odors disseminating in the downwind direction and if an odor is present, estimate how many feet downwind it is noticeable.
- State when last carcass was added.

TEMPERATURE MONITORING

Proper composting requires sustained elevated temperatures (120F -170F). High temperatures also achieve desired pathogen reduction and a physically stabilized compost material at the end of the process. Ideally, a continuous temperature monitoring device should be utilized. A thermocouple probe, thermistor probe or similar device can be embedded in the compost pile. This device should be connected to a lead wire and data logger, where temperature variations can be recorded over a period of time.

- A temperature probe (bimetal thermometer) with a four foot extension may also be used.
- The probe should be placed so that readings are taken at 12”-36” from the top of the pile in areas where the carcasses are located. As the pile grows, the probe will need to be repositioned.

SAMPLING PLAN

Testing of finished compost will document the presence of certain pathogens and ascertain what re-use the compost product is suitable for. Sampling parameters include pathogenic organisms and pathogen indicator organisms. The Maintenance Environmental Coordinator will be in charge of sampling. Within 3 months after start-up of the project, a compost sampling and analysis plan will be submitted to DEC for approval. Parameters to be analyzed may include total coliform, fecal coliform, E.coli, Salmonella, Cryptosporidium, total carbon and total Kjehldal nitrogen. Bacteria causing Lyme disease will not survive temperatures above 130F and as long as composting achieved proper temperatures, testing for this pathogen will not be necessary.

RECYCLING OF FINAL COMPOST PRODUCT

Material that is fully composted may be re-used as a base for a new compost pile. Compost that has been determined safe by inspection of records and the sampling analysis, can be land applied within the highway right-of-way subject to DEC approval.

CONTINGENCY PLAN

If any activity does not go according to plan, contact the Resident Engineer. In the event that problems develop which result or may result in environmental or public health impacts or nuisance conditions, the compost operation should be suspended and corrective measures should be taken to mitigate impacts. Problems which will trigger implementation of the contingency plan will include, but not be limited to, odors detected beyond the facility boundary, animals scavenging in the compost piles or receipt of deer carcasses at a rate which exceeds the handling capacity of the compost facility. Corrective measures will include, but not be limited to, covering with additional woodchips and/or addition of lime to control odors, fencing the area to prevent access by animals, temporarily covering the piles with a tarp, cessation of operation until the adverse impacts have been mitigated and, if other measures fail, removal and disposal of the pile contents by pit burial in accordance with applicable DEC regulations and DOT guidelines or disposal of pit contents at an approved solid waste management facility.

CLOSURE PLAN

The Maintenance Environmental Coordinator (MEC) is contacted before composting is started and needs to be contacted in order to officially close out a composting activity. The MEC will schedule a site visit at that time, possibly with NYSDEC. Composting records should be made available at that time and elements of the process should be discussed. At that time it should be determined, whether composting appears complete and final sampling should be ordered. If yes, the MEC will initiate the sampling process. Sampling results and monitoring records will be provided to NYSDEC. Depending on results, the compost will be recommended for re-use as composting amendment or determined to be suitable as a soil amendment.

If the finished compost will be used as soil amendment, the site approval by the MEC and by DEC is required. To permanently close a composting site, bins should be disassembled and taken to a landfill. The workpad may be kept for other uses, but must be decontaminated using a 5 percent or 10 percent solution of sodium hypochlorite (household bleach) in water. The MEC and NYSDEC will be notified that the deer composting facility has been discontinued.

PERSONAL PROTECTION

Employees should follow the personal protective equipment requirements outlined in the Rabies Safety Bulletin 92-1 (attached) when working with any road kill. The safety bulletin recommends that rubber gloves be worn. Questions in regard to the Safety Bulletin should be directed to the Regional Safety Officer (see Contact Information). If a worker will be in immediate contact with the compost for the purpose of taking a temperature reading or other, personal protective equipment, such as rubber gloves. Disposable face mask should be available and worn at the discretion of the employee.

Emaciated deer or deer showing untypical behaviors (either alive or before becoming roadkill) should be reported to NYSDEC Wildlife Pathology Unit in Albany (Phone number 518/478-3032). Do not add animals other than deer to the compost!

ENVIRONMENTAL CONTROLS

Environmental quality will be addressed by carefully choosing a site (see Guidelines II.1.). In order to ensure proper site selection, the Maintenance Environmental Coordinator should conduct a site screening via a physical walk-over.

To ensure that the active compost pile does not pose risks not addressed through proper setbacks, the following should be considered:

- If nuisance vectors, such as flies etc are attracted to the pile, more woodchips should be added to cover the pile.

- Any leachate that may have puddled around the pile needs to be absorbed by woodchips and adequately covered.
- Odors would also indicate that additional woodchip coverage is necessary.

Experiences of various entities utilizing composting has shown that carnivorous animals will not be attracted to compost piles as long as the pile is adequately covered.

Prior to releasing the finished compost product to the environment, monitoring records such as the temperature logs and pile records will be reviewed. The temperature log will indicate whether the material has properly composted and whether the temperature necessary for pathogen kill was reached. The operators of the pile should ensure that adequate temperatures are reached as outlined in the Guidelines. Composting shall not be considered complete unless adequate temperature data is collected after addition of the last carcass to demonstrate that a minimum temperature of 131 F has been reached and maintained for a minimum of three consecutive days. The final sampling test results will also determine the safety of the compost.

STAFFING PLAN AND CONTACT INFORMATION

The Highway Maintenance Supervisor II assigned to the yard is responsible for day to day operations, monitoring and proper functioning of the compost pile.

Correspondence, composting performance evaluation, procedural guidance and sampling will be coordinated by the Maintenance Environmental Coordinator.

Elisabeth Kolb, Maintenance Environmental Coordinator Tel. 845/575-6158

11.31. NYSDOT's Draft Metric for Assessing Performance of Integrated Vegetation Management on ROW

Example 34: NYSDOT's Draft Metric for Assessing Performance of Integrated Vegetation Management on the ROW

PRINCIPLE #1: COMPLIANCE WITH LAWS

1.1 Vegetation management shall respect all national and local laws, for example, use of pesticides by certified applicators, Best Management Practices and other protective measures for water quality, that exist within the state or other appropriate jurisdiction(s) in which the operations occur.

1.2 Vegetation management areas should be protected from unauthorized activities.

PRINCIPLE #2: TENURE AND USE RIGHTS AND RESPONSIBILTIES

2.1. Clear evidence of long-term land use rights (e.g., land title or lease agreements) should be demonstrated, including clearly identified, on-the-ground land boundaries.

PRINCIPLE #3: COMMUNITY RELATIONS AND WORKERS' RIGHTS

3.1. The communities adjacent to the vegetation management area should be given opportunities for other professional services from the vegetation manager such as representation in local civic activities, e.g., Earth Day clean-up, Arbor Day plantings, etc. or contribution to public education about vegetation management practices in conjunction with schools, community colleges, and/or other providers of training and education.

3.2. Vegetation management meets or exceeds all applicable laws and regulations covering health and safety of employees, including the development and implementation of safety programs and procedures that include:

a) Well-maintained and safe machinery and equipment

b) Use of safety equipment appropriate to each task

c) Documentation and posting of safety procedure in the workplace

d) Education and training

e) Contracts with safety requirements

f) Safety records, training reports, and certificates

PRINCIPLE #4: UNDERSTANDING PEST AND ECOSYSTEM DYNAMICS
4.1. Vegetation managers are knowledgeable about the managed ecosystem, especially with regard to the basic biology and ecology of all organisms in the system, and the environment in which they live.

4.2. Research and development activities are engaged to produce missing basic information on ecology of the managed ecosystem.

4.3. Vegetation managers are provided opportunities to improve their skills and knowledge through training.

PRINCIPLE #5: SETTING MANAGEMENT OBJECTIVES AND TOLERANCE LEVELS
5.1. Management planning, including the development of management objectives, shall incorporate the results of evaluations of social impact. Consultations should be maintained with people and groups directly affected by management operations (see also PRINCIPLE #8).

5.2. Tolerance levels are used to develop thresholds for when vegetation management activities are applied to control vegetation.

5.3. People and groups affected by management operations are apprised of proposed vegetation management activities and associated environmental and aesthetic effects in order to solicit their comments or concerns.

5.4. Significant concerns identified in Criteria 5.1 and 5.3 are addressed in management policies and plans (for example, management activities are modified in response to concerns, or a rationale is provided for not responding to a concern).

PRINCIPLE #6. COMPILATION OF A BROAD ARRAY OF TREATMENT OPTIONS
6.1. A wide variety of different mechanical, physical, chemical, cultural, and biological/ecological treatments are available for use/consideration on all sites.

6.2. New treatments are progressively added to the vegetation management program, with emphasis on non-herbicide alternatives.

6.3. Where possible, treatments are featured that lead to, directly or indirectly, pest prevention and biological and ecological control of pests.

PRINCIPLE #7: ACCOUNTING FOR ECONOMIC AND ECOLOGICAL EFFECTS OF TREATMENTS
7.1. Vegetation management should strive toward economic viability, while taking into account the full environmental, social, and operational costs of vegetation management. Treatment choices are made with full consideration of cost effectiveness, including a wide array of positive and negative environmental externalities, as follows.

a) Water resources: perennial and ephemeral streams, wetlands, vernal pools, seeps (see also Criterion 7.5)

b) Wildlife: common plants, animals and their habitats, and imperiled, threatened, and endangered species and their habitats (according to state and federal statutory listings)

c) Biodiversity: efforts are made to control invasive, exotic plants; also, if state or federal listings and species databases indicate the likely presence of a rare, threatened or endangered species or plant community type, either a survey is conducted prior to management activities being carried out (to verify the species presence or absence) or the vegetation manager manages as if the species were present. If an applicable species and plant community type is determined to be present, its location is reported to the manager of the applicable database, and necessary modification are made in both the management plan and its implementation.

d) Aesthetics: visual impacts of treatments are assessed.

Written guidelines should be prepared and implemented to address management of these resources.

7.2. Management systems shall promote the development and adoption of environmentally-sensitive, non-chemical methods of pest management and strive to minimize the use of chemical pesticides. If chemicals are used, proper equipment and training should be provided to minimize health and environmental risks. (See also Criterion 1.1)

7.3. Chemicals are used to control plants only when non-chemical management practices have proven ineffective or cost prohibitive.

7.4. When chemicals are used, a section is included in the prescription that fully describes the risks and benefits of their use and the precautions that workers must employ. Records are kept to document the occurrence of pests, measures to control them, and incidences of worker exposure to chemicals.

7.5. Broken and leaking equipment and parts are repaired and removed from a right-of-way as they may contaminate a site with fuel, oil, or other chemicals; discarded parts are taken to a designated disposal facility. Equipment is not parked in riparian zones, or near groundwater supplies, where fluid can leak into them.

7.6. Chemicals, containers, liquid and solid non-organic wastes including fuel and oil should be disposed of in an environmentally appropriate manner at off-site locations. (See also Criterion 1.1)

7.7. Use of exotic species in planting is carefully controlled and actively monitored to avoid adverse ecological impacts. Furthermore, use of exotic plant species is contingent on peer-reviewed scientific evidence that any species in question is non-invasive and does not diminish biodiversity. If non-invasive exotic plant species are used, the location of their use is documented, and their ecological effects actively monitored.

7.8. Special cultural, ecological, economic or religious resources should be clearly identified, recognized and protected by vegetation managers.

PRINCIPLE #8: MANAGEMENT PLANNING

8.1. A strategic management plan and supporting documents must be in place that provide:

a) Management objectives

b) Description of the resources to be managed (e.g., water, wildlife, aesthetics) and socioeconomic conditions, and a profile of adjacent lands

c) Description of the vegetation management system, based on the ecology of the ecosystem in question and information gathered through resource inventories

d) Provisions for monitoring

e) Environmental limitations and safeguards based on environmental assessments

f) Plans for biodiversity

g) Maps describing the resource base.

8.2. Tactical management plans are developed that report local considerations and activity plans on a year-by-year basis.

8.3. Strategic and tactical management plans should be periodically revised to incorporate the results of monitoring or new scientific and technical information, as well as to respond to changing environmental, social, and economic circumstances.

8.4. A summary of vegetation management activities is produced annually, and both strategic and tactical management plans are revised at least every 10 years.

8.5. Workers shall receive adequate training and supervision to ensure proper implementation of the management plans.

8.6. While respecting the confidentiality of information, vegetation managers shall make publicly available a summary of primary elements of the management plan, including those listed in Criterion 8.1.

PRINCIPLE #9: SITE SPECIFIC IMPLEMENTATION OF TREATMENTS

9.1. Land management units are designated within rights-of-way, for example, buffers to protect water resources, conservation areas, and vegetative communities that may cause a change in successional directions and rate or warrant different vegetation treatment.

9.2. Written prescriptions (or operational plans) are used to describe/prescribe treatments on a land management unit basis, and justify treatment choices using ecological, socioeconomic and administrative opportunities and constraints.

Prescriptions should include:

a) Land management unit designation

b) Description of current vegetation and environmental conditions

c) Desired future conditions

e) Definition of treatment

f) Justifications for treatment based on tolerance thresholds (also see PRINCIPLE # 5) and ecological, environmental, socioeconomic, and administrative considerations

g) Site-specific maps that detail land management units, and show important cultural and environmental features

9.3. Prescriptions and the decision to treat are based on contemporary inventories of vegetation and environmental conditions.

PRINCIPLE #10: ADAPTIVE MANAGEMENT AND MONITORING
10.1 Monitoring procedures should be consistent and replicable over time to allow comparison of results and assessment of change. Implementation of the strategic and tactical management plans are periodically monitored to assess:

a) The degree to which the management vision, goals, and objectives have been achieved

b) Deviations from the plan

c) Unexpected effects of management activities and other disturbances

d) Social and environmental effects of management

10.2. Vegetation management should include the research and data collection needed to monitor, at a minimum, the following indicators:

a) Condition of the right-of-way

b) Composition and changes in the flora and fauna

c) Environmental and social impacts of operations

d) Chemical use

e) Cost, productivity, and efficiency of vegetation management

10.3. Results of monitoring should be incorporated into the implementation and revision of the management plan.

10.4. While respecting the confidentiality of information, vegetation managers shall make publicly available a summary of the results of monitoring indicators, including those listed in 10.1.

11.32. NCDOT Roadside Vegetation Management Guidelines in Marked Areas

Example 35: NCDOT Roadside Vegetation Management Guidelines in Marked Areas

- No mowing April 1-November 15.
- No herbicides, no fertilizers. (Exceptions can be made for herbicides under special circumstances, discussed below.)
- Mowing from November 16-March 31 is allowed and, in most cases (*see exception below), should be done at least *every other year*. Winter mowing every year is acceptable. If regular contract mowers are unable to mow the sites under this time frame, NCDOT mowers may be used during the winter.
- Mowing should not be conducted when the soil is wet, as compaction and rutting will occur.

- In some instances, rare plants may be growing right along the edge of the road. Ideally, the plants should be protected if at all possible in this situation, but if NCDOT division staff determine that the road shoulder should be mowed during the growing season for safety or visibility, then the shoulder may be mowed accordingly. If possible, an NCDOT biologist can visit the site and mark where individual plants are, so they can be avoided.
- NCDOT mowing contracts are under modification to ensure that contractors are responsible for finding out if any endangered plants are within the areas they will be working, and for avoiding injury to the plants. The County Mowing Inspector or the Division Roadside Environmental Engineer should review the No Mow policy with each county maintenance office and mowing contractor prior to any mowing activities on roads with rare plant populations.
- The standard mowing height is usually four inches; ideally, the mower should be set at a level to avoid scalping the ground and damaging rare plants.
- Clippings from winter mowing should be left on site so any rare plant seeds produced will have the opportunity to germinate within the population. An exception can be made if only weeds are reproducing.
- Prior to entering the site, mowers and equipment should be cleaned off, removing any accumulated vegetative debris that contains weed seeds.
- Rare plants along roadsides often extend into utility line ROWs. Utilities managing plant growth in DOT ROWs must be told that herbicide use on DOT ROW is unlawful without a permit. Utilities conducting plant management *adjacent* to DOT ROWs should be notified when rare plants are present.

* Mowing Exception

There is an exception to winter mowing for Virginia spiraea. This shrub is found along streams, rivers and roadsides in the mountains. Because it is a woody shrub it should **never** be mowed, regardless of the time of year. Trimming or selective thinning of other woody vegetation that compete with this species may be recommended for management.

Signs/Stakes
When rare plants are discovered on NCDOT's ROW, the population should be marked with 'Do Not Mow' signs. These signs should be large enough to be easily noticed by roadside mowers. A variety of signs have already been placed along roadside populations; most simply state, 'Do Not Mow' while others include dates for the no mow period (April 1 - November 15), or add 'Do Not Spray.' To ensure that signs are readily understood by a variety of workers, signs with universal symbols for 'Do Not Mow' and 'Do Not Spray' are under review for future use.

Do Not Mow signs should be positioned at both ends of a population, facing so mowers will see the signs as they approach the No Mow area. Where rare plants occur along a significant stretch of roadway it is suggested that double sided Do Not Mow signs be placed periodically along the population - two Do Not Mow signs placed back to back on a single post. The reasoning for this is that if a sign at one end of the population disappears, the mower will encounter another Do Not Mow sign before the entire population is mowed. Maintaining the signs and seeing that they are visible and in good condition is critical in order to protect these populations. Damaged or missing signs should be replaced as soon as possible, especially during the growing season. If possible, signs should be placed at a low enough level for the mower operator to see.

White-topped wooden stakes can also be useful in alerting mower operators that the site is designated as a No Mow area. These should be used in addition to (not instead of) Do Not Mow signs. The wooden stakes are approximately 40 inches long with the top six inches painted white, the same stakes used to delineate mowing patterns and areas that are off limits to mowers. Stakes should be placed at regular intervals along the entire edge of the roadway side of the population.

Encroachments/Maintenance
Division environmental officers, district offices and maintenance units should make sure rare plant sites are taken into consideration for proposed ROW encroachments and maintenance work. ROW encroachments such as driveways, utility work, minor widenings, installation of utility lines and pipes for driveways have the potential to damage rare plant populations. All ROW access requests and driveway access applications in areas where rare species are known to occur should be reviewed to ensure there will be no impacts. If impacts to rare plants are likely

to occur, efforts should be made to avoid or minimize damage. District offices should maintain secondary road files with a notation to remind them that the road has a protected species.

Roadside maintenance activities, such as grading and ditch maintenance can also harm rare plants. As above, if impacts to rare plants are likely to occur, efforts should be made to avoid or minimize damage. Heavy equipment should be kept out of rare plant areas during the No Mow period. Employees working in the area should be shown the rare plant so they can avoid damaging them.

Herbicide Use

To reduce competition from invasive weeds, herbicides should only be used when mechanical removal is not an option. Herbicides can be used near rare plant populations when specifically prescribed by someone familiar with the biology of the rare plant. Two main herbicides have been recommended for use on roadside rare plant populations. These herbicides have been tried in a variety of situations by NCDOT and are believed to be most suitable for managing these sites, glyphosate triclopyr for woody vegetation. All herbicide applications for roadside rare plant sites should be conducted by a Licensed Pesticide Applicator.

---

1. Research for the AASHTO Standing Committee on the Environment, NCHRP 25-25, http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+25-25.

2. Bryon, J.M. Strategic Planning for Public and Nonprofit Organizations: A Guide to Strengthening and Sustaining Organizational Achievement. Jossey-Bass, San Francisco (1995) pp. 2, 9.

3. Venner, M., project for the USDOT Volpe Center, 2002; and overview of state DOT EMSs prepared for AASHTO, June, 2003.

4. Livable Delaware Goals & Executive Order, www.deldot.net/static/pubs_forms/manuals/livable_delaware/goals_exec_ord.html.

5. State of Florida Department of Transportation, "Planning Policy." http://www.dot.state.fl.us/planning/policy/pdfs/src_brochure_pt.pdf.

6. State of Florida Department of Transportation, "Florida DOT Environmental Policy." http://www.dot.state.fl.us/emo/pubs/FDOT_Environmental_Policy.pdf.

7. Personal communication, Charlie Adams, MDSHA Director of Environment & Design, (July 9, 2004).

8. New Jersey Department of Transportation, "Environmental Stewardship." http://www.itre.ncsu.edu/AASHTO/stewardship/NJstewardship.doc.

9. NYSDOT Environmental Policy, http://www.dot.state.ny.us/eab/files/policyen.pdf.

10. NYSDOT Environmental Policy, http://www.dot.state.ny.us/eab/files/policyen.pdf.

11. NYSDOT Environmental Initiative Statement, 1999, http://www.dot.state.ny.us/eab/eistate.html.

12. Kentucky Transportation Cabinet, "Environmental Policy." http://transportation.ky.gov/KYTCEP2.HTML.

13. Maine Department of Transportation's Environmental Policy. http://www.maine.gov/mdot/planning-process-programs/env-policy.php.

14. Pennsylvania Department of Transportation, "Green Policy Statement." http://www.gggc.state.pa.us/about/1998-1.pdf.

15. New South Wales, Australia, Roads and Traffic Authority, "Environmental Policy." http://www.rta.nsw.gov.au/environment/downloads/rtaenviropolicy.pdf.

16. Davies, P. T., "Contributions from Qualitative Research," *In* Davies, T.O., Nutley, S. M., and Smith, P.C., What works: Evidence-Based Policy and Practice in Public Services. The Policy Press, Bristol (2000).

17. Massachusetts Department of Transportation, "Environmental Management System Manual." http://www.mass.gov/mhd/environ/hazmat/emsmanual.pdf.

18. Personal communication, Tony Warfield, WSDOT EMS Manager (April 13, 2004).

19. From NHDOT Procedure for Determining Environmental Aspects and Significant Aspects (December 12, 2001).

20. New South Wales, Australia, Roads and Traffic Authority, "Environmental Planning and Management Processes." http://www.rta.nsw.gov.au/environment/environmentalplanningmgt/index.html.

21. New South Wales, Australia, Roads and Traffic Authority, "Environmental Impact Assessment Policy, Guidelines, and Procedures." Chapter 5.2.2.1 http://www.rta.nsw.gov.au/environment/downloads/environmental_impact_assessment_guidelines.html.

22. New South Wales, Australia, Roads and Traffic Authority, "Environmental Impact Assessment Policy, Guidelines, and Procedures." Chapter 5.2.2.2 http://www.rta.nsw.gov.au/environment/downloads/environmental_impact_assessment_guidelines.html.

23. New South Wales, Australia, Roads and Traffic Authority, "Environmental Impact Assessment Policy, Guidelines, and Procedures." Chapter 5.2.2.4 and 9.10.3 http://www.rta.nsw.gov.au/environment/downloads/environmental_impact_assessment_guidelines.html.

24. Venner, M., "Measuring Environmental Performance at State Transportation Agencies," TRB Annual Meeting, 2003.

25. Olsen, J.B., and Eadie, D.C., The Game Plan: Governance with Foresight. Council of State Planning Agencies. Washington, DC (1982) p. 4.

26. Bryson, J.M., Strategic Planning for Public and Nonprofit Organizations: A Guide to Strengthening and Sustaining Organizational Achievement. Jossey-Bass, San Francisco (1988) p. 5.

27. Steiner, G.A., Strategic Planning: What Every Manager Must Know. Free Press, New York (1979).

28. Barry, B.W., Strategic Planning Workbook for Nonprofit Organizations. Amherst H. Wilder Foundation, St. Paul, MN (1986).

29. Byrson, J.M., Van de Ven, A.H., and Roering, W.D. "Strategic Planning and the Revitalization of the Public Service." *In* Denhardt and Jennings (Eds.) Toward a New Public Service. Extension Publications, University of Missouri (1987).

30. Venner, M., unpublished survey, 2002.

31. McVoy, G., Sengenberger, M. and Novak, E., "The NYSDOT Environmental Initiative Guidelines and Procedures for a New Paradigm." white paper. http://www.dot.state.ny.us/eab/eitrbdot.pdf.

32. McVoy, G., Sengenberger, M. and Novak, E., "The NYSDOT Environmental Initiative Guidelines and Procedures for a New Paradigm." white paper. http://www.dot.state.ny.us/eab/eitrbdot.pdf.

33. McVoy, G., Sengenberger, M. and Novak, E., "The NYSDOT Environmental Initiative Guidelines and Procedures for a New Paradigm." white paper. http://www.dot.state.ny.us/eab/eitrbdot.pdf.

34. Case studies developed by the author for the AASHTO EMS Workshop for State DOTs in August 2003, included as part of the AASHTO EMS Handbook by Dave Soltis, at: http://environment.transportation.org/environmental_issues/environmental_management_systems/CaseStudy_8_NY.htm.

35. Personal communication, Raja Veeramachaneni, (rveeramachaneni@sha.state.me.us), MDSHA Director of Planning and Preliminary Engineering, MDSHA Stewardship Council Co-Chair (April 14, 2004).

36. Information in this section was provided by Julie Hunkins, Director, NCDOT Office of Environmental Quality, July 2003.

37. Personal communication, Julie Hunkins, Director, NCDOT Office of Environmental Quality (April 1, 2004).

38. Commonwealth of Pennsylvania, "Executive Order 1998-1." http://www.gggc.state.pa.us/about/1998-1.pdf.

39. Mallory, Brad, Secretary of PennDOT, Presentation at TRB Annual Meeting (January, 2001).

40. Mallory, Brad, Secretary of PennDOT, Presentation at TRB Annual Meeting (January, 2002).

41. Venner, 2003 and 2002 study on DOT-Funded Positions at resource agencies.

42. Venner, 2003 and 2002 study on DOT-Funded Positions at resource agencies.

43. Venner, 2003 and 2002 study on DOT-Funded Positions at resource agencies.

44. Federal Highway Administration, "Domestic Scan: Environmental Commitment Implementation: Innovative and Successful Approaches." http://environment.fhwa.dot.gov/strmlng/domScanRpt/index.htm.

45. Personal communication, Wayne Hall, Natural Resources Manager (2002 and 2003).

46. California Department of Transportation, "Construction Manual." Hancock, J., (Ed.). State of California Transportation Publication, Sacramento CA (2002) 878 pp. pp 7-1.1.

47. Federal Highway Administration, "Domestic Scan: Environmental Commitment Implementation: Innovative and Successful Approaches." http://www.environment.fhwa.dot.gov/strmlng/domScanRpt/appc.htm also http://biomitigation.org/.

48. Personal communication, Patty Lynch, WSDOT (March 26, 2004).

49. Federal Highway Administration, "Committed to Excellence: Successful State Approaches to Implementing Environmental Commitments," *Successes in Streamlining Newsletter* (July 2003) http://environment.fhwa.dot.gov/strmlng/newsletters/jul03nl.htm.

50. Venner, M., project for the USDOT Volpe Center, 2002.

51. U.S. Executive Order 13148, "Greening the Government through Leadership in Environmental Management." Presidential Signature. (April 21st, 2000) http://ceq.eh.doe.gov/nepa/regs/eos/eo13148.html.

52. Burbank, C., "Memorandum: Environmental Management Systems as a tool to demonstrate Environmental Stewardship." Federal Highway Administration (July 23, 2002) www.fhwa.dot.gov/environment/guidebook/vol2/emsmemo.htm.

53. The Federal Highway Administration, "FHWA's Vital Few Goal- Environmental Stewardship and Streamlining." http://www.fhwa.dot.gov/environment//strmlng/essovervw.htm.

54. AASHTO Center for Environmental Excellence http://environment.transportation.org/indexnew.asp

55. Council on Environmental Quality, "Modernizing NEPA Implementation." (September, 2003) http://ceq.eh.doe.gov/ntf/report/finalreport.pdf.

56. The DOT anecdotes and examples herein were collected by the author for AASHTO in preparation for AASHTO's EMS Workshop for DOTs in 2003. Some of these examples were subsequently included in AASHTO's Implementation Guide for EMSs.

57. Kleiner, A. "What Does It Mean to be Green?" Harvard Business Review, (July/August 1991) pp.39-47, *In* Darnall, N., Gallagher, D.R., Andrews, R.N.L., and Amaral, D., "Environmental Management Systems: Opportunities for Improved Environmental and Business Strategy?" Environmental Quality Management, Wiley Publishers (2000) http://www.eli.org/pdf/eqm.pdf.

58. Sisk, S., "Compliance-Focused Environmental Management System - Enforcement Agreement Guidance." National Enforcement Investigations Center, *EPA330/9-97-002R* (December, 2001) www.epa.gov/compliance/resources/publications/incentives/ems/ems12elemr.pdf.

59. Davis, S.P., Glover, M.A., and Philip J. Stapleton, P.J. "An Implementation Guide for Small and Medium-Sized Organizations." http://www.epa.gov/owm/iso14001/ems2001final.pdf.

60. Comments provided by Christine Olson, Maine DOT EMS Manager, June 2003.

61. AASHTO Center for Environmental Excellence, "Success Stories." http://environment.transportation.org/environmental_issues/environmental_management_systems/success_stories.htm.

62. Gallagher, D. R., Darnall, N., and Andrews, R.N.L., International Standards for Environmental Management Systems: A Future Promise for Environmental Policy? University of North Carolina (November 1999) http://ndems.cas.unc.edu/.

63. Personal communication, Fred Murphy, former NHDOT EMS Manager (May 14, 2003).

64. Personal communications, Christine Olson, Maine DOT EMS Manager (May and June, 2003).

65. Personal communications, Christine Olson, Maine DOT EMS Manager (May and June, 2003).

66. Comments made at an EMS Stakeholder Meeting attended by the author in December 2002.

67. Slaugenhoop, J. Presentation at PENNDOT District 10, at AASHTO's EMS Workshop for State Transportation Agencies (August 2003).

68. Knezo, G., and McMurtry, V., "Performance Measure Provisions in the 105th Congress: Analysis of a Selected Compilation," Congressional Research Service (January 7, 1999).

69. American Productivity and Quality Center, "Strategic Planning: What Works ... And What Doesn't." Presentations from APQC's Third Knowledge Management Symposium (1999) www.apqc.org/free/whitepapers/dispWhitePaper.cfm?ProductID=672.

70. Gallagher, R., D., Darnall, N., and Andrews, R.N.L. "International Standards for Environmental Management Systems: A Future Promise for Environmental Policy?" University of North Carolina (November 1999) http://ndems.cas.unc.edu/.

71. Andrews, R.N.L., "Environmental Management Systems: Do They Improve Performance?" www.newmoa.org/Newmoa/htdocs/prevention/webconferences/emsweb/Minicucci.pdf.

72. Andrews, R. N.L. "Environmental Management Systems: Do They Improve Performance?" www.newmoa.org/Newmoa/htdocs/prevention/webconferences/emsweb/Minicucci.pdf.

73. Jackson, S. L. The ISO 14001 Implementation Guide: Creating an Integrated Management System. John Wiley & Sons (February 1997).

73. Personal communication, Tony Warfield, WSDOT EMS Manager (April 13, 2004).

75. Appendix A, NWS RTA EMS Manual

76. Venner, M., "Measuring Environmental Performance at State Transportation Agencies," TRB Annual Meeting, 2003.

77. American Productivity and Quality Center, "Strategic Planning: What Works ... And What Doesn't," presentations from APQC's Third Knowledge Management Symposium (1999) www.apqc.org/free/whitepapers/dispWhitePaper.cfm?ProductID=672.

78. Schick, A. "Getting Performance Measures to Measure Up." *In* "Quicker, Better, Cheaper? Managing Performance in American Government." Forsythe, D., (Ed.) Rockefeller Institute Press (September, 2001) p. 43.

79. Hatry, H. P. Performance Management: Getting Results. Washington DC. Urban Institute Press (1999) *In* "Quicker, Better, Cheaper?" Nathan, R.P. (Ed.), Managing Performance in American Government (2000).

80. American Productivity and Quality Center, "Strategic Planning: What Works ... And What Doesn't," presentations from APQC's Third Knowledge Management Symposium (1999) www.apqc.org/free/whitepapers/dispWhitePaper.cfm?ProductID=672.

81. U.S. Government Accounting Office, "Managing for Results: EPA Faces Challenges in Developing Results-Oriented Performance Goals and Measures." *GAO/RCED-00-77* (April 2000).

82. Venner, 2002 survey.

83. Venner, 2003 and 2002 study on DOT-Funded Positions at resource agencies.

84. Venner, 2002 survey.

85. Venner, 2002 survey.

86. Venner, 2002 survey.

87. Venner, 2002 survey.

88. Venner, 2002 survey.

89. McVoy, G., Sengenberger, M. and Novak, E., "NYSDOT Environmental Initiative Guidelines and Procedures," http://www.dot.state.ny.us/eab/eitrbdot.pdf.

90. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 20.

91. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 21.

92. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 22.

93. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 23.

94. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 24.

95. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 25/26.

96. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 27.

97. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 28.

98. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 29.

99. Ossinger, M. "Success Standards for Wetland Mitigation Projects: A Guideline" Washington State Department of Transportation (1999) 34 pp.

100. Gilbert, R. and Myrans, K., "Sustainable Transportation Performance Indicators." Center for Sustainable Transportation, http://www.cstctd.org/CSTadobefiles/STPI%20synopsis%20final%20English.pdf.

101. Gilbert, R. and Myrans, K., "Sustainable Transportation Performance Indicators." Center for Sustainable Transportation, http://www.cstctd.org/CSTadobefiles/STPI%20synopsis%20final%20English.pdf.

102. Australian Standard *AS/NZ1SO 14010*: "Guidelines for Environmental Auditing - General Principles." (1996) *In* New South Wales, Australia, Roads and Traffic Authority Guidelines for Environmental Auditing of Construction Works.

103. New South Wales Australia, Roads and Traffic Authority, "Guidelines for Environmental Auditing of Construction Works." The program description in this section is condensed from this resource.

104. Federal Highway Administration, New Jersey DOT Contractor Performance Rating System Procedure Pilot Program: Quality Assurance Process, http://www.fhwa.dot.gov/programadmin/contracts/njproc.htm.

105. Federal Highway Administration, New Jersey DOT Contractor Performance Rating System Procedure Pilot Program: Quality Assurance Process, http://www.fhwa.dot.gov/programadmin/contracts/njproc.htm.

106. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations," (July 2001) p. 4.6.30.

107. Survey by the AASHTO Construction Subcommittee Contract Administration Task Force http://www.fhwa.dot.gov/programadmin/contracts/perflong.htm.

108. California Department of Transportation, "Construction Manual." Hancock, J., (Ed.). State of California Transportation Publication, Sacramento CA (2002) 878 pp., p 7-1.1.

109. Williams, K., "Environmental Stewardship in NYSDOT Highway Maintenance," 2003 Proceedings of the International Conference of Ecology and Transportation, Irwin, C.L., Garrett, P., and McDermott, K.P. (Eds.) Raleigh NC Center for Transportation and the Environment, North Carolina State University.

110. Williams, K., "Environmental Stewardship in NYSDOT Highway Maintenance," 2003 Proceedings of the International Conference of Ecology and Transportation, Irwin, C.L., Garrett, P., and McDermott, K.P., (Eds.) Raleigh NC Center for Transportation and the Environment, North Carolina State University.

111. Pennsylvania Department of Transportation, Center for Performance Excellence, Transportation University http://www.dot.state.pa.us/internet/secinet.nsf.

112. California Department of Transportation, "Innovative Practices in State DOT Workforce Management: Work Breakdown Structure." http://www.nhi.fhwa.dot.gov/transworkforce/IP_CA.PDF. Contact: Nigel_Blampied@dot.ca.gov or Terry_Murphy@dot.ca.gov.

113. NYSDOT Environmental Analysis Bureau Training and Presentation Slides, http://www.dot.state.ny.us/eab/slides.html.

114. Transportation Association of Canada "Syntheses of Best Practices Road Salt Management: Training , (September, 2003) http://www.tac-atc.ca/english/pdf/training.PDF.

115. LTAP Training Administration, http://www.ltapt2.org/handbook/train-admin.htm.

116. Personnel conversation, Jerry Chaney, Utah DOT: Program overview (March 3, 2002) Contact: (801) 965-4317 or jchaney@utah.gov.

117. Forman, R.L., "AGC of New Jersey Thinks Green," *Constructor*, Vol. 84, No. 4 (April 2002) pp. 35, 37.

118. Associated General Contractors of America, Taming Stormwater in Illinois," *Constructor*, Vol. 85, No. 9 (September 2003,) p. 18.

119. Caltrans, College Training Related to Stormwater Pollution Prevention, http://www.dot.ca.gov/hq/construc/stormwater/swppp_cctraining.htm.

120. Edson, J., Presentation at the 2003 AASHTO-TRB Maintenance Meeting, Duluth, MN (July 2003).

121. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Training , (September, 2003) http://www.tac-atc.ca/english/pdf/training.PDF.

122. LTAP Training Tools and http://www.ltapt2.org/handbook/train-tools.htm and Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Training (September, 2003) http://www.tac-atc.ca/english/pdf/training.PDF.

123. Amabile, T., "Motivating Creativity in Organizations." *California Management Review* , Vol. 40, No. 1 pp. 39-58 (1997).

124. Mason, J.M., and Anderson, J.A. "Certification Programs and Professional Development," Transportation Frontiers for the Next Millennium: 69th Annual Meeting of the Institute of Transportation Engineers, Institute of Transportation Engineers, Las Vegas, NV (August 1999).

125. Virginia Department of Transportation Environmental Division Erosion and Sediment Control Contractor Certification, www.virginiadot.org/business/environmental-essce-main.asp.

126. Virginia DOT Memo to Contractors, "VDOT Erosion and Sediment Control Contractor Certification (VDOT ESC Contractor Certification) Program, (January 1, 2002) http://www.virginiadot.org/business/resources/Env-essce-ltr.pdf.

127. Virginia DOT Memo to Contractors, "VDOT Erosion and Sediment Control Contractor Certification (VDOT ESC Contractor Certification) Program (January 1, 2002) http://www.virginiadot.org/business/resources/Env-essce-ltr.pdf.

128. Personal communication, Ricky Woody, Virginia DOT Natural Resources Program Section Manager, (February 11, 2004)

129. Contact for TennDOT Erosion and Sediment Control Training and Certification: Presley, Mike, Phone: (865) 693-0247, Email: mpresley@mail.state.tn.us.

130. Hymel, D., "AGC of Washington Education Foundation Partners With Local DOT for the Good of the Environment," *Constructor*, Vol. 84(f) (April 2002) p. 22.

131. Anderson, C., "Iowa Department of Transportation Technical Training Activities," A Presentation at the Mid-Continent Transportation Research Symposium in Ames, Iowa (August 2003).

132. Gylywoychuk, D., "Integration of Safety, Health and Environment Management Systems: Lessons from the Private Sector." Annual Conference of the Transportation Association of Canada (September 2002).

133. National Institute for Certification in Engineering Technologies, http://www.nicet.org/certification/.

134. National Institute for Certification in Engineering Technologies, http://www.nicet.org/certification/.

135. AASHTO Center for Environmental Excellence, http://environment.transportation.org/.

136. Smithson, Leland, "Training: The Key to Technology Implementation," 2003 AASHTO-TRB Maintenance Meeting, Duluth, MN (July 2003).

137. Snow and Ice Pooled Fund Cooperative Research Program (SICOP), http://www.sicop.net/index.htm.

138. Muench, S. "Rolling A Perfect Score: Compaction Video Game Proving To Be An Effective Learning Tool." *Roads and Bridges*, Vol. 48 No. 8 (August 2003) pp. 36-39.

139. Local Technology Assistance Centers, http://www.ltapt2.org/resources/ruralresources.htm.

140. Council of University Transportation Centers, http://cutc.tamu.edu.

141. Center for Transportation and the Environment, http://www.itre.ncsu.edu/cte/gateway/home.html.

142. New York State DOT Engineering Instruction 99-026, "Environmental Initiative Guidelines and Procedures." http://www.dot.state.ny.us/eab/eieab3.pdf.

143. NYSDOT Environmental Initiative Statement, Revision: (February 9, 1999), http://www.dot.state.ny.us/eab/eistate.html.

144. U.S. General Accounting Office, "Ecosystem Conservation in Transportation Planning." *Report GAO-04-536* (May 2004), p. 12. http://www.gao.gov/new.itms/d04536.pdf.

145. AASHTO Environmental Stewardship Demonstration Program, http://www.itre.ncsu.edu/aashto/stewardship/proj_view-APP.asp.

146. National Transportation Enhancements Clearinghouse, "Transportation Enhancements: Summary of Nationwide Spending as of FY 2003, http://www.enhancements.org/misc/tedatafy03.pdf.

147. National Transportation Enhancements Clearinghouse, "Transportation Enhancements: Summary of Nationwide Spending as of FY 2003, http://www.enhancements.org/misc/tedatafy03.pdf.

148. Personal communication, Donald Lyford, Project Manager, New Hampshire Department of Transportation. Also, National Transportation Enhancement Clearinghouse, http://www.enhancements.org/.

149. Federal Highway Administration, Special Issue on Context Sensitive Design, *Greener Roadsides*, Vol. 10, No. 3 (Fall 2003) p. 2.

150. Texas Transportation Institute Environmental Management Program, "Guidelines for Aesthetic Design in Highway Corridors: Tools and Treatments for Texas Highways." http://tti.tamu.edu/enviro_mgmt/projects/2113/.

151. Kaplan, S., "Perception and Landscape: Conceptions and Misconceptions. *In* "Environmental Aesthetics, Theory, Research, and Applications." Nasar, J. (Ed.) Cambridge: Cambridge University Press (1988) as noted in http://tti.tamu.edu/enviro_mgmt/projects/2113/.

152. "Thinking Beyond the Pavement: A National Workshop" Brochure for the program. http://www.fhwa.dot.gov/csd/mdbroch.pdf.

153. AASHTO Transportation Center of Excellence, http://www.transportation.org/aashto/success.nsf/allpages/AllStories.

154. AASHTO Success Stories: "Maryland's Neighborhood Conservation Program Gives a Facelift to Older Neighborhoods" http://www.transportation.org/aashto/success.nsf/allpages/10MarylandSmartGrowth.

155. Mn/DOT, 2003 AASHTO Environmental Excellence Project Application.

156. Schutt, J.R., Phillips, K.L., Landphair, H.C., "Guidelines for Aesthetic Design in Highway Corridors: Tools and Treatments for Texas Highways." *FHWA/T02-2113-3*, Texas Department of Transportation and Federal Highway Administration, Washington, DC (September, 2001) 94 pp.

157. Personal communication Nelson Hoffman, N. TRIS, VTrans, Phone: (802) 828-0445.

158. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 910-1.

159. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 910-7.

160. Green Book available by order online at: https://www.transportation.org/publications/bookstore.nsf/ViewPublication?openform&ParentUNID=6BAA51C12B7F431D86256A3800574f81.

161. AASHTO Center for Environmental Excellence, “WisDOT’s Community Sensitive Design Development.” Environmental Stewardship Demonstration Program http://www.itre.ncsu.edu/AASHTO/stewardship/projectinfo.asp?id=130.

162. Wisconsin Department of Transportation, “Aesthetic Considerations for Context-Sensitive Design.” (February, 2003) http://www.dot.wisconsin.gov/library/research/docs/tsrs/tsraestheticsincontextsensitivedesign.pdf.

163. Roadway Aesthetic Treatments photo Album WorkbookBriefing Paper (August 2001) http://www.nhi.fhwa.dot.gov/tccc/aashto_soc_2001/roadway-aesthetic_treatments.doc.

164. Institute of Transportation Engineers, “Traditional Neighborhood Development: Street Design Guidelines.” (1999 http://www.ite.org.

165. Klein, T., and Sebastian, L. “Assessing Historic Significance for Transportation Programs.” *Transportation Research Circular E-C055* (August, 2003) 102 pp., p. 93, http://gulliver.trb.org/publications/circulars/ec055.pdf, p. 93.

166. Pima County Environmentally Sensitive Roadway Guidelines (December, 2003) http://www.dot.pima.gov/transeng/roaddesign/.

167. AASHTO Success Stories: Arizona DOT Projects Preserve History , Save Money.” http://transportation.org/aashto/success.nsf/allpages/azpreservinghistory?opendocument.

168. Pima County Environmentally Sensitive Roadway Guidelines (December, 2003) http://www.dot.pima.gov/transeng/roaddesign/.

169. Gibbon, G., Johnson, C.M., and Morris, S. “A Predictive Model of Precontact Archaeological Site Location for The State of Minnesota.” Chapter 5: The Archaeological Database, http://www.mnmodel.dot.state.mn.us/chapters/ch51#ch51.

170. FHWA Successes in Streamlining Newsletter, , “Preserving History While Advancing Transportation: US 77 in Texas.” (August 2003) http://environment.fhwa.dot.gov/strmlng/newsletters/aug03nl.htm.

171. “Arkansas Bridges the Gap between Functionality and Aesthetics.” Research Technology Reporter (January, 2002) http://www.tfhrc.gov/trnsptr/jan02/jan02.htm.

172. AASHTO Success Stories: “New Hampshire: Rebuilding Bridges.” http://transportation.org/aashto/success.nsf/allpages/07-NHCoveredBridges.

173. Venner, unpublished survey, 2002.

174. Bissonette, J., “Evaluation of the Use and Effectiveness of Wildlife Crossings.” NCHRP 25-27 Project http://www4.trb.org/trb/crp.nsf/0/29f4dcb2345e34d685256d0b0065f79d?OpenDocument.

175. Venner, unpublished survey, 2002.

176. Venner, unpublished survey, 2002.

177. Ruediger, B., USDA Forest Service, presentation at the International Conference on Ecology and Transportation, Lake Placid NY (August 2003).

178. Venner, unpublished survey, 2002.

179. Venner, unpublished survey, 2002.

180. Venner, unpublished survey, 2002.

181. Hardy, A., “An Overview of Methods and Approaches for Evaluating the Effectiveness of Wildlife Crossing Structures: Emphasizing the Science in Applied Science,” International Conference on Ecology and Transportation, Lake Placid NY (August 2003).

182. U.S. Forest Service, “Wildlife Crossing Toolkit.” www.wildlifecrossings.info.

183. Clevenger, A., "Long-Term, Year-Round Monitoring Of Wildlife Crossing Structures and the Importance of Temporal and Spatial Variability in Performance Studies," International Conference on Ecology and Transportation, Lake Placid NY, (August 2003).

184. Hardy, A., "An Overview of Methods and Approaches for Evaluating the Effectiveness of Wildlife Crossing Structures: Emphasizing the Science in Applied Science," International Conference on Ecology and Transportation, Lake Placid NY, August 2003.

185. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

186. Clevenger, A.P., Chruszcz, F. and Gunson, K.E. "Highway Mitigation Fencing Reduces Wildlife–Vehicle Collisions," *Wildlife Society Bulletin,* Vol. 29, No. 2 (2001).

187. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

188. U.S. Forest Service, "Wildlife Crossing Toolkit." www.wildlifecrossings.info.

189. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

190. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

191. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

192. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

193. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

194. Clevenger, A. and Waltho, N., "Dry Drainage Culvert Use and Design Considerations for Small- and Medium-Sized Mammal Movement Across a Major Transportation Corridor." http://www.dot.state.fl.us/emo/sched/ms.pdf.

195. Personal communication, Tony Clevenger (April 2004).

196. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

197. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

198. Evink, G., "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

199. Evink, G., "Interaction between Roadways and Wildlife Ecology: A Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf.

200. Colorado DOT, Shortgrass Prairie Conservation Strategy and Biological Assessment, 2003.

201. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

202. U.S. General Accounting Office. "Restoring Fish Passage Through Culverts on Forest Service and BLM Lands in Oregon and Washington Could Take Decades." *GAO-02-136*, Washington, DC (2001).

203. Personal Communication. Michael Merrill, MA Riverways Program.

204. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

205. U.S. General Accounting Office. "Restoring Fish Passage Through Culverts on Forest Service and BLM Lands in Oregon and Washington Could Take Decades." *GAO-02-136*, Washington, DC (2001).

206. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

207. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

208. Personal communication, Jay F. Levine, North Carolina State University, Raleigh Department of Civil Engineering, Phone: (919) 513-6397, Email: Jay_Levine@ncs.edu (May 18, 2004).

209. Riley, C., "Fish Passage at Selected Culverts on the Hoonah Ranger District, Tongrass National Forest." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

210. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

211. Johansen, K. D. "Design and Construction of Aquatic Organism Passage and Road-Stream Crossings: Construction Challenges and Case Studies of Stream Simulation Structures for Aquatic Organism Passage." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

212. TransSafety, Inc. "Designing Highway Culverts That Do Not Impede the Movements of Resident Fish Species." *Road Engineering Journal,* (November 1, 1997) http://www.usroads.com/journals/p/rej/9711/re971102.htm.

213. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

214. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

215. Williams, J.D., Warren M.L., Cummings, K.S., Harris, J.L., and Neves, R.J., "Conservation Status of Freshwater Mussels of the United States and Canada." *Fisheries*, Vol.18, No.9 (1993) pp. 6-22.

216. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

217. Jackson, S.D., "Ecological Considerations in the Design of River and Stream Crossings." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

218. Riley, C., "Fish Passage at Selected Culverts on the Hoonah Ranger District, Tongrass National Forest." Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

219. Personal communication, Kevin Donahoo, Nebraska Department of Roads (May 18, 2004).

220 Alberta Transportation, "Fish Habitat Manual: Guidelines and Procedures forWatercourse Crossings in Alberta." http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp4.pdf.

221 Alberta Transportation, "Fish Habitat Manual: Guidelines and Procedures forWatercourse Crossings in Alberta." http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp4.pdf.

222. California Department of Fish and Game, "California Salmonid Stream Habitat Restoration Manual." Fish Passage Evaluation, Habitat Conservation Division (April 2003) Chapter IX; p.46.

223 Alberta Transportation, "Fish Habitat Manual: Guidelines and Procedures forWatercourse Crossings in Alberta." http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp4.pdf.

224. National Marine Fisheries Service, Southwest Region, "California Guidelines for Salmonid Passage at Stream Crossings." (September, 2001) p. 8.

225. National Marine Fisheries Service, Southwest Region, “California Guidelines for Salmonid Passage at Stream Crossings.” (September, 2001) p. 8.

226. National Marine Fisheries Service, Southwest Region, “California Guidelines for Salmonid Passage at Stream Crossings.” (September, 2001) p. 8.

227. National Marine Fisheries Service, Southwest Region, “California Guidelines for Salmonid Passage at Stream Crossings.” (September, 2001) p. 4, http://swr.ucsd.edu/hcd/NMFSSCG.PDF.

228. Jackson, S.D., “Ecological Considerations in the Design of River and Stream Crossings.” Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

229. Gubernick, B. “Design And Construction of Aquatic Organism Passage at Road-Stream Crossings Designing Culverts for Aquatic Organism Passage: Stream Simulation.” Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

230. Gubernick, B. “Design And Construction of Aquatic Organism Passage at Road-Stream Crossings Designing Culverts for Aquatic Organism Passage: Stream Simulation.” Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

231. Gubernick, B. “Design And Construction of Aquatic Organism Passage at Road-Stream Crossings Designing Culverts for Aquatic Organism Passage: Stream Simulation.” Proceedings of International Conference on Ecology and Transportation, Lake Placid, NY (August, 2003).

232. California Department of Fish and Game, “California Salmonid Stream Habitat Restoration Manual.” Fish Passage Evaluation, Habitat Conservation Division (April 2003) Chapter IX; p.46.

233. Washington State Department of Transportation, “Environmental Procedures Manual.” (March, 2004) 1148 pp.

234. Kosicki, A.J., Davis, S.R., “Consideration of Stream Morphology in Culvert and Bridge Design.” *Transportation Research Record No. 1743*, Transportation Research Board, Washington, DC (2001) pp 57-59.

235. National Marine Fisheries Service, Southwest Region, “California Guidelines for Salmonid Passage at Stream Crossings.” (September, 2001) p. 9.

236. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

237. Lewis, L., “Soil Bioengineering - An Alternative to Roadside Management.” USDA Forest Service (September, 2000) 47 pp. http://www.wsdot.wa.gov/eesc/design/roadside/SB/pdf/Soil%20bioeng.pdf.

238. Doll, B.A., Grabow, G.L., Hall, K.R., Halley, J., Harman, W.A., Jennings, G.D., Wise, D.E, “Stream Restoration: A Natural Channel Design Handbook.” North Carolina Stream Restoration Institute, http://www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/sr_guidebook.pdf.

239. Washington State Department of Transportation, “Roadside Manual.” (July, 2003) 324 pp., p. 740-1.

240. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

241. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

242. Ontario Ministry of Natural Resources, “Natural Channel Systems: An Approach to Management and Design.” Ontario Ministry of Natural Resources, Toronto (1994)103 pp.

243. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

244. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

245. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

246. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

247. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

248. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

249. Alberta Transportation, “Fish Habitat Manual: Guidelines and Procedures for Watercourse Crossings in Alberta.” http://www.trans.gov.ab.ca/Content/docType123/Production/FishChp8.pdf.

250. Washington State Department of Transportation, “Roadside Manual.” (July, 2003) 324 pp., p. 740-20.

251. Bryson, D.W., Ghere, D.G., Hulbert, W.H., “European Practice for Bridge Scour and Stream Instability Countermeasures” Transportation Research Record No. 169, Transportation Research Board, Washington, DC (2000) pp 236-243.

252. USEPA, “Principles for the Ecological Restoration of Aquatic Resources.” *EPA841-F-00-003,* Office of Water (4501F), United States Environmental Protection Agency, Washington, DC (2000) 4 pp.

253. Research underway and due in 2005. Mn/DOT contact is Nambisan, Shashi S. Phone: (702) 895-1338.

254. Research underway and due in mid 2006. Georgia DOT contact is Jared, David, Phone: (404) 363-7569 Email: david.jared@dot.state.ga.us.

255. Unpublished research “Regional Channel Characteristics for Maintaining Natural Fluvial Geomorphology in Florida Streams,” Report due in 2005. Personal communication, Josh Boan, FDOT, Phone: (850) 922-7208, 5/17/04.

256. Personal communication, Paul Garrett, (May 18, 2004).

257. Personal communication, Tim Hess, NCHRP 24-19 and Salix Applied Earthcare (May, 2004)

258. Fischenich, J.C. “Effects of Riprap on Riverine and Riparian Ecosystems,” Army Corps of Engineers, Wetlands Regulatory Assistance Program, *ERDC/EL TR-03-4*, (April 2003) http://www.wes.army.mil/el/wrap/pdf/trel03-4.pdf.

259. Fischenich, J.C. “Effects of Riprap on Riverine and Riparian Ecosystems,” Army Corps of Engineers, Wetlands Regulatory Assistance Program, *ERDC/EL TR-03-4*, (April 2003) http://www.wes.army.mil/el/wrap/pdf/trel03-4.pdf.

260. Fischenich, J.C. “Effects of Riprap on Riverine and Riparian Ecosystems,” Army Corps of Engineers, Wetlands Regulatory Assistance Program, *ERDC/EL TR-03-4*, (April 2003) http://www.wes.army.mil/el/wrap/pdf/trel03-4.pdf.

261. U.S. Army Corps of Engineers, “Annotated Bibliography of Impacts of Riprap Habitats on Fish Populations.” (June, 2001) http://wdfw.wa.gov/hab/ahg/ispg_app_k_lit_review.pdf.

262. Fischenich, J.C. “Effects of Riprap on Riverine and Riparian Ecosystems,” Army Corps of Engineers, Wetlands Regulatory Assistance Program, *ERDC/EL TR-03-4*, (April 2003). http://www.wes.army.mil/el/wrap/pdf/trel03-4.pdf.

263. “Florida Erosion and Sediment Control Inspector’s Manual.” http://www.dep.state.fl.us/water/nonpoint/docs/erosion/chapter5.pdf.

264. Temporary Instream Construction Measures Maryland Department of the Environment Waterway Construction Guidelines Revised (November 2000) http://www.mde.state.md.us/assets/document/wetlandswaterways/sec2-9.pdf.

265. Alaska Division of Fish and Game, “Root Wads.” http://www.sf.adfg.state.ak.us/sarr/restoration/techniques/rootwad.cfm.

266. Jennings, G., “A Two Stage Evaluation of NCDOT Stream Mitigation Practices.” Federal Highway Administration and North Carolina State University *FHWA /NC/2002-015*, Transportation Research Board, Washington, DC (June, 2002) 24 pp.

267. Jennings, G., “A Two Stage Evaluation of NCDOT Stream Mitigation Practices.” Federal Highway Administration and North Carolina State University *FHWA /NC/2002-015*, Transportation Research Board, Washington, DC (June, 2002) 24 pp.

268. Jennings, G., "A Two Stage Evaluation of NCDOT Stream Mitigation Practices." Federal Highway Administration and North Carolina State University *FHWA /NC/2002-015*, Transportation Research Board, Washington, DC (June, 2002) 24 pp.

269. Alaska Division of Fish and Game, "Fascine." http://www.sf.adfg.state.ak.us/sarr/restoration/techniques/fascine.cfm.

270. Alaska Division of Fish and Game, "Brush Layering" http://www.sf.adfg.state.ak.us/sarr/restoration/techniques/brushlayer.cfm.

271. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp. p. 740-17.

272. Alaska Division of Fish and Game, "Brush Matting" http://www.sf.adfg.state.ak.us/sarr/restoration/techniques/brushmat.cfm.

273. Alaska Division of Fish and Game, "Coir Logs" http://www.sf.adfg.state.ak.us/sarr/restoration/techniques/coir.cfm.

274. Washington State Department of Transportation, "Road Maintenance Guidelines." (August, 2003).

275. Faucette, B. and Ruhlman, M., "Stream Bank Stabilization Utilizing Compost." *Biocycle: Journal of Composting and Organics Recycling,* Vol. 45, No. 1 (January, 2004) p. 27.

276. Faucette, B. and Ruhlman, M., "Stream Bank Stabilization Utilizing Compost." *Biocycle: Journal of Composting and Organics Recycling,* Vol. 45, No. 1 (January, 2004) p. 27.

277. Jennings, G., "A Two Stage Evaluation of NCDOT Stream Mitigation Practices." Federal Highway Administration and North Carolina State University *FHWA /NC/2002-015*, Transportation Research Board, Washington, DC, (June, 2002) 24 pp.

278. Jennings, G., "A Two Stage Evaluation of NCDOT Stream Mitigation Practices." Federal Highway Administration and North Carolina State University *FHWA /NC/2002-015*, Transportation Research Board, Washington, DC, (June, 2002) 24 pp.

279. Jennings, G., "A Two Stage Evaluation of NCDOT Stream Mitigation Practices." Federal Highway Administration and North Carolina State University *FHWA /NC/2002-015*, Transportation Research Board, Washington, DC, (June, 2002) 24 pp.

280. Maryland Fact Sheet on Boulder Placement, http://www.mde.state.md.us/assets/document/wetlandswaterways/sec3-1.pdf.

281. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p. 3-2.

282. New York State Department of Transportation, Region 8, "Operations & Maintenance Manual for Stormwater Facilities." (September, 2003) http://www.dot.state.ny.us/eab/manual/nysdot8storm_a.pdf.

283. Venner, M. "Quality Research Needs: Survey." *NCHRP Project 25-20 (02)* (2002).

284. Barber, M., Schaftlein, S., Anderson, D., "Stormwater Runoff Cost/Benefit Project Prioritizing Stormwater Outfalls, *WA-RD 418.1* (1997) 99 pp.

285. Barber, M., Schaftlein, S., Anderson, D., "Stormwater Runoff Cost/Benefit Project Prioritizing Stormwater Outfalls, *WA-RD 418.1* (1997) 99 pp.

286. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p.2.6.2.81.

287. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 120-1.

288. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management: Interim Report." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 36.

289. Claassen, V.P., Zasoski, R.J., and Southard, R.J., "Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes." *FHWA Report FHWA/CA/TL – 96/01*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 151 pp.

290. Claassen, V.P., Zasoski, R.J., and Southard, R.J., "Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes." *FHWA Report FHWA/CA/TL – 96/01*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 151 pp.

291. Claassen, V.P., Haynes, J.F., and Zasoski, R.J., "Revegetation of Disturbed Soils with Topsoil and Fertilizer Amendments." *In* Claassen, V.P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) pp. 277-287.

292. Perry, D.A., and Amaranthus, M.P., "The Plant-Soil Bootstrap: Microorganisms and Reclamation of Degraded Ecosystems." *In* Berger, J.J. (Ed.), Environmental Restoration. Island Press, Washington, DC (1990) pp. 94-102.

293. Vitousek, P.M. and Matson, P.A., "Disturbance, Nitrogen Availability, and Nitrogen Losses in an Intensively Managed Loblolly Pine Plantation." *Ecology*, Vol. 66, No. 4 (1985) pp. 1360-1376.

294. Claassen, V.P., Haynes, J.F., and Zasoski, R.J., "Revegetation of Disturbed Soils with Topsoil and Fertilizer Amendments." *In* Claassen, V.P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) pp. 277-287.

295. Reeves, F.B., Wagner, D., Moorman, T., and Kiel, J., "The Role of Endomycorrhizae in Revegetation Practices in the Semi-Arid West.I. A Comparison of Incidence of Mycorrhizae in Severely Disturbed vs. Natural Environments." *American Journal of Botany*, Vol. 66, No. 1 (1979), pp. 6-13.

296. Claassen, V.P., Haynes, J.F., and Zasoski, R.J., "Revegetation of Disturbed Soils with Topsoil and Fertilizer Amendments." *In* Claassen, V.P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) pp. 277-287.

297. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

298. Claassen, V.P., Zasoski, R.J., and Southard, R.J., "Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes." *FHWA Report FHWA/CA/TL – 96/01*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 151 pp.

299. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

300. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

301. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

302. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

303. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 700-8.

304. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

305. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

306. Claassen, V.P., Zasoski, R.J., and Southard, R.J., “Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes.” FHWA Report FHWA/CA/TL – 96/01, Federal Highway Administration and State of California Department of Transportation (June, 1995) 151 pp.

307. Classsen, V.P. and Hogan, M.P., “Generation of Water-stable Soil Aggregates for Improved Erosion Control and Revegetation Success.” *FHWA Report FHWA/CA/TL – 98/18,* Federal Highway Administration and State of California Department of Transportation (March, 1998) 111 pp.

308. Clary, R.F. “Planting Techniques and Materials for Revegetation of California Roadsides.” Caltrans Highway Research Report *FHWA/USDA Publication LMPC-2* (1983) 49 pp.

309. Schafer, W.M. and Nielsen, G.A. “Soil Development and Plant Succession on 1- to 50-year-old Strip Mine Spoils in Southeastern Montana.” *In* Wali, M.K. (Ed.) Ecology and Coal Resource Development, Pergamon Press, New York (1978) pp. 541-549.

310. Hargis, N.E. and Redente, E.F., “Soil Handling for Surface Mine Reclamation.” *Journal of Soil and Water Conservation*, Vol. 5 (1984) pp. 300-305.

311. Claassen, V. P., “The Use of Compost and Co-compost as a Primary Erosion Control Material.” *FHWA Report FHWA/CA/TL – 2002/30*, Federal Highway Administration and State of California Department of Transportation (March, 2001) 71 pp.

312. Claassen, V. P., “The Use of Compost and Co-compost as a Primary Erosion Control Material.” *FHWA Report FHWA/CA/TL – 2002/30*, Federal Highway Administration and State of California Department of Transportation (March, 2001) 71 pp.

313. McVay, B. “Federal Contacts Dispatch.” (April, 2000) http://www.fedgovcontracts.com/pe00-127.htm.

314. Callicot, J.B. and Lore, G.K., “The Nature of Roadsides and the Tools to Work with It.” Office of Natural and Human Environment, *FHWA Report FWHA –EP-03005*, Transportation Research Board, Washington, DC (1999) 32 pp.

315. Transportation Association of Canada, “Syntheses of Best Practices Road Salt Management: Drainage and Stormwater Management.” (September, 2003) 9 pp. pp. 6-4, http://www.tac-atc.ca/english/pdf/vegetation.PDF.

316. Tabler, R.D., “Design Guidelines for the Control of Blowing and Drifting Snow.” *SHRP-H-38,* National Research Council, Washington, DC (1994) http://www.trb.org/publications/shrp/SHRP-H-381.pdf.

317. Tabler, R.D., “Design Guidelines for the Control of Blowing and Drifting Snow.” *SHRP-H-381,* National Research Council, Washington, DC (1994) http://www.trb.org/publications/shrp/SHRP-H-381.pdf.

318. Federal Highway Administration, “Snow Fences Save Money and Lives.” *FHWA-SA-96-045 (CS101)*, Transportation Research Board, Washington, DC http://www.fhwa.dot.gov/winter/roadsvr/CS101.htm.

319. Transportation Association of Canada, Syntheses of Best Practices - Road Salt Management: Road and Bridge Design (September 2003), . http://www.tac-atc.ca/english/pdf/roadandbridge.PDF.

320. Tabler, R.D., “Design Guidelines for the Control of Blowing and Drifting Snow.”(See also the Snow Fence Guide, *SHRP-H-320*.) *SHRP-H-381,* National Research Council, Washington, DC, 364 pp. http://www.trb.org/publications/shrp/SHRP-H-381.pdf.

321. Tabler, R.D., “Snow Fence Guide.” *SHRP W/FR-91-106,* National Research Council, Washington, DC, 64 pp., http://gulliver.trb.org/publications/shrp/SHRP-H-320.pdf.

322. Tabler, R.D., “Snow Fence Guide.” *SHRP W/FR-91-106*, National Research Council, Washington, DC, 64 pp., http://gulliver.trb.org/publications/shrp/SHRP-H-320.pdf.

323. Tabler, R.D., “Design Guidelines for the Control of Blowing and Drifting Snow.” National Research Council, Washington, DC (1994) *SHRP-H-381*, http://www.trb.org/publications/shrp/SHRP-H-381.pdf.

324. Federal Highway Administration, “Software Helps Keep Snow in Its Place.” *FOCUS*, Turner Fairbank Highway Research Center, (June 1998) http://www.tfhrc.gov/focus/archives/Fcs698/068snow.htm.

325. Federal Highway Administration, “Activities by Topic: Snow Fences.” http://www.fhwa.dot.gov/winter/exchange/topics/snow_fences.html.

326. Tabler, R.D., "Design Guidelines for the Control of Blowing and Drifting Snow." National Research Council, Washington, DC (1994) *SHRP-H-381*, http://www.trb.org/publications/shrp/SHRP-H-381.pdf.

327. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management." Minnesota Technology Transfer (T2) LTAP Program, 2000, 132 pp., p. 55.

328. Iowa Department of Transportation, "Iowa's Cooperative Snow Fence Program." (July, 2000) http://www.dot.state.ia.us/maintenance/snowfence/snow_fence_booklet.pdf.

329. Iowa Department of Transportation, "Common Snow Fence Questions and Answers." http://www.dot.state.ia.us/snowfenceqa.pdf.

330. Minnesota Department of Transportation, Mn/DOT Asks Farmers to Leave Some Corn Rows Standing for Winter." Minnesota Department of Transportation News Release (September 15, 2003) http://www.dot.state.mn.us/newsrels/03/09/15snow.html.

331. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Drainage and Stormwater Management." (September, 2003) 9 pp. http://www.tac-atc.ca/english/pdf/drainage.pdf.

332. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p. Appendix E and p. 30, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

333. Maine Department of Transportation, "Fate of Road Salt in Uncontaminated Bedrock Aquifers," Research Division, Child Street, 16 State House Station Augusta, ME 04333-0016 USA Phone: (207) 287-2551.

334. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Drainage and Stormwater Management." (September, 2003) 9 pp. http://www.tac-atc.ca/english/pdf/drainage.pdf.

335. University of New Hampshire Technology Transfer Center, "Snow Disposal: Recommendations for Environmentally Safe Disposal." Durham, NH (Fall, 2001) http://www.t2.unh.edu/fall01/pg8.html.

336. Federal Highway Administration, "Is Highway Runoff: A Serious Problem?" *Environmental Technology Brief*, Turner-Fairbank Highway Research Center. McLean VA, http://www.tfhrc.gov/hnr20/runoff/runoff.htm.

337. Alaska Department of Transportation and Public Facilities, "Synthesis of Best Management Practices for Snow Storage Areas." University of Alaska (2003).

338. Wheaton, S.R., and Rice, W.J., "Snow Site Storage Design and Placement." Adapted from "Siting, Design and Operational Controls for Snow Disposal Sites." *Technology for Alaskan Transportation*, Vol. 28, No. 1 (Spring, 2003) pp. 18-20.

339. Wheaton, S.R., and Rice, W.J., "Snow Site Storage Design and Placement." Adapted from "Siting, Design and Operational Controls for Snow Disposal Sites." *Technology for Alaskan Transportation*, Vol. 28, No. 1 (Spring, 2003) pp. 18-20.

340. Wheaton, S.R., and Rice, W.J., "Snow Site Storage Design and Placement." Adapted from "Siting, Design and Operational Controls for Snow Disposal Sites." *Technology for Alaskan Transportation*, Vol. 28, No. 1 (Spring, 2003) pp. 18-20.

341. Transportation Association of Canada, "Syntheses of Best Practices in Salt Management." Chapter 8.0 Snow Storage and Disposal, p. (8-1-12).

342. New Hampshire Department of Environmental Services, "Snow Disposal Guidelines." Environmental Fact Sheet WMB-3 (1992) http://www.des.state.nh.us/factsheets/wmb/wmb-3.htm.

343. Wheaton, S.R., and Rice, W.J., "Snow Site Storage Design and Placement." Adapted from "Siting, Design and Operational Controls for Snow Disposal Sites." Technology for Alaskan Transportation, Vol. 28, No. 1 (Spring, 2003) pp. 18-20.

344. Wheaton, S.R., and Rice, W.J., "Snow Site Storage Design and Placement." Adapted from "Siting, Design and Operational Controls for Snow Disposal Sites." Technology for Alaskan Transportation, Vol. 28, No. 1 (Spring, 2003) pp. 18-20.

345. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 630-12.

346. ADOT SPR 566, contact: Semmens, John, Phone: (602) 712-3137 http://www.dot.state.az.us/ABOUT/atrc/Research/FY2004SPRrpt.htm#566.

347. “Ozone Action Plans Submitted,” *Georgia State Personnel News*, Vol. 22, No. 2 (April 1998) pp. 1-2.

348. “It All Adds Up to Cleaner Air,” EPA/DOT Community Demonstration Case Studies, http://www.italladdsup.gov/pdfs/mktkit/EPADOT100_DemoCom%20R-3.pdf.

349. Virginia DOT, “EPA calls VDOT ‘Model of Environmental Leadership: Employee Benefits Reduce Congestion, Improve Air Quality in Richmond.” Press Release (May 29, 2002) www.virginiadot.org/infoservice/news/CO05292002-EPA.asp.

350. “Triad Early Action Compact: Potential Local and Regional Ozone Emission Reduction Strategies for Attainment of 8 Hour Ozone Standard.” http://www.nwpcog.dst.nc.us/EAC/strategy_list.pdf.

351. Turner Fairbank Highway Research Center, *Transporter,* October 2003, http://www.tfhrc.gov/trnsptr/oct03/index.htm#report.

352. Shrouds, J., and Borinsky, S., FHWA, Memo on CMAQ Program, September 19, 2002.

353. Strumberger, N., Kipke, J.J., Stefancic, G., “Material Recycling in Transport,” *Promet Traffic-Traffico*, Vol. 11, No. 5 (1999) pp. 303-308.

354. Park, K., Hwang, Y., Seo, S., Seo, H., “Quantitative Assessment of Environmental Impacts on Life Cycle of Highways.” *Journal of Construction Engineering and Management*, Vol. 129, No. 1 (January, 2003) pp. 25-31.

355. Park, K., Hwang, Y., Seo, S., Seo, H., “Quantitative Assessment of Environmental Impacts on Life Cycle of Highways.” *Journal of Construction Engineering and Management*, Vol. 129, No. 1 (January, 2003) pp. 25-31.

356. Amirkhanian, S. N., “A Laboratory and the Field Evaluation of the Use of Waste Materials in Highway Construction.” *FHWA-SC-99-01, Final Report*, Washington, DC (1999) 372 pp.

357. Schroeder, R.L., “The Use of Recycled Materials in Highway Construction.” *Public Roads On-Line* (Autumn, 1994) Vol. 58, No. 2, http://www.tfhrc.gov/pubrds/fall94/p94au32.htm.

358. “Recycling and Use of Waste Materials and By-Products in Highway Construction.” *NCHRP Synthesis of Highway Practice 199*, Transportation Research Board, National Research Council, Washington, DC (1994) pp. 84.

359. “Recycling and Use of Waste Materials and By-Products in Highway Construction.” *NCHRP Synthesis of Highway Practice 199*, Transportation Research Board, National Research Council, Washington, DC (1994) pp. 84.

360. Recycled Materials Resource Center, “Framework for Evaluating Use of Recycled Materials in the Highway Environment.” http://www.rmrc.unh.edu/Partners/Framework/Start/start.htm.

361. Recycled Materials Resource Center, “Recycled Materials Use in the Highway Environment: Use, Technologies and Policies.” www.rmrc.unh.edu/Resources/PandD/ScanningTrip/scanning.asp.

362. Recycled Materials Resource Center, “Recycled Materials Use in the Highway Environment: Use, Technologies and Policies.” www.rmrc.unh.edu/Resources/PandD/ScanningTrip/scanning.asp.

363. Recycled Materials Resource Center, “Summary of FHWA International Technology Scanning Program for Recycled Materials Use in Highway Environments: Uses Technologies and Policies”. www.rmrc.unh.edu/Resources/PandD/ScanningTrip/scanningsummarydoc.asp.

364. Rees, W. and Wackernagel, M., “Ecological Footprints and Appropriated Carrying Capacity: Measuring the Natural Capacity Requirements of the Human Economy.” *In* Investing in Natural Capital, Jansson, A. Hammer, M., Folke, C. and Costanza, R. (Eds.) Island Press, Washington DC (1994).

365. LaRegina, C., “Waste Management and Environmental Management: Recycling, Waste Reduction, Pollution Prevention, Brownfields: Resource Paper.” Environmental Research Needs in Transportation Conference Proceedings 28, Washington, DC (March 2002) pp. 201-207.

366. AASHTO Designation: M 318-01, “Standard Specification for Glass Cullet Use for Soil-Aggregate Base Course.” pp. 318-1 – 318-5, http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/gcsabc/finalglassculletspec-aashto.pdf.

367. Federal Highway Administration, “Standard Specification for Reclaimed Concrete Aggregate for Use as Coarse Aggregate in Portland Cement Concrete”, pp. 319-1-319-7 http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/docs/FinalSpecRCA-PCC.pdf.

368. AASHTO Designation: M 319-02 “Standard Specification for Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course.” http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/rcgb/recconcbase.pdf.

369. Chesner Engineering, “White Paper and Specification for Coal Combustion Fly Ash for Structural Fills and Embankments.” (2002) 17 pp. http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/docs/CCFADraft.pdf.

370. AASHTO Designation: MP-10. “Standard Specification for Compost for Erosion/Sediment Control (Compost Blanket).” http://www.dot.state.pa.us/penndot/Bureaus/chiefeng.nsf/specpercent20compostpercent20blankets?OpenPage.

371. AASHTO Designation: MP XXX “Standard Specification for Compost for Erosion/Sediment Control (Filter Berms).” 8 pp. http://www.rmrc.unh.edu/Research/Rprojects/Project21/specs/ASTMFilterberm7.pdf.

372. Recycled Materials Resource Center, “Resources and Specifications.” www.rmrc.unh.edu/Resources/Specifications/rmrcspecs.asp.

373. Government of Western Australia, “Essentials - Noise Management in the Construction Industry: A Practical Approach.” http://www.safetyline.wa.gov.au/pagebin/noisgenl0019.htm.

374. Wayson, R.L., “Synthesis of Highway Practice 268: Relationship between Pavement Surface Texture and Highway Traffic Noise.” *NCHRP Synthesis Report 268,* Transportation Research Board, Washington, DC (1998) 96pp. http://www.igga.net/downloads/noise/NCHRP_Syn268.pdf.

375. Federal Highway Administration and Urban Systems Research and Engineering, Inc. of Cambridge, “The Audible Landscape: A Manual for Highway Noise and Land Use.” (August 1976) http://www.fhwa.dot.gov/environment/audible/al7.htm.

376. Federal Highway Administration and Urban Systems Research and Engineering, Inc. of Cambridge”, The Audible Landscape: A Manual for Highway Noise and Land Use.” (August 1976) http://www.fhwa.dot.gov/environment/audible/al7.htm.

377. Finegold, L.S., Harris, C.S., and von Gierke, H.E. “Community Annoyance and Sleep Disturbance: Updated Criteria for Assessing the Impacts of General Transportation Noise on People.” *Noise Control Engineering Journal*, Vol. 42, No. 1 (November, 1993) pp.25-30, http://users.aol.com/NCEJABS/ab420104.html.

378. N.N., “Future Noise Policy.” *Green Paper of the European Commission*, (1996) http://europa.eu.int/en/record/green/gp9611/noisesum.htm.

379. Berglund, B., & Lindvall, T. (Eds.). “Community Noise.” *Archives of the Center for Sensory Research*, Vol. 2, No. 1, (1995) pp. 1-195.

380. Berglund, B.,Lindvall, T., Schwela, D.H., “Guidelines for Community Noise.” World Health Organization (Eds.) (1999) http://www.who.int/docstore/peh/noise/ComnoiseExec.htm.

381. World Health Organization, “Guidelines for Community Noise: Adverse Health Effects of Noise.” (1999) http://www.who.int/docstore/peh/noise/Comnoise3.htm.

382. Berglund, B., Lindvall, T., Schwela, D.H., “Guidelines for Community Noise.” World Health Organization (Eds.) (1999) http://www.who.int/docstore/peh/noise/ComnoiseExec.htm.

383. Berglund, B., Lindvall, T., Schwela, D.H., “Guidelines for Community Noise.” World Health Organization (Eds.) (1999) http://www.who.int/docstore/peh/noise/ComnoiseExec.htm.

384. Rust, A., and Affenzeller, J., CALM - An EU Network for Strategic Planning of Future Noise Research, 5th European Conference on Noise Control (EURONOISE) held in Naples / Italy on May 19 - 21, 2003. AVL List GmbH, Graz, Austria, alfred.rust@avl.com, josef.affenzeller@avl.com. http://www.calm-network.com/index_preports.htm.

385. Federal Highway Administration, “Noise Introduction.” http://www.fhwa.dot.gov/environment/probresp.htm#intro.

386. Noss, R., “The Ecological Effects of Roads.” http://www.eco-action.org/dt/roads.html.

387. Noss, R., “The Ecological Effects of Roads.” http://www.eco-action.org/dt/roads.html.

388. Bondello, M.C., “The Effects of High-Intensity Motorcycle Sounds on the Acoustical Sensitivity of the Desert Iguana, Dipsosaurus Dorsalis.” M.A. Thesis. California State University, Fullerton (1976) 37 pp.

389. Bondello, M.C. and B.H. Brattstrom, "The Experimental Effects of Off-Road Vehicle Sounds on Three Species of Desert Invertebrates." Report to the Bureau of Land Management (1979) 61 pp.

390. Bunnell, F. L., Dunbar, D., Koza, L. and G. Ryder, G., "Effects of Disturbance on the Productivity and Numbers of White Pelicans in British Colombia - Observations and Models." *Colonial Waterbirds*, Vol. 4, (1981) pp. 2-11.

391. Fletcher, J.L., "Effects of noise on wildlife: a review of relevant literature 1971-1978." (1980) pp. 611-620 *In* Tobias, J.V. Jansen, G. and Ward, W.D. (Eds.) Proceedings of the Third International Congress on Noise as a Public Health Problem. American Speech-Language-Hearing Association, Rockville, MD.

392. Fletcher, J.L., "Review of Noise and Terrestrial Species: 1983-1988. pp. 181-188." (1990) *In:* Berglund, B. and Lindvall, T., (Eds.) Noise as a Public Health Problem, Vol. 5: New Advances in Noise Research Part II. Swedish Council for Building Research, Stockholm. National Park Service (1994).

393. Reijnen, R., Foppen, R., ter Braak, Cajo J.F., Thissen, J. (1995) "The Effects of Car Traffic on Breeding Bird Populations in Woodland. III. Reduction of Density in Relation to the Proximity of Main Roads." *Journal of Applied Ecology*, Vol. 32: No. 1, pp.187-202.

394. Reijnen, R., "Disturbance by Car Traffic as a Threat to Breeding Birds in the Netherlands." Dlo Instituut Voor Bos En Natuuronderzoek (Ibn Dlo) (1995) 140 pp.

395. Reijnen, R.; Foppen, R.; Veenbaas, G., "Disturbance by traffic of breeding birds: Evaluation of the effect and considerations in planning and managing road corridors." *Biodiversity and Conservation*, Vol. 6: No. 4 (1997) pp. 567-581. http://www.kluweronline.com/issn/0960-3115.

396. Barrett, D.E., "Traffic-Noise Impact Study for Least Bell's Vireo Habitat along California State Route 83" Transportation Research Record 1559. The study and its implications were reviewed in *U.S. Roads*, www.usroads.com/journals/p/rej/9710/re971003.htm.

397. Barrett, D.E., "Traffic-Noise Impact Study for Least Bell's Vireo Habitat along California State Route 83" Transportation Research Record 1559. The study and its implications were reviewed in *U.S. Roads*, www.usroads.com/journals/p/rej/9710/re971003.htm.

398. Personal communication, Caltrans (February, 2004).

399. Hastings, M.C., "Clarification of the Meaning of Sound Pressure Levels and the Known Effects of Sound on Fish." Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. (2002) 8 pp.

400. Yelverton, J.T., Richmond, D.R., Hicks, W., Saunders, K., Fletcher R., "The Relationship Between Fish Size and Their Response Tt Underwater Blast." Lovelace Foundation for Medical Education and Research Albuquerque, NM (1975).

401. Longmuir, C.,. Lively. T., "Bubble Curtain Systems for Use during Marine Pile Driving." Fraser River Pile and Dredge Ltd.. New Westminister, BC (2001) 9 pp.

402. NOAA Fisheries, "Biological Opinion for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project." Santa Rosa, CA: Southwest Region (2001).

403. Stotz, T., and Colby, J., "Dive Report for Mukilteo Wingwall Replacement Project." Washington State Ferries Memorandum (January 2001) 5 pp. + appendices.

404. NOAA Fisheries. "Biological Opinion for the Benicia-Martinez New Bridge Project." Santa Rosa, California: Southwest Region (2003).

405. NOAA Fisheries, Hanson, J., Helvey, M. and Strach, R. (Eds.). "Non-fishing Impacts to Essential Fish Habitat and Recommended Conservation Measures." National Marine Fisheries Service. Alaska Region, Northwest Region and Southwest Region. Version 1 (August 2003).

406. Federal Highway Administration, "Noise Introduction." http://www.fhwa.dot.gov/environment/probresp.htm#intro.

407. National Cooperative Highway Research Program - Anticipated Project, Project 1-44, FY 2005, Quiet Pavement Pilot Project Study, Overview.

http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/8b854b22ff79cad985256e82004a7ec0?OpenDocument.

408. National Cooperative Highway Research Program - Anticipated Project, Project 1-44, FY 2005, Quiet Pavement Pilot Project Study, Overview. http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/8b854b22ff79cad985256e82004a7ec0?OpenDocument.

409. Hickman, H., *Knoxville News-Sentinel* (Oct. 15, 1999) pg. A1.

410. Bessonette, C., *The Atlanta Journal and Constitution* (August 5, 1999) pg. 2A.

411. Chavez, S., *Sun-Sentinel* (September 17, 1999) pg. 1B.

412. National Cooperative Highway Research Program - Anticipated Project, Project 1-44, FY 2005, Quiet Pavement Pilot Project Study, Overview. http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/8b854b22ff79cad985256e82004a7ec0?OpenDocument.

413. Wayson, R.L., "Synthesis of Highway Practice 268: Relationship between Pavement Surface Texture and Highway Traffic Noise." *NCHRP Synthesis Report 268,* Transportation Research Board, Washington, DC (1998) 96pp. http://www.igga.net/downloads/noise/NCHRP_Syn268.pdf.

414. Wayson, R.L., "Synthesis of Highway Practice 268: Relationship between Pavement Surface Texture and Highway Traffic Noise." *NCHRP Synthesis Report 268,* Transportation Research Board, Washington, DC (1998) 96pp. http://www.igga.net/downloads/noise/NCHRP_Syn268.pdf.

415. Hibbs, B.O., and Larson, R., "Surface Finishing of Portland Cement Concrete Pavements." *Report FHWA-SA-96-068,* Transportation Research Board, Washington, DC (May 1996).

416. Schmiedlin, R.B. and Bischoff, D.L. "Stone Matrix Asphalt: The Wisconsin Experience." Wisconsin Department of Transportation Study # 91-07, *WI/SPR-02-02* (January 2002).

417. "Transport Ten Year Plan 2000 http://www.dft.gov.uk/stellent/groups/dft_transstrat/documents/pdf/dft_transstrat_pdf_503944.pdf.

418. Rochat, J., "Using Quiet Pavements to Help Reduce Highway Traffic Noise: Wayside Noise Measurement Studies in California and Arizona and FHWA's Quiet Pavement Pilot Program," Presentation at the Annual Meeting of the National Association of Environmental Professionals (April 27, 2004).

419. AASHTO Center for Environmental Excellence, "Caltrans Research Reduces Highway Noise: Caltrans Success Story." http://www.transportation.org/aashto/success.nsf/allpages/CASoundBarriers.

420. National Cooperative Highway Research Program - Anticipated Project, Project 9-41, FY 2005, Cold Weather Performance of New Generation Open-Graded Friction Courses, http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/78c1e5513718e7fc85256e8200540cfe?OpenDocument.

421. National Cooperative Highway Research Program - Anticipated Project, Project 9-41, FY 2005, Cold Weather Performance of New Generation Open-Graded Friction Courses, http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/78c1e5513718e7fc85256e8200540cfe?OpenDocument.

422. National Cooperative Highway Research Program - Anticipated Project, Project 9-41, FY 2005, Cold Weather Performance of New Generation Open-Graded Friction Courses, http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/78c1e5513718e7fc85256e8200540cfe?OpenDocument.

423. Public Pavement Association, "Cano & Way Brief Federal Agencies." *Rubber Pavements Newsletter* (Fall 2002) http://www.rubberpavements.org/newsletter/fall2002/pg6.html.

424. Fickes, M., "The Asphalt Phenomenon: When Asphalt Rubber Silenced Road Noise on an Arizona Freeway, the Public Demanded More." http://www.asphaltalliance.com/upload/Asphalt%20Rubber%20Phenonmenon.pdf.

425. Sacramento County Department of Environmental Review and Assessment and Bollard and Brennan, Inc., "Effectiveness of Rubberized Pavements in Reducing Traffic Noise," http://www.rubberpavements.org/library/sacramento_noise_study/executivesummary.htm.

426. Van Bochove, G.G., "Twinlay, A New Concept of Drainage Asphalt Concrete," Heijmans Road Construction Company B.V. Netherlands.

427. N.N., "Quiet Roads: Engineering Aspects." http://www.xs4all.nl/~rigolett/ENGELS/zoab/zoabeng.htm.

428. Rochat, J., "Using Quiet Pavements to Help Reduce Highway Traffic Noise: Wayside Noise Measurement Studies in California and Arizona and FHWA's Quiet Pavement Pilot Program," Presentation at the Annual Meeting of the National Association of Environmental Professionals (April 27, 2004).

429. Gress, D. 9th Quarterly Report for RMRC Research Project #5, "Concrete Mixtures with Inclusions to Improve the Sound Absorbing Capacity of PCC Pavements." (May, 2003) http://www.rmrc.unh.edu/Research/Rprojects/Project5/reports/p5q9.pdf.

430. Gress, D. 9th Quarterly Report for RMRC Research Project #5, "Concrete Mixtures with Inclusions to Improve the Sound Absorbing Capacity of PCC Pavements." (May, 2003) http://www.rmrc.unh.edu/Research/Rprojects/Project5/reports/p5q9.pdf.

431. Rochat, J., "Using Quiet Pavements to Help Reduce Highway Traffic Noise: Wayside Noise Measurement Studies in California and Arizona and FHWA's Quiet Pavement Pilot Program," Presentation at the Annual Meeting of the National Association of Environmental Professionals (April 27, 2004).

432. Federal Highway Administration, "Noise Introduction." http://www.fhwa.dot.gov/environment/probresp.htm#intro.

433. Kombe, T.Arizona DOT, further information on SPR 555 and SPR 572, ADOT research in progress. Ph: (602) 712-3135, email: ekombe@dot.state.az.us.

434. Federal Highway Administration, "Highway Traffic Noise Barrier Construction Trends." www.fhwa.dot.gov/environment/noise/barrier/tintro.htm.

435. Kombe, T. Arizona DOT, information on SPR 499, ADOT research in progress. Ph: (602) 712-3135, email: ekombe@dot.state.az.us.

436. Kombe, T., Arizona DOT, information on SPR 555 and SPR 572, ADOT research in progress. : (602) 712-3135, email: ekombe@dot.state.az.us.

437. Thalheimer, E., "Construction Noise Control Program and Mitigation Strategy at the Central Artery/Tunnel Project." (July, 2001) 9 pp. http://www.bigdig.com/thtml/pdf/noise.pdf.

438. Thalmeier, E.S., "Construction Noise Control Program." Acoustical Society of America Meeting, Atlanta, Georgia, (May 2000) p.9.

439. Fistel, M., and Thalheimer, E.S., "Window Sound Proofing for Construction Noise at the Central Artery / Tunnel Project", No. 97, presented at Inter-Noise99 (December, 1999).

440. Massachusetts Highway Department, Central Artery (I-93) / Tunnel (I-90) Project, "CA/T Construction Noise Off-Site Residential Mitigation Policy" (Effective November, 97).

441. Massachusetts Turnpike Authority, Central Artery (I-93) / Tunnel (I-90) Project, "C17A6 Noise Study - Noise Analysis and Mitigation Options", Final Report (June, 1999).

442. American Association of State Highway and Transportation Officials, "Guide on Evaluation and Attenuation of Traffic Noise."(1993).

443. Organization for Economic Cooperation and Development (OECD), Roadside Noise Abatement (1995).

444. NCHRP Research and Technology Initiatives, (January 22, 2004) http://www.fhwa.dot.gov/rnt4u/init_operations.htm.

445. Spotts, P. N. "Putting a Lid on the Light: Inefficient Use of Artificial Light is Having a Detrimental Effect on Creatures Great and Small." *Christian Science Monitor* (September 19, 2002) http://www.csmonitor.com/2002/0919/p11s01-sten.html.

446. Verheijen, F. J. “Photopollution: Artificial Light Optic Spatial Control Systems Fail to Cope with Incidents, Causations, Remedies.” *Experimental Biology* (1985) pp. 1-18.

447. Finch, D.M. “Atmospheric Light Pollution.” *Journal of Illuminating Engineering Society* Vol. 7, No. 2 (January, 1978) p. 105.

448. Witherington, B.E., “The Problem of Photopollution for Sea Turtles and Other Nocturnal Animals.” *In* Clemmons, J.R., and R. Buchholz (Eds.), Behavioral Approaches to Conservation in the Wild. Cambridge University Press, Cambridge England (1997).

449. Environmental Building News. “Light Pollution: Efforts to Bring Back the Night Sky.” *Environmental Building News,* Vol. 7 No. 8 (1998).

450. Sinnadurai, S., “High Pressure Sodium Street Lights Affect Crops in Ghana.” *World Crops* (Nov/Dec, 1981) pp. 120–122.

451. Cathey, H.M., and Campbell, L.E.. “Effectiveness of Five Vision-Lighting Sources on Photoregulation of 22 Species of Ornamental Plants*.” Journal of the American Horticultural Society* (1975) Vol. 100, pp. 65–71.

452. de Molenaar, J.G., Jonkers, D.A. and Sanders, M.E., “Road Illumination and Black-Tailed Godwit.” presented at The Urban Wildlands Group and Ecological Consequences of Artificial Night Lighting, Los Angeles, California (February 23-24, 2002) http://www.urbanwildlands.org/abstracts.html.

453. Eisenbeis, G., “Artificial Night Lighting and Insects in Germany.” presented at The Urban Wildlands Group and Ecological Consequences of Artificial Night Lighting, Los Angeles, California (February 23-24, 2002) http://www.urbanwildlands.org/abstracts.html.

454. Witherington, B.E., and Martin, R.E., “Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches.” *FMRI Technical Report TR-2*, Florida Marine Research Institute, St. Petersburg, Florida (2000) 73 pp.

455. Beier, P. “Dispersal of Juvenile Cougars in Fragmented Habitat*.” Journal of Wildlife Management* (1995) Vol. 59, pp. 228–237.

456. Illuminating Engineering Society of North America, “Standard Practice Committee of the IESNA Roadway Lighting Committee.” American National Standard Practice for Roadway Lighting. *ANSI/IESNA RP-8-00*, New York (2000).

457. Illuminating Engineering Society, IES Lighting Handbook. New York (2000).

458. Illuminating Engineering Society, “American National Standard Practice for Roadway Lighting.” *ANSI/IES RP-8* (2000).

459. Illuminating Engineering Society of North America, “Recommended Practice for Outdoor and Environmental Lighting.” *Report RP-33-99* (1999).

460. American Association of State Highway Transportation Officials. Informational Guide for Roadway Lighting. (1984).

461. Leslie, R.P. and Rodgers, P.A., The Outdoor Lighting Pattern Book. McGraw-Hill (1996).

462. Grigione, M.M., “Turning Night into Day: The Effects of Artificial Night Lighting on Endangered and Other Mammal Species.” presented at The Urban Wildlands Group and Ecological Consequences of Artificial Night Lighting, Los Angeles, California (February 23-24, 2002) http://www.urbanwildlands.org/abstracts.html.

463. Frank, K.D., “Impact of Artificial Lighting on Moths.” presented at The Urban Wildlands Group and Ecological Consequences of Artificial Night Lighting, Los Angeles, California (February 23-24, 2002) http://www.urbanwildlands.org/abstracts.html.

464. Lewin, I., Box, P., and Stark, R.E., “Roadway Lighting: An Investigation and Evaluation of Three Different Light Sources.” *Final Report FHWA-AZ-03-522,* Arizona Department of Transportation and Federal Highway Administration, Transportation Research Board, Washington, DC (May, 2003) 137 pp., p.2, http://ntl.bts.gov/lib/24000/24600/24606/AZ522.pdf.

465. Lewin, I., Box, P., and Stark, R.E., “Roadway Lighting: An Investigation and Evaluation of Three Different Light Sources” *Final Report FHWA-AZ-03-522*, Arizona Department of Transportation and Federal Highway Administration, Transportation Research Board, Washington, DC (May, 2003) http://www.dot.state.az.us/ABOUT/atrc/Publications/SPR/AZ522.pdf.

466. Florida Power and Light, "Coastal Roadway Lighting Manual: A Handbook of Practical Guidelines for Managing Street Lighting to Minimize Impacts to Sea Turtles" (May, 2002) http://www.floridaconservation.org/psm/turtles/manual.pdf.

467. Lewis, I., "Should Vision Influence Roadway Lighting Design." *Better Roads* (October 1999) http://betterroads.com/articles/broct99b.htm.

468. Kramer, E.J., "Light the Roadway... Not the Neighborhood: Light Trespass, Light Pollution., and the Roadway Lighting in Your Neighborhood." http://www.metrolux.com/roadway.htm.

469. Ellis, R.D., and Washburn, S., "Evaluation of the Safety and User Response to Embedded Roadway Lighting Systems on an FDOT Demonstration Project of the University of Florida." *Final Report, BC354-31*, University of Florida (March, 2003) http://www.dot.state.fl.us/researchcenter/Completed_Proj/Summary_EMO/FDOT_BC354_31.pdf.

470. California Energy Commission, "Staff Workshop Before the California Energy Resources Conservation and Development Commission in the Matter of Outdoor Lighting Standards Research Reports." Sacramento, CA, (June18, 2002).

471. California Energy Commission, "Staff Workshop Before the California Energy Resources Conservation and Development Commission in the Matter of Outdoor Lighting Standards Research Reports." Sacramento, CA, (June18, 2002).

472. Kramer, E.J., "There's GOLD in Them Thar Highway Medians!" http://www.metrolux.com/medians.htm.

473. Kramer, E.J., "Technology Means Better Road Lighting," *Better Roads* (October 1999) http://betterroads.com/articles/broct99a.htm.

474. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 610-1.

475. AASHTO EMS Workshop for State DOTs (August 2003) EMS Roadmap for Rest Area Facility Design.

476. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 630-2.

477. Washington State Department of Transportation, "WSDOT Pavement Guide." (June, 1999) 41 pp., http://www.wsdot.wa.gov/fasc/engineeringpublications/Manuals/Volume1.pdf.

478. Federal Highway Administration, "Priorities, Market-Ready Technologies and Innovations Accelerated Construction," http://www.fhwa.dot.gov/rnt4u/ti/accel_const.htm.

479. Federal Highway Administration, "Priorities, Market-Ready Technologies and Innovations Accelerated Construction," http://www.fhwa.dot.gov/rnt4u/ti/accel_const.htm.

480. Federal Highway Administration, "Preserving History While Advancing Transportation: US 77 in Texas."http://www.environment.fhwa.dot.gov/strmlng/newsletters/aug03nl.htm.

481. Johansen, K. D. "Design and Construction of Aquatic Organism Passage and Road-Stream Crossings: Construction Challenges and Case Studies of Stream Simulation Structures for Aquatic Organism Passage." Proceedings of International Conference on Ecology and Transportation (August, 2003).

482. North Carolina Department of Transportation, "BMPs for Construction and Maintenance Activities" Manual (August 2003) pp. 111, p. 3.4.14.

483. Temporary Instream Construction Measures Maryland Department of the Environment Waterway Construction Guidelines Revised (November 2000).

484. Florida Erosion and Sediment Control Inspector's Manual, p. 4-7, http://www.dep.state.fl.us/water/nonpoint/docs/erosion/chapter4.pdf.

485. Washington State Department of Transportation, "Erosion Control Designers Course." (April, 2001) http://www.wsdot.wa.gov/environment/wqec/docs/Erosion_DCMASTER1.pdf.

486. Venner, M. "Quality Research Needs: Survey." *NCHRP Project 25-20 (02)* (2002).

487. Barber, M., Schaftlein, S., Anderson, D., Stormwater Runoff Cost/Benefit Project Prioritizing Stormwater Outfalls. *WA-RD 418.1* (1997) 99 pp.

488. Caltrans Stormwater Compliance Review Task Force "Construction Dewatering Operations: Management Options and NPDES Permit Requirements." *California Department of Transportation Construction Stormwater Pollution Prevention Bulletins* (2001) http://www.dot.ca.gov/hq/env/stormwater/publicat/const/index.htm.

489. North Carolina Department of Transportation, "BMPs for Construction and Maintenance Activities" Manual (August 2003) 111 pp.

490. Nyhan, K.T., "Best Management Practices for Routine Roadway Maintenance Activities in New Hampshire" New Hampshire Department of Transportation and New Hampshire Department of Environmental Services, Concord, NH (August, 2001) 54 pp., p.3-14.

491. North Carolina Department of Transportation, "BMPs for Construction and Maintenance Activities" Manual (August 2003) 111 pp., p. 3.6.17.

492. Caltrans, Construction Stormwater Fact Sheet on Fiber Rolls, http://www.dot.ca.gov/hq/construc/stormwater/SC-05.doc.

493. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p. 2.4.4.71 http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm.

494. Caltrans, Construction Stormwater Fact Sheet on Gravel Bag Berms, http://www.dot.ca.gov/hq/construc/stormwater/SC-06.doc.

495. King, N., Darnaby, K., and Foster, A., "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002) http://www.dot.state.tx.us/env/nrmstormwatermanual.htm.

496. "When Best Management Practices Become the Worst Management Practices." *CE News* (September, 1999) pp. 70-77.

497. "When Best Management Practices Become the Worst Management Practices." *CE News* (September, 1999) pp. 70-77.

498. "When Best Management Practices Become the Worst Management Practices." *CE News* (September, 1999) pp. 70-77.

499. King, N., Darnaby, K., and Foster, A., "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002) http://www.dot.state.tx.us/env/nrmstormwatermanual.htm.

500. Caltrans District 7 Erosion Control Pilot Study Report, June 2000.

501. Hathhorn, W.E., and Yonge, D.R. "The Assessment of Groundwater Pollution Potential Resulting from Stormwater Infiltration BMP's.", *WA-RD 389.1*, Washington State Transportation Center and Federal Highway Administration, Washington, DC (January 1996).

502. King, N., Darnaby, K., and Foster, A., "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002) http://www.dot.state.tx.us/env/nrmstormwatermanual.htm.

503. Alaska Highway Drainage Manual, "Erosion and Sediment Control." Chapter 16, (October, 2001) page16-4.

504. King, N., Darnaby, K., and Foster, A., "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002) http://www.dot.state.tx.us/env/nrmstormwatermanual.htm.

505. King, N., Darnaby, K., and Foster, A., "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002) http://www.dot.state.tx.us/env/nrmstormwatermanual.htm.

506. Caltrans, Construction Stormwater Fact Sheet on Check Dams, http://www.dot.ca.gov/hq/construc/stormwater/SC-04.doc.

507. King, N., Darnaby, K., and Foster, A., "Stormwater Management Guidelines for Construction Activities Manual." Texas Department of Transportation (2002) http://www.dot.state.tx.us/env/nrmstormwatermanual.htm.

508. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 710-14.

509. Nyhan, K.T., "Best Management Practices for Routine Roadway Maintenance Activities in New Hampshire" New Hampshire Department of Transportation and New Hampshire Department of Environmental Services, Concord, NH (August, 2001) 54 pp., p. 3-6.

510. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p. Appendix E and p. 30, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

511. New York State Department of Transportation-Region 8 "Stormwater Facilities Operations & Maintenance Manual" (September, 2003) pp 27-29.

512. Nyhan, K.T., "Best Management Practices for Routine Roadway Maintenance Activities in New Hampshire" New Hampshire Department of Transportation and New Hampshire Department of Environmental Services, Concord, NH (August, 2001) 54 pp., p.3-9.

513. Yonge, D.R., "Contaminant Detention in Highway Grass Filter Strips." *WA-RD474.1*, Washington State Transportation Center and Federal Highway Administration, Washington, DC (January 13, 2000) 76 pp.

514. Cammermayer, J.W., Horner, R.R., Chechowitz, N., "Vegetated Stormwater Facility Maintenance." *WA-RD 495.1*, Washington State Transportation Center and Federal Highway Administration, Washington, DC (December 2000) 246 pp.

515. Cammermayer, J.W., Horner, R.R., Chechowitz, N., "Vegetated Stormwater Facility Maintenance." WA-RD 495.1, Washington State Transportation Center and Federal Highway Administration, Washington, DC (December 2000) 246 pp.

516. State of California, "Wind Erosion Control Fact Sheet." http://www.dot.ca.gov/hq/construc/stormwater/WE-1.doc.

517. Megahan, W.F., Monsen, S.B., Wilson, M.D. Lozano, N., Haber, D.F., Booth, G.D., "Erosion Control Practices Applied To Granitic Road Fills for Forest Roads fn Idaho: Cost Effectiveness Evaluation. *Land Degradation and Rehabilitation,* Vol. 3 (1992) pp. 55-65.

518. Megahan, W.F., Monsen, S.B., Wilson, M.D. Lozano, N., Haber, D.F., Booth, G.D., "Erosion Control Practices Applied To Granitic Road Fills for Forest Roads in Idaho: Cost Effectiveness Evaluation. *Land Degradation and Rehabilitation*, Vol. 3 (1992) pp. 55-65.

519. Luce, C.H., "Effectiveness of Road Ripping in Restoring Infiltration Capacity of Forest Roads." *Restoration Ecology*, Vol. 5, No. 3, pp. 265-270.

520. Luce, C.H., "Effectiveness of Road Ripping in Restoring Infiltration Capacity of Forest Roads." *Restoration Ecology*, Vol. 5, No. 3, pp. 265-270.

521. Storey, B.B., McFalls, J.A., and Godfrey, S.H., "The Use of Compost and Shredded Brush on Rights-of-Way for Erosion Control." Final Report, Texas Transportation Institute *Contract No. 0-1352*, Texas A&M University System, College Station Texas (1995).

522. Ettlin, L., and Stewart, B., "Yard Debris Compost for Erosion Control." *BioCycle.* Vol. 34 No. 12 (1993) pp. 46–47.

523. Metro 1994, "Summary of Projects Using Yard Debris Compost for Erosion Prevention and Control." *Final Report.* Solid Waste Department, Planning Department Portland, OR (June 1994).

524. State of California, http://www.dot.ca.gov/hq/env/stormwater/special/newsetup/index.htm.

525. Venner, 2003 and 2002 study on DOT-Funded Positions at resource agencies.

526. From UDOT environmental training for contractors, provided by Jerry Chaney of UDOT on March 3, 2004.

527. WSDOT, AASHTO Environmental Excellence Award Application, "Erosion and Sedimentation Control Program." (2003).

528. Caltrans, Construction Stormwater Fact Sheet on Vehicle and Equipment Cleaning, http://www.dot.ca.gov/hq/construc/stormwater/NS-08.doc.

529. Caltrans, Construction Stormwater Fact Sheet on Vehicle and Equipment Fueling, http://www.dot.ca.gov/hq/construc/stormwater/NS-09.doc.

530. Caltrans, Construction Stormwater Fact Sheet on Vehicle and Equipment Maintenance, http://www.dot.ca.gov/hq/construc/stormwater/NS-10.doc.

531. Inyang, H.I., "Framework for Recycling of Wastes in Construction." *Journal of Environmental Engineering*, Vol. 129, No. 10 (October, 2003) pp.887-898.

532. Nelson, P. O., et. al. "Primer Environmental Impact of Construction and Repair Materials on Surface and Ground Waters: Summary of Methodology, Laboratory Results and Model Development." Transportation Research

Board, National Research Council, Washington, DC (2001) 137 pp. http://gulliver.trb.org/publications/nchrp/nchrp_rpt_448.pdf.

533. Recycled Materials Resource Center, "Project 32 - Monitoring and Analysis of Leaching from Subbases Constructed with Industrial Byproducts". http://www.rmrc.unh.edu/Research/Rprojects/Project32/project32.asp.

534. U.S. EPA Office of Air and Radiation, Office of Transportation and Air Quality, "Clean Fuel Options for Heavy-Duty Diesel Trucks and Buses." *EPA420-F-03-015* (June 2003). http://www.epa.gov/otaq/retrofit/documents/f03015.pdf.

535. U.S. EPA. Air and Radiation, "Heavy-duty Diesel Emission Reduction Project Retrofit/Rebuild Component." Prepared by Northeast States for Coordinated Air Use Management. *EPA420-R99-014* (June 1999).

536. U.S. EPA, "New Emission Standards for Heavy-Duty Diesel Engines Used In Trucks and Buses *EPA 420-F-97-016*, (October 1997).

537. U.S. EPA "Voluntary Diesel Retrofit Program: Diesel Emissionshttp://www.epa.gov/otaq/retrofit/overdieselemissions.htm.

538. U.S. EPA, "Diesel Exhaust in the U.S.," http://www.epa.gov/otaq/retrofit/documents/420f03022.pdf.

539. U.S. EPA, "Voluntary Diesel Retrofit Program: Idling Reduction." http://www.epa.gov/otaq/retrofit/idling.htm.

540. Schattanek, G., Kasprak, A., Weaver, D., Cooper, C., "Implementation of Retrofit/Clean Fuels Program for Diesel Equipment during the Construction Phase of Two Large Transportation Projects" Paper presented at the AWMA Annual Conference & Exhibition in Baltimore, Maryland (June 2002).

541. Schattanek, G., Kasprak, A., Weaver, D., Cooper, C., "Implementation of Retrofit/Clean Fuels Program for Diesel Equipment during the Construction Phase of Two Large Transportation Projects" Paper presented at the AWMA Annual Conference & Exhibition in Baltimore, Maryland (June 2002).

542. Connecticut DOT, I-95 New Haven Connecticut Clean Air Construction Initiative Fact Sheet, http://www.i95newhaven.com/upload/files/Fact_Sheets/FACTSHEET_CLEANAIR.pdf.

543. Schattanek, G., Kasprak, A., Weaver, D., Cooper, C., "Implementation of Retrofit/Clean Fuels Program for Diesel Equipment during the Construction Phase of Two Large Transportation Projects" Paper presented at the AWMA Annual Conference & Exhibition in Baltimore, Maryland (June 2002).

544. Dolan, J., Kasprak, A., Schattanek, G., Wan, P.K., "Use of PM10 Monitoring Data to Evaluate the Effectiveness of the Dust Control Program During the Construction of the Central Artery Tunnel Project," Presented at the Air & Waste Management Association's 91st Annual Meeting & Exhibition, (June , 1998) San Diego, California.

545. Dolan, J., Kasprak, A., Schattanek, G., Wan, P.K., "Use of PM10 Monitoring Data to Evaluate the Effectiveness of the Dust Control Program During the Construction of the Central Artery Tunnel Project," Presented at the Air & Waste Management Association's 91st Annual Meeting & Exhibition, (June , 1998) San Diego, California.

546. Dolan, J., Kasprak, A., Schattanek, G., Wan, P.K., "Use of PM10 Monitoring Data to Evaluate the Effectiveness of the Dust Control Program During the Construction of the Central Artery Tunnel Project," Presented at the Air & Waste Management Association's 91st Annual Meeting & Exhibition, (June , 1998) San Diego, California.

547. Asphalt Pavement Environmental Council, "Best Management Practices to Minimize Emissions during HMA Construction." National Asphalt Pavement Association (NAPA) (2000) 13 pp., p. *i.*

548. Asphalt Pavement Environmental Council, "Best Management Practices to Minimize Emissions during HMA Construction." National Asphalt Pavement Association (NAPA) (2000) 13 pp., p. 4.

549. Asphalt Pavement Environmental Council, "Best Management Practices to Minimize Emissions during HMA Construction." National Asphalt Pavement Association (NAPA) (2000) 13 pp., p. 4, 5.

550. Asphalt Pavement Environmental Council, "Best Management Practices to Minimize Emissions during HMA Construction." National Asphalt Pavement Association (NAPA) (2000) 13 pp., p. 8.

551. Asphalt Pavement Environmental Council, "Best Management Practices to Minimize Emissions during HMA Construction." National Asphalt Pavement Association (NAPA) (2000) 13 pp., p. 10.

552. Andrady, A. L. "Pavement Marking Materials: Assessing Environment-Friendly Performance." *NCHRP Project 4-22, Research Report 392*, Transportation Research Board, Washington, DC (1998).

553. Korman, R., Daniels, S.H., Kohn, D., "Construction Industry Works with Federal Government to Ensure Worker Hearing Protection." *Engineering News-Record*, Vol. 244, No. 11 (March, 2000) p 36 http://ops.fhwa.dot.gov/wz/workshops/accessible/Schexnayder_paper.htm.

554. Laborers' Health & Safety Fund of North America, http://www.lhsfna.org/Noise_and_Noise_control_CIMA_8-00.pdf.

555. Personal communication, John Stadler, NOAA Fisheries, March 3, 2004.

556. Würsig, B., J. Greene, C.R., Jefferson, T.A. 2000. "Development of an Air Bubble Curtain to Reduce Underwater Noise of Percussive Pile Driving." *Marine Environmental Research* Vol. 49, p. 79-93, http://www.sciencedirect.com/science/journal/01411136.

557. Longmuir, C., and Lively. T., "Bubble Curtain Systems for Use during Marine Pile Driving." Report by Fraser River Pile and Dredge Ltd. New Westminister, British Columbia (2001) 9 pp.

558. Christopherson, A., and Wilson, J., Technical letter report regarding the San Francisco-Oakland Bridge East Span Project noise energy attenuation mitigation. Anchorage, AK: Peratrovich, Nottingham, and Drage, Inc. (2002)27 pp.

559. Reyff, J.A., and Donovan, P., "Benicia-Martinez Bridge Bubble Curtain Test - Underwater Sound Measurement Data." Memo to Caltrans (January 31, 2003) 3 pp.

560. Hastings, M.C. "Clarification of the Meaning of Sound Pressure Levels and the Known Effects of Sound on Fish." Document in support of Biological Assessment for San Francisco-Oakland Bay Bridge East Span Seismic Safety Project (2002) 8 pp.

561. Personal communications with Hastings, WSDOT (2004).

562. Alberta Transportation, "Blasting Mitigation Construction Practices Fact Sheet."http://www.trans.gov.ab.ca/Content/docType123/Production/FishFSm3.pdf.

563. Thalheimer, E.S., "The Importance of Community Involvement in a Successful Construction Noise Control Program." Acoustical Society of America Meeting, Atlanta, Georgia, (May 31, 2000) p. 2.

564. Thalheimer, E.S., "Construction Noise Control Program and Mitigation Strategy at the Central Artery/Tunnel Project." (July, 2001) 9 pp. http://www.bigdig.com/thtml/pdf/noise.pdf.

565. Montgomery County Maryland Construction Noise Rule and Practices, www.montgomerycountymd.gov/content/dep/noise/construction.pdf.

566. "Construction Noise." http://www.nonoise.org/news/const.htm.

567. Thalheimer, E.S., "Construction Noise Control Program and Mitigation Strategy at the Central Artery/Tunnel Project." Institute of Noise Control Engineering (August 4, 2000) p. 7.

568. Federal Highway Administration, "Effective Noise Control during Nighttime Construction." http://ops.fhwa.dot.gov/wz/workshops/accessible/Schexnayder_paper.htm

569. Thalheimer, E.S., "Proactive Construction Noise Control Policies Developed for the Central Artery/Tunnel Project's C17a6 Contract." Portland, Maine (October, 2001).

570. Brown, L., "Construction Noise for New Stadium Regulated by Noise Levels, Rather Than Curfews in Tacoma, Washington." *Washington News Tribune* (August 14, 1998) p. B1.

571. Commonwealth of Massachusetts, "Boston Central Artery and Tunnel Project Construction Noise Control Spec 721.56." http://www.nonoise.org/resource/construc/bigdig.htm.

572. Thalheimer, E., "Construction Noise Control Program and Mitigation Strategy at the Central Artery/Tunnel Project." Institute of Noise Control Engineering (August 4, 2000) p. 7.

573. Massachusetts Turnpike Authority, Central Artery (I-93) / Tunnel (I-90) Project, "C17A6 Noise Study - Noise Analysis and Mitigation Options", Final Report (June, 1999).

574. Personal communication, Loughlin, WSDOT, (May 10, 2004).

575. Commonwealth of Massachusetts, "Construction Noise Control: Boston Central Artery and Tunnel Project Construction Noise Control Spec." http://www.nonoise.org/resource/construc/bigdig.htm.

576. Caltrans Stormwater Compliance Review Task Force "Follow-Up Inspections of Maintenance Facilities." *California Department of Transportation Construction Stormwater Pollution Prevention Bulletin*, Vol. 2, No. 10 (October, 1999) 1 p.

577. Jacoby, P.W. "Chemical Control." Vegetative Rehabilitation and Equipment Workshop. 41st Annual Report. U.S. Forest Service, Boise, Idaho. (1987).

578. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p. 3-3.

579. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management", Minnesota Technology Transfer (T^2) LTAP Program, 2000, 132 pp., p. 81, http://www.lrrb.gen.mn.us/PDF/200019.pdf.

580. Alaska Highway Drainage Manual Effective October 1, 2001, p. 16-8-2. https://www.dot.state.ak.us/stwddes/desbridge/pop_hwydrnman.shtml.

581. Idaho Department of Transportation Environmental Section "Erosion and Sediment Control Manual Best Management Practices" Manual (December 2001) 132 pp., p. 4.16.97.

582. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., pp. 700-1, 700-13.

583. Bradshaw, A.D. and Chadwick, M.J. The Restoration of Land. Blackwell. Oxford (1980).

584. Claassen, V. P. and Zasoski, R.J., "The Effects of Topsoil Reapplication on Vegetation Reestablishment." *FHWA Report FHWA/CA/TL – 94/18*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 52 pp.

585. Claassen, V.P., Zasoski, R.J., and Southard, R.J., "Soil Conditions and Mycorrhizal Infection Associated with Revegetation of Decomposed Granite Slopes." *FHWA Report FHWA/CA/TL – 96/01*, Federal Highway Administration and State of California Department of Transportation (June, 1995) 151 pp.

586. Bradshaw, A.D. and Chadwick, M.J. The Restoration of Land. Blackwell. Oxford (1980).

587. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p.2.7.5.88.

588. Personal communication, Jennings, Stuart R., Montana State University, Bozeman (April 2004) regarding research results to be finalized in 2006.

589. Delaware Department of Transportation, "Publications and Forms." http://www.deldot.net/static/pubs_forms/manuals/livable_delaware/roadside_environment_attach.html.

590. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 800-18.

591. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p. 3-3.

592. Minnesota Department of Transportation, "Seeding Manual." (2003) pp. 28-32 http://www.dot.state.mn.us/environment/seeding_manual/SeedingManual2003.pdf.

593. Brown, C.S., Rice, K.J., Claasen, V.P. "Competitive Growth Characteristics of Native and Exotic Grasses" *FHWA Report FHWA/CA/ESC – 98/07*, Federal Highway Administration and State of California Department of Transportation, Transportation Research Board, Washington, DC (July, 1998) 226 pp.

594. Claassen, V.P. and Hogan, M.P. "Generation of Water-Stable Soil Aggregates for Improved Erosion Control and Revegetation Success." *Caltrans Final Report RTA53X461*, Chapter 3 (1998).

595. Brown, C.S., Rice, K.J., Claasen, V.P. "Competitive Growth Characteristics of Native and Exotic Grasses" *FHWA Report FHWA/CA/ESC – 98/07*, Federal Highway Administration and State of California Department of Transportation, Transportation Research Board, Washington, DC (July, 1998) 226 pp.

596. Brown, C.S., Rice, K.J., Claasen, V.P. "Competitive Growth Characteristics of Native and Exotic Grasses" *FHWA Report FHWA/CA/ESC – 98/07*, Federal Highway Administration and State of California Department of Transportation, Transportation Research Board, Washington, DC (July, 1998) 226 pp.

597. Schopmeyer, C.S., (Ed.) "Seeds of Woody Plants in the United States." U.S. Department of Agriculture Agronomy Handbook 450. U.S. Department of Agriculture, Forest Service, Washington, DC (1974).

598. Fordham, A.J., and Spraker, L.S., "Propagation Manual of Selected Gymnosperms." *Arnoldia* Vol.37: (1977) pp.1-88.

599. Hartmann, H., and Kester, D.E. Plant Propagation: Principles and Practice. Prentice-Hall, Englewood Cliffs, NJ (1983).

600. Dirr, M.A., and C.W. Heuser, C.W. The Reference Manual of Woody Plant Propagation. Varsity Press, Athens, GA (1987).

601. Federal Interagency Stream Restoration Working Group, "Stream Corridor Restoration: Principles, Processes, and Practices."(August, 2001) Chapter 9: "Restoration Implementation, Monitoring, and Management." http://www.usda.gov/stream_restoration/PDFFILES/CHAPTER9.pdf.

602. Personal communication, Randy Swanigan, Missouri DOT Roadside Management Specialist (May 21, 2004).

603. Dremann, C. "Blue Book of Ecosystem Values for Non-riparian Ecological Restoration." The Reveg Edge Consulting Services, (2003) www.ecoseeds.com/standards.html.

604. Dremann, C., "Releasing the Native Seedbank: An Innovative Approach to Restoring a Coastal California Ecosystem" *Ecological Restoration*, Vol.20, No.2 (June 2002) pp. 102-106, http://www.ecologicalrestoration.info/.

605. Dremann, C. "Blue Book of Ecosystem Values for Non-riparian Ecological Restoration." The Reveg Edge Consulting Services, (2003), www.ecoseeds.com/standards.html.

606. Dremann, C. "Releasing the Native Seedbank: An Innovative Approach to Restoring a Coastal California Ecosystem" *In* Ecological Restoration, Vol.20, No.2 (June 2002) pp. 102-106.

607. "Alaska Department of Transportation and Public Facilities, Highway Drainage Manual." (2001).

608. McGinnies, W.J., Seeding and Planting. *In* Vegetative Rehabilitation and Equipment Workshop, 38th Annual Report, U.S. Forest Service, Rapid City, South Dakota (1984) pp. 23-25.

609. Federal Interagency Stream Restoration Working Group, "Stream Corridor Restoration: Principles, Processes, and Practices."(August, 2001) Chapter 9: "Restoration Installation, Monitoring, and Management." http://www.nrcs.usda.gov/technical/stream_restoration/newtofc.htm.

610. Goldner, B.H., "Riparian Restoration Efforts Associated with Structurally Modified Flood Control Channels." *In* California Riparian Systems, Warner, R.B., and Hendrix, K.M. (Ed.). University of California Press, Berkeley, CA (1984) pp. 445-451.

611. Montana Department of Transportation, "Evaluation of Organic Matter Compost Addition and Incorporation on Steep Cut Slopes." Research in progress.

612. Federal Highway Administration, "Missouri DOT 2002 Contractor Performance Questionnaire." (2002) http://www.fhwa.dot.gov/programadmin/contracts/cpq2002.htm.

613. Federal Highway Administration, "Pavement Maintenance Effectiveness." *FHWA-SA-96-007*, Federal Highway Administration, Washington, DC (1995).

614. Schlect, E.D., and Huddleston, J. "Pavement Maintenance Strategies." *Centerline*, Vol. 2, Issue 3 (Fall 1997) pp. 1-4.

615. State of California Department of Transportation, "State of the Pavement Report." 2002 p. 5, http://www.dot.ca.gov/hq/maint/2002_SOP.pdf.

616. Federal Highway Administration, "Asphalt Pavement Repair Manuals of Practice." *SHRP-H-348*, National Research Council, Washington, DC (1993).

617. Bemanian, S., "How Recycling Fits Nevada's Pavement Program." *Better Roads*, Vol. 73, No. 7 (July 2003) 7 pp.

618. Environment Canada, Technical Pollution Prevention Guide for Asphalt Preparation Operations in the Lower Fraser Basin, 1996. http://www.rem.sfu.ca/FRAP/9612.pdf

619. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

620. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

621. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

622. Personal communication, Douglas Gransberg, Principal Investigator, Chip Sealing Practice Synthesis.

623. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

624. Idaho Department of Transportation Maintenance Manual, http://www.itd.idaho.gov/Highways/ops/maintenance/Manuals/CDBurn/Maintenance/full%20manual.pdf.

625. Envirochem Special Projects Inc, Technical Pollution Prevention Guide for Ready Mix Concrete Operations in the Lower Fraser Basin, 97-13.

626. Envirochem Special Projects Inc, Technical Pollution Prevention Guide for Ready Mix Concrete Operations in the Lower Fraser Basin, 97-13.

627. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

628. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

629. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

630. Environment Canada, "Concrete Washwater: What Precautions Can Be Taken?" http://www-heb.pac.dfo-mpo.gc.ca/water_quality/fish_and_pollution/conc_prec_e.htm.

631. Environment Canada, "Concrete Washwater: What Precautions Can Be Taken?" http://www-heb.pac.dfo-mpo.gc.ca/water_quality/fish_and_pollution/conc_prec_e.htm.

632. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

633. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

634. California Stormwater Quality Association, "California Municipal BMP Handbook: Road and Street Maintenance SC-70." Handbook 3 of 9 (January, 2003). www.cabmphandbooks.com.

635. California Department of Transportation, "Specification: Remove Traffic Stripe and Pavement Marking." http://www.dot.ca.gov/hq/esc/oe/specifications/SSPs/99-SSPs/Sec_10/15/15-300_A08-17-01.doc.

636. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

637. International Road Federation, "Making the Most of Waste." *World Highways/Routes du Monde*, Vol. 8, No.5, (July, 1999) pp. 51-52.

638. U.S. Department of Transportation Federal Highway Administration, "Pavement Recycling". http://www.fhwa.dot.gov/pavement/recycle.htm.

639. Federal Highway Administration, "User Guidelines for Waste and Byproduct Materials in Pavement Construction." www.tfhrc.gov/hnr20/recycle/waste/index.htm.

640. Federal Highway Administration, "User Guidelines for Waste and Byproduct Materials in Pavement Construction." www.tfhrc.gov/hnr20/recycle/waste/asp.htm.

641. Center for Transportation Research, "Using Recycled Materials in Concrete." http://www.utexas.edu/research/ctr/recycle/concrete.html.

642. Federal Highway Administration, National Highway Institute Courses, http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=231.

643. Federal Highway Administration, National Highway Institute Courses, http://www.nhi.fhwa.dot.gov/coursedesc.asp?coursenum=232.

644. Aspalt Alliance Fact Sheet, "Aspahlt: The Recyling Leader," http://www.asphaltalliance.com/upload/focus_recycling-FS.pdf.

645. Asphalt Alliance Press Release: "Asphalt is America's Most Recycled Product." http://www.asphaltalliance.com/upload/focus_recycling-PR.pdf.

646. "Back to Being Super: Research Shows Reclaimed Asphalt Can Be Used in Superpave." *Roads and Bridges*, Vol. 40, No. 10 (October, 2002) pp. 24-27.

647. Polak, M. L. "Polishing Monuments." *Roads and Bridges*, Vol. 41, No. 10 (October, 2003).

648. Collins, R.J., Ciesielski, S.K., "Recycling and Use of Waste Materials and Byproducts in Highway Construction." Volumes 1 & 2 (1993).

649. Collins, R.J., Ciesielski, S.K., "Recycling and Use of Waste Materials and Byproducts in Highway Construction." Volumes 1 & 2 (1993).

650. Federal Highway Administration, "Recovered Materials Guidelines." Turner-Fairbank Highway Research Center, www.tfhrc.gov/hnr20/recycle/waste/.

651. Collins, R.J., Ciesielski, S.K., "Recycling and Use of Waste Materials and Byproducts in Highway Construction." Volumes 1 & 2 (1993).

652. National Cooperative Highway Research Program - Anticipated Project Project 1-41, FY 2003 "Selection, Calibration, and Validation of a Reflective Cracking Model for Asphalt Concrete Overlays." http://www4.nationalacademies.org/trb/crp.nsf/f42b364caa3b01038525672f00635743/ef72f2b99aa7263685256b990044587b?OpenDocument.

653. Turner Fairbank Research Center, http://www.tfhrc.gov/hnr20/recycle/waste/index.htm.

654. Solaimanian, M. and Kennedy, T.W., "Production Variability Analysis of Hot-Mixed Asphalt Concrete Containing Reclaimed Asphalt Pavement." *Research Report #2818-1F* (February, 1995) University of Texas at Austin, Department of Civil Engineering Center for Transportation Research, 129 pp. http://www.utexas.edu/research/ctr/recycle/hmac.html.

655. Cosentino, P.J., Kalajian, E.H., Shieh, C.S., Mathurin, W.J., Gomez, F.A., Cleary, E.D., Treeratrakoon, A., "Developing Specifications for Using Recycled Asphalt Pavement as Base, Subbase or General Fill Materials, Phase II." Florida Department of Transportation, *FL/DOT/RMC/06650-7754, Final Report*, Tallahassee, FL (July, 2003) 271 pp.

656. McDaniel, R., Anderson, R. M. "Incorporation of Reclaimed Asphalt Pavement in the Superpave System," R.M., *NCHRP Project 9-12*, *Research Results Digest*, No. 253 (March 2001) p.1.

657. McDaniel, R., Anderson, R. M. "Incorporation of Reclaimed Asphalt Pavement in the Superpave System," R.M., *NCHRP Project 9-12*, *Research Results Digest*, No. 253 (March 2001) p.1.

658. Illinois Department of Transportation. "Standard Specifications for Road and Bridge Construction." Departmental Policies D&E-2, Springfield, IL (2002).

659. Illinois Dept. of Transportation, "Special Provision for RAP Mixtures for Class I, Type 1 and 2 Bituminous Concrete Binder, Leveling Binder and Surface Course (Mixture C and D)." Springfield, IL (1994).

660. U.S. Department of Transportation Federal Highway Administration, "Utilization of Recycled Materials in Illinois Highway Construction: Reclaimed Asphalt Pavement" http://www.fhwa.dot.gov/pavement/reclpav.htm.

661. McDaniel, R., Soleymani, H., Shah, A., "Use of Reclaimed Asphalt Pavement (RAP) Under Superpave Specifications: A Regional Pooled Fund Study", Federal Highway Administration, *FHWA/IN/JTRP-2002/6, Final Report*, Washington, DC (May, 2002) 79 pp.

662. Cereoli, M., "Answers to Why Cold In-Place Recycling Should be an Everyday Practice." *Roads & Bridges*, Vol. 40, No. 10 (October 2002).

663. Bemanian, S., "How Recycling Fits Nevada's Pavement Program." *Better Roads*, Vol. 73, No. 7 (July 2003) 7 pp.

664. Lander, K., "Recycling as a Life-Extending Maintenance Tactic." *Better Roads*, Vol. 72, No. 7 (July, 2002).

665. Kazmierowski, T., Marks, P., Lee, S., "Ten-Year Performance Review of In Situ Hot-Mix Recycling in Ontario." *Transportation Research Record, No. 1684*, Transportation Research Board, Washington, DC (1999) pp. 194-202.

666. Romanoschi, S.A., Hossain, M., Heitzman, M., Gisi, A.J., "Foamed Asphalt Stabilized Reclaimed Asphalt Pavement: A Promising Technology for Mid-Western Roads." Mid-Continent Transportation Research Symposium, Ames Iowa, (August 2003) 11 pp.

667. Mohammad, L.N., Abu-Farsakh, M.Y., Wu, Z., Abadie, C., "Louisiana Experience with Foamed Recycled Asphalt Pavement Base Materials." *Transportation Research Record, No. 1832*, Transportation Research Board, Washington, DC (2003) pp.17-24.

668. Kuennen, T., "California Puts Foamed Asphalt To The Test." *Better Roads*, Vol. 73, No. 7 (July, 2003) pp. 16-19.

669. "Just Following Policy." *Roads and Bridges*, Vol. 41, No. 10 (October, 2003).

670. Marquis, B., Peabody, D., and Mallick, R., Maine DOT & Worcester Polytechnic Institute, "Using Foamed Asphalt as a Stabilizing Agent in Full Depth Reclamation of Route 8 in Belgrade, Maine," Recycled Materials Resource Center, University of New Hampshire (October 2002).

671. Uchikawa, H., "Approaches to Ecologically Benign System in Cement and Concrete Industry." *Journal of Materials in Civil Engineering*, Vol. 12, No. 4 (November, 2000) pp. 320-329.

672. Chesner, W. H., Collins, R.J., and MacKay, M.H., "Users Guidelines for Waste and By-Product Materials in Pavement Construction." Federal Highway Administration, *Report No. FHWA-RD-97-148*, Transportation Research Board, Washington, DC (1998). www.tfhrc.gov/hnr20/recycle/waste/index.htm.

673. Ayers, M., Haislip, S., Waalkes, S., "Have It Repaired: Concrete Maintenance is Easy and Affordable." *Roads and Bridges*, Vol. 42, No. 1 (January, 2004).

674. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

675. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

676. U.S. Department of Transportation Federal Highway Administration, "Recycled Concrete Aggregate: Federal Highway Administration National Review." www.fhwa.dot.gov/pavement/rca.htm.

677. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

678. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

679. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

680. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

681. Harrington, J. "Recycling in Transportation, Part 1: The Engineering Challenge—Recycled-Concrete Review" 83rd Annual Meeting of the Transportation Research Board, Washington, DC, (January 11-15, 2004).

682. Illinois Dept. of Transportation. Standard Specifications for Road and Bridge Construction. Departmental Policies D&E-2, Springfield: Illinois Dept. of Transportation (January 2002).

683. U.S. Department of Transportation Federal Highway Administration, "Utilization of Recycled Materials in Illinois Highway Construction: Recycled Concrete Material." http://www.fhwa.dot.gov/pavement/recymat.htm.

684. Indiana Department of Transportation (1999) and Standard Specifications, American Concrete Institute (1991) Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91) *cited in a white paper* by Wongkaew, K., "Optimal Use of Recycled Materials in Highway Construction, an INDOT case study," Parsons-Brinkerhoff, San Francisco.

685. AASHTO Specification for Recycled Concrete as Aggregate in PCC Pavements.

686. AASHTO Specification for Recycled Concrete as Aggregate in PCC Pavements.

687. AASHTO Specification for Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course: AASHTO Designation: M 319-02.

688. AASHTO Specification for Reclaimed Concrete Aggregate for Unbound Soil-Aggregate Base Course: AASHTO Designation: M 319-02.

689. Button, J.W., Williams, D., and Scherocman, J.A. "Roofing Shingles and Toner in Asphalt Pavements." *Report FHWA-TX-97/1344-2F*, Texas Dept. of Transportation, Research and Technology Transfer Office, Austin, Texas (1996).

690. Marks, V.J. and G. Petermeier, G. "Let Me Shingle Your Roadway." Record No. 1589, Washington DC, Transportation Research Board, National Research Council (1997).

691. "Draft White Paper for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt." (April, 2003) http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/RASAC/drftwhite41503.pdf.

692. Van Tassel, E. L., Tikalsky, P.J. and Christensen, D.W. "Review of PennDOT Publication 406 for the Use of Recycled Co-Product Materials." Commonwealth of Pennsylvania Dept. of Transportation, Office of Planning & Research, Harrisburg, PA (April 1999).

693. Janisch, D.W. and Turgeon, C.M., "Minnesota's Experience Using Shingle Scrap in Bituminous Pavements" *MN/PR-96/34*, Minnesota Dept. of Transportation, Office of Minnesota Road Research Physical Research Record Section, Maplewood, MN (October 1996).

694. Ketchem, B., "Recycled Products." http://www.doh.dot.state.nc.us/preconstruct/highway/dsn_srvc/value/recycle/.

695. Stroup-Gardiner, M., et al. "Permanent Deformation and Low Temperature Behavior of Roofing-Modified HMA." Symposium Proceedings - Recovery and Effective Reuse of Discarded Materials and Byproducts for Construction of Highway Facilities, (October 1993).

696. "Shingle Scrap in Asphalt Concrete," Unpublished Report, *Study No. 9PR1010*, Minnesota Department of Transportation (1991).

697. U.S. Department of Transportation Federal Highway Administration, "Utilization of Recycled Materials in Illinois Highway Construction: Roof Shingles," http://www.fhwa.dot.gov/pavement/recroof.htm.

698. Nash, P.T., Jayawickrama, P., et. al, "Guidelines for Using Hydrated Fly Ash as a Flexible Base" *Research Report #1365-1F*, Texas Tech University, Department of Civil Engineering (1995).

699. Federal Highway Administration, "Coal Fly Ash – Material Description." http://www.tfhrc.gov/hnr20/recycle/waste/cfa51.htm.

700. Federal Highway Administration, "Fly Ash Facts for Highway Engineers." http://www.fhwa.dot.gov/pavement/fach02.htm.

701. State of Massachusetts, "Cement Concrete Specifications." http://www.state.ma.us/mhd/recycle/specifications/m40200.pdf.

702. Little, D.N., Godiwalla, A.M., Oshiro, P.Y., Tang, P.S., "Characterization of Design Properties (Compressive Strength and Resiliente Modulus) of Lime, Cement, Fly Ash Stabilized Recycled Concrete Base as Function of Curing Time." Maintenance and Rehabilitation of Pavements and Technological Control Conference, University of Minho, Guimaraes, Portugal (July, 2003) 12 pp.

703. Sobhan, K., Mashnad, M., "Mechanical Stabilization of Cemented Soil-Fly Ash Mixtures with Recycled Plastic Strips." *Journal of Environmental Engineering*, Vol. 129, No. 10 (October, 2003) pp. 943-947.

704. Texas Transportation Institute, "Hydrated Fly Fish Base Performing Well." Texas Transportation Researcher, Vol. 36, No. 1, http://tti.tamu.edu/researcher/v36n1/flyash.stm.

705. State of Massachusetts, "Controlled Density Fill Specification http://www.state.ma.us/mhd/recycle/specifications/m4080.pdf.

706. Show, K.Y., Tay, J.H., Goh, A.T.C., "Reuse of Incinerator Fly Ash in Soft Soil Stabilization." *Journal of Materials in Civil Engineering*, Vol. 15, No. 4 (July, 2003) pp. 335-343.

707. American Coal Ash Association, "Fly Ash Facts for Highway Engineers". *FHWA Report IF-03-019*. Washington, DC (2003) 76 pp. http://www.fhwa.dot.gov/pavement/fa17007.htm.

708. White Paper And Specification - Coal Combustion Fly Ash for Structural Fills and Embankment, http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/docs/CCFADraft.pdf.

709. Federal Highway Administration, "Fly Ash Facts for Highway Engineers." http://www.fhwa.dot.gov/pavement/fach02.htm.

710. Federal Highway Administration, "Fly Ash Facts for Highway Engineers." http://www.fhwa.dot.gov/pavement/fach02.htm.

711 FHWA, Utilization of Waste Foundry Sand in Construction in Illinois, http://www.fhwa.dot.gov/pavement/recsand.htm

712 Foundry Industry Recycling Starts Today (FIRST), www.foundryrecycling.org/whatis.html

713 FHWA, Utilization of Waste Foundry Sand in Construction in Illinois, http://www.fhwa.dot.gov/pavement/recsand.htm

714. Environmental Protection Agency, "Characterization of Municipal Solid Waste in the United States: 1992 Update, Executive Summary." *EPA/530-S-92-019*, Washington, DC, (1992) *(1998 Update)* http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/98charac.pdf.

715. "Glasphalt' Utilization Dependent upon Availability." *Roads & Bridges* (February 1993) pp. 59-61.

716. Meyer, C. "Glass Concrete." *Concrete International*, Vol. 25, No. 6 (June, 2003) pp. 55-58.

717. Federal Highway Administration, "Utilization of Recycled Materials in Illinois Highway Construction: Glass Aggregate". http://www.fhwa.dot.gov/pavement/recglass.htm.

718. "Glass: A Cutting Edge Road Material." *World Highways/Routes du Monde*, Vol. 11, No. 7 (September, 2002) 15 pp.

719. Federal Highway Administration, "User Guidelines for Waste and Byproduct Materials in Pavement Construction." www.tfhrc.gov/hnr20/recycle/waste/index.htm.

720. Anderson, C. and Steele, R.S., New York State Department of Transportation, "Filtration Technologies That Work: Use of Crushed Glass as a Filtration Media for Construction Projects." Region 3, NYWEA Spring Technical Conference & Exhibition.

721. Anderson, C. and Steele, R.S., New York State Department of Transportation, "Filtration Technologies That Work: Use of Crushed Glass as a Filtration Media for Construction Projects." Region 3, NYWEA Spring Technical Conference & Exhibition.

722. Anderson, C. and Steele, R.S., New York State Department of Transportation, "Filtration Technologies That Work: Use of Crushed Glass as a Filtration Media for Construction Projects." Region 3, NYWEA Spring Technical Conference & Exhibition.

723. State of Massachusetts, "Processed Glass Aggregate Specifications." http://www.state.ma.us/mhd/recycle/specifications/m2018.pdf.

724. State of Massachusetts, "Ordinary Borrow Specifications." http://www.state.ma.us/mhd/recycle/specifications/m1010.pdf.

725. State of Massachusetts, "Special Borrow Specifications." http://www.state.ma.us/mhd/recycle/specifications/m1020.pdf.

726. State of Massachusetts, “Gravel Borrow Specifications.” http://www.state.ma.us/mhd/recycle/specifications/m1030.pdf.

727. State of Massachusetts, “Processed Gravel Specifications.” http://www.state.ma.us/mhd/recycle/specifications/m1031.pdf.

728. State of Massachusetts, “Sand Borrow Specifications.” http://www.state.ma.us/mhd/recycle/specifications/m1040.pdf.

729. State of Massachusetts, “Sand Borrow for Subdrains Specifications.” http://www.state.ma.us/mhd/recycle/specifications/m1041.pdf.

730. State of Massachusetts, “Dense Graded Crushed Stone Specifications.” http://www.state.ma.us/mhd/recycle/specifications/m2017.pdf.

731. State of Massachusetts, “Mineral Aggregate in Class I Bituminous Concrete Specifications.” http://www.state.ma.us/mhd/recycle/specifications/m31100.pdf.

732. Nash, P.T., Jayawickrama, P., Richard W. Tock, R.W., Sanjaya Senadheera, S., Krishnan Viswanathan, K., Binli Woolverton, B., “Use of Glass Cullet in Roadway Construction”, *Research Report #1331-1*, Texas Tech University, College of Engineering, http://www.utexas.edu/research/ctr/recycle/cullet.html.

733. Federal Highway Administration, “Recovered Materials Guidelines.” Turner-Fairbank Highway Research Center, www.tfhrc.gov/hnr20/recycle/waste/.

734. Kandahl, P. S. and Hoffman, G.L., “Evaluation of Steel Slag Fine Aggregate in Hot-Mix Asphalt Mixtures.” *Record No. 1583*, Transportation Research Board, National Research Council Washington, DC (1997).

735. FHWA TFHRC, Steel Slag Material Description, http://www.tfhrc.gov/hnr20/recycle/waste/ssa1.htm.

736. Steel Recycling Institute, “Steel Takes Leed with Recycled Content.”(2000) http://www.recycle-steel.org/.

737. Collins, R.J., Ciesielski, S.K., “Recycling and Use of Waste Materials and Byproducts in Highway Construction.” Volumes 1 & 2 (1993).

738. Concrete Reinforcing Steel Institute, http://www.crsi.org/.

739. Federal Highway Administration, “Utilization of Recycled Materials in Illinois Highway Construction.” http://www.fhwa.dot.gov/pavement/recsteel.htm.

740. CDOT Research News-Notes, January 2004. Also, personal communication, Rich Griffin, CDOT.

741. Saylak, D., Estakhri, C.K., Viswanathan, Tauferner, R.D. and Chimakurthy, H. “Evaluation of the Use of Coal Combustion By-Products in Highway and Airfield Pavement Construction.” *TX-97/2969-1F*, Texas Department of Transportation, Research and Technology Transfer Office, Austin, Texas (November 1996).

742. Turner Fairbank Research Center, http://www.tfhrc.gov/hnr20/recycle/waste/index.htm.

743. Schroeder, R. “The Use of Recycled Materials in Highway Construction.” *Engineering News Record* (February 22, 1993), p. 42.

744. Scrap Tire Management Council, http://www.p2pays.org/ref/11/10504/html/biblio/htmls2/prh6.htm.

745. Scrap Tire Management Council, http://www.p2pays.org/ref/11/10504/html/biblio/htmls2/prh6.htm.

746. *“Draft White Paper for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt.” (April, 2003)* http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/RASAC/drftwhite41503.pdf.

747. Jorgenson, L., “Tires Make the Road - Asphalt Rubber Pavement Construction.” *Public Works*, Vol. 134, No. 1 (January, 2003) pp. 30-31.

748. Turner Fairbank Research Center, http://www.tfhrc.gov/hnr20/recycle/waste/index.htm.

749. Chollar, B. and Memon, M. “CMCRA: Where the Tire Meets the Road” *Public Roads* (Spring 1997) http://www.tfhrc.gov/pubrds/spring97/crum.htm.

750. Hunt, E. A., “Crumb Rubber Modified Asphalt Concrete in Oregon.” Oregon Department of Transportation Research Group, *SPR 355-13*, (1999).

751. Rubber Pavement Association, http://www.rubberpavements.org.

752. Rochat, Judith. 2004. "Using Quiet Pavements to Help Reduce Highway Traffic Noise: Wayside Noise Measurement Studies in California and Arizona and FHWA's Quiet Pavement Pilot Program," 29th Annual Conference of the National Association of Environmental Professionals, Portland, OR, April 26-27, 2004.

753. Moo-Young, H., Sellasie, K., Zeroka, D., Sabnis, G., "Physical and Chemical Properties of Recycled Tire Shreds for Use in Construction." *Journal of Environmental Engineering*, Vol. 129, No. 10 (October 10, 2003) pp. 921-929.

754. State of Massachusetts, "Tire Shreds as Lightweight Fill." www.state.ma.us/mhd/recycle/resproj.htm.

755. Ketchem, B. "State of North Caroline Recycled Products." http://www.doh.dot.state.nc.us/preconstruct/highway/dsn_srvc/value/recycle/.

756. Horner, A. "Use of Scrap Tire Rubber in Carsonite Noise Barrier." Symposium Proceedings - Recovery and Effective Reuse of Discarded Materials and Byproducts for Construction of Highway Facilities (October 1993).

757. Recycled Materials Resource Center, "Evaluation of Recycled Tire Spacer Blocks." http://www.rmrc.unh.edu/Research/Rprojects/Project25/project25.asp.

758. Griffith, M.S., Letter of Acceptance for Recycled Spacer Blocks (March, 27, 2003) http://www.rmrc.unh.edu/Research/Rprojects/Project25/specs/fhwa/B114(Welchblock).pdf.

759. Recycled Resource Materials Center, "Evaluation of Recycled Tire Spacer Blocks: Test Results to 12 Midwest States." http://www.rmrc.unh.edu/Research/Rprojects/Project25/specs/states/P25states.asp.

760. Recycled Resource Materials Center, "Evaluation of Recycled Tire Spacer Blocks: Iowa DOT Specifications for Recycled Tire Spacer Blocks," http://www.rmrc.unh.edu/Research/Rprojects/Project25/specs/iowa/P25iowa.asp.

761. AASHTO Success Story, "Iowa DOT Gives New Meaning to 'Where the Rubber Meets the Road'." http://www.transportation.org/aashto/success.nsf/allpages/2004-02iowa.

762. Zeyher, A. "Present Arms: Roll Call of Soldier in the War Against Advancing Roadside Weeds." *Road and Bridges*, Vol. 39, No. 5 (May, 2001).

763. Texas Department of Transportation, "Tire Rubber Anti-Vegetation Tile Evaluation Project" http://www.dot.state.tx.us/GSD/recycle/tile.htm.

764. "The Wyoming Post: Dot Uses Durable Divider to Ease Problematic Roadways." *Roads and Bridges*, Vol. 40, No. 7 (July, 2002) 44pp.

765. Environmental Protection Agency, "Characterization of Municipal Solid Waste in the United States: 1992 Update, Executive Summary." *EPA/530-S-92-019*, Washington, DC, (1992) *(1998 Update)* http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/98charac.pdf.

766. Schroeder, R. "The Use of Recycled Materials in Highway Construction." *Engineering News Record* (February 22, 1993), p. 42.

767. "Recycled Plastic Finds Home in Asphalt Binder." *Roads and Bridges* (March 1993) pp. 41-47.

768. Federal Highway Administration, "Engineering and Environmental Aspects of Recycled Materials for Highway Construction, Volume I: Final Report." *FHWA Contract No. DTFH61-92-C-00060*, Washington DC, (1993).

769. Memon, G.M., Franco, C.A., "TMB Asphalt (Tire & Milk Bottles) - A New Solution in Asphalt Maintenance." Maintenance and Rehabilitation of Pavements and Technological Control Conference, University of Minho, Guimaraes, Portugal (July, 2003) 8 pp.

770. Hag-Elsafi, O., Elwell, D.J., Glath, G., Hiris, M., "Noise Barriers Using Recycled-Plastic Lumber." Transportation Research Record, No. 1670 (1999) pp. 49-58.

771. Hyde, J., Engel, P., "Life Cycle Assessment Study. Guardrail Offset Blocks: Recycled Plastic, Steel, and Pressure-Treated Wood Blocks." Chelsea Center for Recycling and Economic Development, *Technical Report #27* (August, 2000).

772. Atahan, A.O., Bligh, R.P., Ross, H.E., "Evaluation of Recycled Content Guardrail Posts," *Journal of Transportation Engineering*, Vol. 128, No. 2 (March, 2002) pp. 156-166.

773. Parra, J.R., Loehr, J.E., Hagemeyer, D.J., Bowders, J.J., "Field Performance of Embankments Stabilized with Recycled Plastic Reinforcement." *Transportation Research Record, No. 1849*, Transportation Research Board, Washington, DC (2003) pp. 31-38.

774. State of Massachusetts, "Steel Beam Highway Guard Specification." http://www.state.ma.us/mhd/recycle/specifications/m8070.pdf.

775. State of North Carolina, "Recycling and Solid Waste Management Report Fiscal Year 2001." http://www.doh.dot.state.nc.us/preconstruct/highway/dsn_srvc/value/recycle/taskforce/01report.html.

776. Bowders, J.J., Loehr, J.E., Salim, H., Chen, C-W., "Engineering Properties of Recycled Plastic Pins for Slope Stabilization." *Transportation Research Record, No. 1849 Soil Mechanics*, Transportation Research Board, Washington, DC (2003).

777. Iskander, M., Mohamed, A., Hassan, M., "Durability of Recycled Fiber-Reinforced Polymer Piling in Aggressive Environments" *Transportation Research Record No. 1808, Soil Mechanics*, Transportation Research Board, Washington, DC (2002) pp. 153-161.

778. Berthelsen, G., "Bridge Fenders of Recycled Plastic." *California Department of Transportation Journal*, Vol. 2, No. 4, California Department of Transportation (January, 2002) pp. 38-41.

779. personal communication with Joe Mickes, former MODOT Chief Administrator and Larry Thompson, MODOT Sign Shop Supervisor, on March 4-5, 2004.

780. LTAP Rural Roads Resources, http://www.ltapt2.org/resources/ruralresources.htm.

781. AASHTO EMS Case Study 9, PennDOT EMS.

782. AASHTO EMS Case Study 9, PennDOT EMS.

783. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., p. 22.

784. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., p. 34.

785. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., pp. 34-35.

786. Caltrans Stormwater Compliance Review Task Force, "Preventing Pollutant Discharges from the Maintenance Facility." *Caltrans Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 5, No. 2 (September, 2002) http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m9_02.pdf.

787. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp. p. 2.30.154.

788. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp. p. 2.30.154.

789. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

790. Maine DOT Materials Management Procedure, provided by personal correspondence from Christine Olson, MDOT (February 2004).

791. Caltrans Stormwater Compliance Review Task Force "Cleaning Up Spills of Vehicle and Equipment Fluids." *California Department of Transportation Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 4, No. 1 (July, 2002) 1 p., http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m7_02.pdf.

792. Caltrans Stormwater Compliance Review Task Force, "Soil Stabilization at Maintenance Facilities." *Caltrans Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 6, No. 1 (January, 2003) http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m1_03.pdf.

793. State of California Department of Transportation, "Caltrans Maintenance Manual." Chapter C-6, (June, 1998).

794. Caltrans Stormwater Compliance Review Task Force, "Preventing Pollutant Discharges from the Maintenance Facility." *Caltrans Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 5, No. 2 (September, 2002) http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m9_02.pdf.

795. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual." Publication 23 (July 2001) 494pp.

796. Banasiak, D. (Ed.), "Competitions Honor Salt-Storage Facilities, Equipment Operators." *Roads & Bridges* (December, 1996).

797. Maine DOT Materials Management Procedure, provided by personal correspondence from Christine Olson, MDOT (February 2004).

798. Caltrans Stormwater Compliance Review Task Force "Follow-Up Inspections of Maintenance Facilities." *California Department of Transportation Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 2, No. 6 (June, 1999) 1 p http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m6_99.pdf.

799 Caltrans Stormwater Compliance Review Task Force "Follow-Up Inspections of Maintenance Facilities." *California Department of Transportation Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 2, No. 6 (June, 1999) 1 p http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m6_99.pdf.

800. Caltrans Stormwater Compliance Review Task Force "Sediment Control for Raw Material Storage Areas." *California Department of Transportation Construction Stormwater Pollution Prevention Bulletin*, Vol. 2, No. 9 (September, 1999) 1 p.

801. Iowa Department of Transportation "Anti-Icing Equipment Manual: Storage." http://www.dot.state.ia.us/maintenance/manuals/equip/facilities/facilities3.htm.

802. Iowa Department of Transportation, "Winter Operations." http://www.dot.state.ia.us/maintenance/.

803. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual." Publication 23 (July 2001) 494 pp.

804. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 4.3.25.

805. Transportation Association of Canada, "Syntheses of Best Practices - Road Salt Management: Design and Operation of Road Maintenance Yards " (September 2003) http://www.tac-atc.ca/english/pdf/design.PDF.

806. Alberta Transportation and Utilities Contract Administration Manual http://www.tac-atc.ca/english percent2Dnew/mcdbase/docs/a00001e/002 percent2D1.htm.

807. Ryan, M.M. and Tartline, P., "Stockpile Management." Memo to District Engineers, Commonwealth of Pennsylvania (July 13, 1999).

808. Enginering District 10, PennDOT SEMP Manual: Sound Environmental Practices, District 10 (2002).

809. Ryan, M.M. and Tartline, P., "Winter Material Handling and Storage and Foreman's Stockpile Checklist Procedure." Memo to District Engineers, Commonwealth of Pennsylvania (August 9, 2001).

810. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual.". "Maintenance First' Thru Quality Assurance." Assurance Evaluation Indicators Winter Materials (solid), Publication 23 (July 2001) 494 pp. Chapter 4.

811. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 p. 2.14.115 and p.4.56.234.

812. NYSDOT's "Solid and Hazardous Waste Reduction Policy." (August, 1999) http://www.dot.state.ny.us/eab/manual/wastered.pdf.

813. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual", Publication 23 (July 2001) 494 pp., p. 20.2.5.

814. Personal communication, Christine Olson, Maine DOT HazMat Coordinator (February25, 2004).

815. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual", Publication 23 (July 2001) 494 pp, p. 20.2.6.

816. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual", Publication 23 (July 2001) 494 pp, p. 20.2.6.

817. Maine DOT Administrative Policy Memorandum No. 414, Revised July 11, 2001, Supercedes APM #414 dated June 1, 1987.

818. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual", Pub 23 (7-01) (July 2001) 494 pp., p. 20.7.12.

819. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp. p. 5.1.31.

820. Maine Department of Transportation Bureau of Maintenance and Operations "Procedures Related to Equipment Maintenance" (April 3, 2002).

821. Maine Department of Transportation Bureau of Maintenance and Operations "Procedures Related to Equipment Maintenance" (April 3, 2002), Version 1.5, pp. 1-4.

822. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp.

823. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp.

824. Caltrans Stormwater Compliance Review Task Force "Illegal Dumping and Spill Control BMPs." *California Department of Transportation Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 3, No. 3 (March, 2000) 1 p., http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m3_00.pdf.

825. Kyle, W., "Environmental Stewardship in NYSDOT Highway Maintenance." *In* Irwin, C.L., Garrett, P., and McDermott, K.P. (Ed.) 2003 Proceedings of the International Conference of Ecology and Transportation (2003).

826. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 4.7.30.

827. Caltrans Stormwater Compliance Review Task Force "Follow-Up Inspections of Maintenance Facilities." *California Department of Transportation Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 2, No. 6 (June, 1999) 1 p., http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m6_99.pdf.

828. Indiana DOT Operating Procedure No. 2: Snow and Ice Control. August 24, 1998;

829 (pp. 3 of 13)

830. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., p. p. 53.

831 New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p.4.1.22.

832. Maine Department of Transportation Bureau of Maintenance and Operations "Procedures Related to Equipment Maintenance" (April 3, 2002).

833. New Hampshire Department of Environmental Services, "Holding Tanks for Floor Drains." Fact Sheet *WD-WSEB-22-8*, (2003) http://www.des.state.nh.us/factsheets/ws/ws-22-8.htm.

834. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp.

835. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State

Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., pp. 63-64.

836. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24 Final Report* , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., p. 65.

837. New Hampshire Department of Environmental Services. "Environmental Fact Sheet: Wastewater Discharges from Vehicle Washing." (2003) http://www.des.state.nh.us/factsheets/ws/ws-22-10.htm.

838. State of Oregon, Department of Environmental Quality, "Oregon DOT Best Management Practices for Stormwater Discharges Associated with Industrial Activities." (February, 2001) 58 pp., p. 9, http://www.deq.state.or.us/nwr/Industrial percent20BMPs.pdf.

839. State of Oregon, Department of Environmental Quality, "Oregon DOT Best Management Practices for Stormwater Discharges Associated with Industrial Activities." (February, 2001) 58 pp., p. 9, http://www.deq.state.or.us/nwr/Industrial percent20BMPs.pdf.

840. United Nationals Environmental Program Technical Publications, "Recycling of Wastewater in the Transportation Industry." http://www.unep.or.jp/ietc/publications/techpublications/techpub-8b/recycling.asp.

841. State of Oregon, Department of Environmental Quality, "Oregon DOT Best Management Practices for Stormwater Discharges Associated with Industrial Activities." (February, 2001) 58 pp., p. 9, http://www.deq.state.or.us/nwr/Industrial percent20BMPs.pdf.

842. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 4.2.23.

843. Caltrans Stormwater Compliance Review Task Force, "Above Ground Storage Tank Leak and Spill Control." *California Department of Transportation Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 2, No. 11 (November, 1999) http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m11_99.pdf.

844 California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp. p. 2.15.123 and 4.61.239; also StormWater Attachments, http://www.dot.ca.gov/hq/construc/stormwater/NS-09.pdf.

845. Corson, L.A., "Development of a Database and System for Analyzing the Actual and Potential Impacts on the Environment of Existing and Planned INDOT Sites."*FHWA/IN/JTRP-2002/24* Final Report , Indiana State Department of Transportation and Federal Highway Administration, Washington, DC (February, 2003) 373 pp., p. 34.p. 48.

846. "Documentation of Environmental Indicator Determination," RCRA Corrective Action, Interim Final Guidance, U.S. EPA Office of Solid Waste (February, 1999).

847. "Documentation of Environmental Indicator Determination," RCRA Corrective Action, Interim Final Guidance, U.S. EPA Office of Solid Waste (February, 1999).

848. Turner-Fairbank Highway Research Center "Bridge Coating Technology" http://www.tfhrc.gov/hnr20/bridge/mainbc.htm.

849. Huffman, L.R.; Socci, A.M., "Lead Paint Leaves Its Mark on Bridge Repainting Work." *Journal of Protective Coatings and Linings,* Vol. 17, No. 1, (January, 2000) 5 p.

850. Federal Highway Administration Contact: Larry Jones, 703-235-0523.

851. Cambridge Systems, Inc., "Transportation Asset Management Guide." American Association of State Highway and Transportation Officials, Washington, DC (2002) http://downloads.transportation.org/amguide.pdf.

852. Bushell, C., "How to Preserve Concrete Bridges." *Better Roads,* Vol. 73, No. 5 (May, 2003) 4 p.

853. Vesikari, E. and Soderquist, M.K., "Life-Cycle Management of Concrete Infrastructures for Improved Sustainability." *Transportation Research E-Circular,* presented in 9th International Bridge Management Conference, Orlando, Florida (April, 2003) pp. 15-28. Read Document Online.

854. AASHTO Transportation Center of Excellence, “Comments Sought on National Bridge Inspection Standards.” *Regulatory Monitor*, Vol. 23, No. 43 (September 19, 2003) http://www.transportation.org/publications/HTMLRegs.nsf/ViewItems/2003-43?OpenDocument.

855 AASHTO, “BRASS: After Three Decades, Bigger and Better than Ever.” AASHTO Success Story (2003) http://www.transportation.org/aashto/success.nsf/allpages/2003-24Wyoming.

856. Federal Highway Administration “Managing Highway Assets: Bridge Preservation” Construction and Maintenance Fact Sheets *Report FHWA-IF-02-033* (March 2002), http://www.fhwa.dot.gov/construction/fs02033.htm.

857. Lauzon, R.G. and Dewolf, J.T., “Connecticut’s Bridge Monitoring Program: Making Important Connections Last.” *TRB E-Newsletter*, Vol. 224 (January-February, 2003) 2 pp., http://gulliver.trb.org/publications/trnews/rpo/rpo.trn224.pdf.

858. Webb, A., and Ridder, N.M., “New Mexico University Designs High-Tech Beams to Monitor Bridge Soundness.” *Miami Herald* (March 1, 2004) http://www.miami.com/mld/miamiherald/business/national/8087309.htm.

859. Fu, G., Feng, J., Dekelbab, W., Moses, F., Cohen, H. Mertz, D., and Thompson, P. “Effect of Truck Weight on Bridge Network Costs” *NCHRP Report 495*, Transportation Research Board, Washington D.C. (2003) http://gulliver.trb.org/publications/nchrp/nchrp_rpt_495.pdf.

860. Transportation Research Board “Truck Weight Limits: Issues and Options.” *Special Report 225* (1990), http://gulliver.trb.org/news/blurb_detail.asp?id=2700.

861. Transportation Research Board, “New Trucks for Greater Productivity and Less Road Wear - An Evaluation of the Turner Proposal”, *Special Report 22*, Transportation Research Board, Washington D.C. (1990) 234 pp.

862. Transportation Research Board “Motor Vehicle Size and Weight Regulations, Enforcement, and Permit Operations.” *NCHRP Synthesis of Highway Practice 68* (1980). http://trb.org/news/blurb_detail.asp?id=3488.

863. Dexter, R., and French, C., “Effects of Increasing Truck Weight on Steel and Prestressed Bridges” *Mn/DOT 2003-16*, www.lrrb.gen.mn.us/pdf/200316.pdf.

864. Associated Press, “Engineers Work on ‘Smart’ Bridges, Roads: ‘Smart’ Bridges, Roads Communicate With Engineers May Help Them Build Better Ones.” *The Associated Press* (December 16, 2003) http://abcnews.go.com/wire/US/ap20031216_683.html.

865. Associated Press, “Engineers Work on ‘Smart’ Bridges, Roads: ‘Smart’ Bridges, Roads Communicate With Engineers May Help Them Build Better Ones.” *The Associated Press* (December 16, 2003) http://abcnews.go.com/wire/US/ap20031216_683.html.

866 “Proper Drainage Reduces Roadway Problems.” *Nevada Milepost, Nevada’s Technology Transfer Quarterly,* Vol. 12, No. 1, (Spring 2002) p. 1.

867. Personal communication, Mark Bloschock, TxDOT Bridge Engineer, April 30, 2004.

868. Shahawy, M.A., “Prefabricated Bridge Elements and Systems to Limit Traffic Disruption during Construction.” *NCHRP Synthesis Report 324*, Transportation Research Board, Washington, DC (March 2004) http://trb.org/publications/nchrp/nchrp_syn_324.pdf.

869. Federal Highway Administration, “Prefab Bridges Save Money and Time,” Turner-Fairbank Research Center *Research and Technology Transporter* (April 2003) http://www.tfhrc.gov/trnsptr/apr03/index.htm#pre.

870. Federal Highway Administration, “Prefabricated Bridge Elements and Systems: Innovative Projects to Make Construction Less Disruptive for the Environment.” (2000) http://www.fhwa.dot.gov/bridge/prefab/environ.htm.

871. Federal Highway Administration, “Prefabricated Bridge Elements and Systems: Innovative Projects to Make Construction Less Disruptive for the Environment.” (2000) http://www.fhwa.dot.gov/bridge/prefab/environ.htm.

872. Federal Highway Administration, “Prefabricated Bridge Elements and Systems: Innovative Projects to Make Construction Less Disruptive for the Environment.” (2000) http://www.fhwa.dot.gov/bridge/prefab/environ.htm.

873. Federal Highway Administration, “Prefabricated Bridge Elements and Systems: Innovative Projects to Make Construction Less Disruptive for the Environment.” (2000) http://www.fhwa.dot.gov/bridge/prefab/environ.htm.

874. FHWA, “Performance Test for Geosynthetic-Reinforced Soil Including Effects of Preloading, FHWA-RD-01-018” and “Effects of Geosynthetic Reinforcement Spacing on the Behavior of Mechanically Stabilized Earth Walls, FHWA-RD-03-048

875. Personal communication, Don West, Environmental Planner and Wildlife Biologist, Virginia Department of Transportation, (April 30, 2004).

876. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

877. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

878. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

879. Keeley, B.W. “Bat Use of Bridges.” Bureau of Land Management, Coos Bay District, and the Oregon Department of Fish and Wildlife, Coos Bay, Oregon (1998).

880. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

881. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

882. AASHTO, “TxDOT Success” AASHTO Success Story, http://transportation.org/aashto/success.nsf/allpages/47-TXBats.

883. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

884. Personal communication, Mark Bloschock, TxDOT Bridge Engineer (April 30, 2004).

885. Keeley, B.W., and Tuttle, M., “Bats in American Bridges.” Texas Department of Transportation (1999) http://www.batcon.org/bridge/bababs.html.

886. Zeigler, D. FDOT Research in Progress, Contract/Grant Number: BD433, results due in late 2004. Contact: David Zeigler, Phone: (850) 922-7209, Email: david.ziegler@dot.state.fl.us.

887. Personal communication, Arthur Cleveland, Columbus State University Cleveland_Art@colstate.edu and Stanley Kim, Georgia DOT; stanley.kim@dot.state.ga.us. (May 21, 2004).

888. Kogler, R.A., and Chong, S-L., “Steel Bridge Coatings Research” Federal Highway Administration, (July/August 1997)·Vol. 61, No. 1 http://www.tfhrc.gov/pubrds/july97/brdgct.htm.

889. Kogler, R.A., and Chong, S-L., “Steel Bridge Coatings Research” Federal Highway Administration, (July/August 1997)·Vol. 61, No. 1 http://www.tfhrc.gov/pubrds/july97/brdgct.htm.

890. Bridge Coatings Technology Outreach Team, “Metallized Steel Bridge Coatings” (January, 1997) http://www.tfhrc.gov/hnr20/bridge/metal.htm.

891. “Bridge Coating Technology Team, “Metallizing, the Illinois Experience”, Turner-Fairbank Highway Research Center, http://www.tfhrc.gov/hnr20/bridge/ill.htm.

892. Bridge Coating Technology Team, “Overcoating (Maintenance Painting”, Turner-Fairbank Highway Research Center, (January, 1997) http://www.tfhrc.gov/hnr20/bridge/overct.htm.

893. Bridge Coating Technology Team, “Overcoating (Maintenance Painting”, Turner-Fairbank Highway Research Center, (January, 1997) http://www.tfhrc.gov/hnr20/bridge/overct.htm.

894. Idaho Department of Transportation Maintenance Manual, http://www.itd.idaho.gov/Highways/ops/maintenance/Manuals/CDBurn/Maintenance/full percent20manual.pdf.

895. Federal Highway Administration “Field Manual for Bridge Painting Inspection.” *FHWA-RD-98-084*, http://www.tfhrc.gov/hnr20/bridge/intro.htm.

896. Federal Highway Administration, “Led-based Paint Removal for Steel Highway Bridges.” *NCHRP Synthesis No. 251*, Transportation Research Board, Washington, DC (1997)

897. Federal Highway Administration, "Maintenance Issues and Alternate Corrosion Protection Methods for Exposed Bridge Steel." *NCHRP Synthesis No. 257*, Transportation Research Board, Washington, DC (1998)

898. "Corman Construction Tackles Lead-based Paint on the Woodrow Wilson Bridge." http://www.pentekusa.com/corman.html.

899. Personal communication, Jonathan Bass, Environmental Specialist, NYSDOT (June 28, 2004).

900. Federal Highway Administration "A Study Tour on Bridge Maintenance Coatings Environmental and Worker Protection Practices." *PL-96-031* (January 1997) http://www.iti.northwestern.edu/clear/bridge/fst/fst_ch4.html.

901. Federal Highway Administration "A Study Tour on Bridge Maintenance Coatings Environmental and Worker Protection Practices." *PL-96-031* (January 1997) http://www.iti.northwestern.edu/clear/bridge/fst/fst_ch4.html.

902. Some of the practices in this list are derived from the Turner-Fairbank Highway Research Program checklist for pre-painting and materials. http://www.tfhrc.gov/hnr20/bridge/materialsa.htm.

903. Federal Highway Administration, "Pre-Painting Conference." http://www.tfhrc.gov/hnr20/bridge/prepainting.htm.

904. King County, Washington Department of Transportation, "Green River Gorge Painting Project." http://www.metrokc.gov/kcdot/roads/projects/gorge/.

905. Nebraska Department of Roads "Construction Manual: Bridge Painting Section." http://www.nebraskatransportation.org/ref-man/conmanual/1100/1100.4-02.pdf.

906. Federal Highway Administration, "Issues Impacting Bridge Painting, Overview: Task C, Evaluation of Procedures for Analysis and Disposal of Lead-Based Paint-Removal Debris" *FHWA/RD/94/098* (1995) http://iti.acns.nwu.edu/pubs/fhfr/fhfr_ch4.html#chap4_conc, last updated, 1997.

907. McLean, B. "Environmental Performance Aspects of NYCT's Bridge Painting Program." A Presentation at the 2003 SSPC Annual Meeting Bridges Session on "Abrasive Blasting vs. Over-coating Projects."

908. Kowalski, G., Copenbarger, D., and Trimber, K. "Illinois DOT's Painting Program: A New Approach." *Journal of Protective Coatings and Linings,* Vol. 20, No. 1, (January, 2003) pp. 73-80.

909. Garrick, N.W., Nikolaidis, N.P., and Luo, J. "A Portable Method to Determine Chloride Concentration on Roadway Pavements." The New England Transportation Consortium (September 2002) 49 pp, http://docs.trb.org/00939363.pdf.

910. Kuemmek. D.E., "Managing Roadway Snow and Ice Control Operations." NCHRP Synthesis of Highway Practice 207, Transportation Research Board, National Research Council, Washington, DC (1994) p. 1.

911. Garrick, N.W., Nikolaidis, N.P., and Luo, J. "A Portable Method to Determine Chloride Concentration on Roadway Pavements." The New England Transportation Consortium (September 2002) http://docs.trb.org/00939363.pdf.

912. Brink, M. and Auen, M., "Go Light with the Salt, Please: Developing Information Systems for Winter Roadway Safety." *TR News,* No. 230 (January-February, 2004), pp. 4-9.

913. Mujssato, B.T. "Guidelines for the Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts." National Cooperative Highway Research Program – Active Project; Project 6-16, FY 2003 http://www4.trb.org/trb/crp.nsf/All+Projects/NCHRP+6-16.

914. Wegner, W. and Yaggi, M., "Environmental Impacts of Road Salt and the Alternatives in the New York City Watershed." *Journal for Surface Water Quality Professionals,* Vol. 5, No. 3 (May/June 2004) http://www.forester.net/sw_0107_environmental.html.

915. Canadian Environmental Protection Act (1999) http://www.ec.gc.ca/CEPARegistry/the_act/Download/CEPA_Full_e.htm.

916. Environment Canada. "Priority Substances Assessment Report: Road Salts." (2000) http://www.ec.gc.ca/CEPARegistry/subs_list/PSL2.cfm.

917. Brink, M. and Auen, M., "Go Light with the Salt, Please: Developing Information Systems for Winter Roadway Safety." *TR News,* No. 230 (January-February, 2004), pp. 4-9.

918. Salt Institute, "Highway Salt and Our Environment." Alexandria Virginia (2004) 28 pp. http://www.saltinstitute.org/saltandenvironment-english.pdf.

919. Burtwell, M. "Assessment of the Performance of Prewetted Salt for Snow Removal and Ice Control." *Transportation Research Record 1741*, Transportation Research Board, Washington, DC (2001).

920. Church, P.E. and Friesz, P.J., "Effectiveness of Highway Drainage Systems in Preventing Road-Salt Contamination of Groundwater: Preliminary Findings." *Transportation Research Record 1420*, Transportation Research Board, Washington, DC (1993) http://books.nap.edu/books/NI000009/html/3.html.

921. Hogbin, L. E., "Loss of Salt due to Rainfall on Stockpiles Used for Winter Road Maintenance." RRL Report 30, Road Research Laboratory, Crowthorne, United Kingdom (1966), *in* Burtwell, M. "Assessment of the Performance of Prewetted Salt for Snow Removal and Ice Control." *Transportation Research Record 1741*, Transportation Research Board, Washington, DC (2001).

922. Gustafsson, M. and Blomquist, G., "Modeling Exposure of Roadside Environment to Airborne Salt Case Study" *Transportation Research Circular E-C063: Snow Removal and Ice Control Technology,* Transportation Research Board (2004) p. 305. http://trb.org/publications/circulars/ec063.pdf.

923. Blomquist, G. "Patterns of Chloride Deposition Next to Roads as Influenced by Salting Occasions and Winds." Presented at 82nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2003. http://199.79.179.82/Sundev/Search.cfm.

924. Frederick, R., USEPA, "Winter Maintenance and the Environment," http://www.wsdot.wa.gov/partners/pns/pdf/Deicer2pres percent5B1 percent5D.ppt.

925. Resource Concepts, Inc. for Caltrans and Nevada DOT, "Roadside Erosion Control and Revegetation Needs Associated with the Use of Deicing Salt within the Lake Tahoe Basin," (September 1990).

926. Burtwell, M., "Assessment of the Performance of Prewetted Salt for Snow Removal and Ice Control." *Transportation Research Record 1741*, Transportation Research Board, Washington, DC (2001).

927. Fishcel, M "Evaluation of Selected Deicers Based on a Review of the Literature." *Report CDOT-DTD-R-2001-15*, Colorado Department of Transportation Research (October 2001) 169 pp., http://www.dot.state.co.us/publications/PDFFiles/deicers.pdf.

928. Environment Canada, "Priority Substances Assessment Report: Road Salts." (2000) http://www.ec.gc.ca/CEPARegistry/subs_list/PSL2.cfm.

929. Fishcel, M "Evaluation of Selected Deicers Based on a Review of the Literature." *Report CDOT-DTD-R-2001-15,* Colorado Department of Transportation Research (October 2001) 169 pp., http://www.dot.state.co.us/publications/PDFFiles/deicers.pdf.

930. Lewis, W.M., "Studies of Environmental Effects of Magnesium Chloride Deicer in Colorado." Colorado Department of Transportation, *Report CDOT-DTD-R-99-10*, Denver (November, 1999) http://www.dot.state.co.us/publications/PDFFiles/magchlorideenveffects.pdf.

931. California Department of Transportation, "Evaluation of Deicing Substitutes on Certain Routes During the 1989-90 Snow Season," (July 3, 1990) http://www.dot.ca.gov/hq/roadinfo/snwicecontrol.pdf.

932. Xi, Y., Xie, Z., "Corrosion Effects of Magnesium Chloride and Sodium Chloride on Automobile Components." Colorado Department of Transportation, *Report CDOT-DTD-R-2002-4* (May 2002) 76 pp., http://www.dot.state.co.us/publications/PDFFiles/MagAutoCor.pdf.

933. Lewis, W.M., "Studies of Environmental Effects of Magnesium Chloride Deicer in Colorado." Colorado Department of Transportation *Report CDOT-DTD-R-99-10*, Denver (November, 1999) http://www.dot.state.co.us/publications/PDFFiles/magchlorideenveffects.pdf.

934. Fishcel, M., "Evaluation of Selected Deicers Based on a Review of the Literature." *Colorado Report No. CDOT-DTD-R-2001-15*, Colorado Department of Transportation Research (October 2001) 169 pp., http://www.dot.state.co.us/publications/PDFFiles/deicers.pdf.

935. Horner, R. R.: Environmental Monitoring and Evaluation of Calcium Magnesium Acetate. *NCHRP Report 305,* Transportation Research Board, National Research Council, Washington, DC (1998).

936. Burkett, A. and Gerr, N. "Icy Road Management with Calcium Magnesium Acetate to Meet Environmental and Customer Expectations in New Zealand," Transportation Research Circular E-C063: Snow Removal and Ice Control Technology, TRB (2004) http://trb.org/publications/circulars/ec063.pdf.

937. Horner, R.R., and Brenner, M.V., "Environmental Evaluation of Calcium Magnesium Acetate for Highway Deicing Applications." *Resources, Conservation, and Recycling*, Vol. 7, (1992) pp. 213–237.

938. Fishcel, M., "Evaluation of Selected Deicers Based on a Review of the Literature." *Report CDOT-DTD-R-2001-15*, Colorado Department of Transportation Research (October 2001) 169 pp., http://www.dot.state.co.us/publications/PDFFiles/deicers.pdf.

939. California Department of Transportation, "Evaluation of Deicing Substitutes on Certain Routes During the 1989-90 Snow Season," *In* "Snow and Ice Control Operations." (March, 1999) http://www.dot.ca.gov/hq/roadinfo/snwicecontrol.pdf.

940. California Department of Transportation, "Evaluation of Deicing Substitutes on Certain Routes During the 1989-90 Snow Season," *In* "Snow and Ice Control Operations." (March, 1999) http://www.dot.ca.gov/hq/roadinfo/snwicecontrol.pdf.

941. Manning, D. and Crowder, L., "Comparative Field Study of the Operational Characteristics of Calcium Magnesium Acetate and Rock Salt." National Research Council, *Transportation Research Record 1246*, Transportation Research Board, National Research Council, Washington, DC (1989).

942. Lee, H., Cody, R.B., Cody, A.M., and Spry, P. G., "Effects of Various Deicing Chemicals on Pavement Concrete Deterioration." Mid-Continent Transportation Symposium Proceedings (2000) pp. 151-155, http://www.ctre.iastate.edu/pubs/midcon/Lee.pdf.

943. "Using Salt and Sand for Winter Road Maintenance." *U.S. Roads Road Management Journal,* (December 1997) http://www.usroads.com/journals/p/rmj/9712/rm971202.htm.

944. Frederick, R., USEPA, "Winter Maintenance and the Environment," http://www.wsdot.wa.gov/partners/pns/pdf/Deicer2pres percent5B1 percent5D.ppt.

945. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) http://www.odot.state.or.us/eshtm/images/4dman.pdf.

946. Salt Institute, "Salt and the Environment Report." (2004) http://www.saltinstitute.org/publications/saltandenvironment-english.pdf.

947. University of New Hampshire Technology Transfer Center, "Pros and Cons of Sand on Ice and Snowpack." Durham, N.H., (Fall 2001) http://www.t2.unh.edu/fall01/pg6-7.html.

948. New York State Department of Transportation Environmental Analysis Bureau, "NYSDOT Guidance – Road Salt Contamination: NYSDOT Procedures to Evaluate and Resolve Road Salt Contamination Complaints." (January, 2002).

949. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) http://www.odot.state.or.us/eshtm/images/4dman.pdf.

950. Shi, X., "Recommendations for Winter Traction Materials Management on Roadways Adjacent to Bodies of Water." Montana Department of Transportation, Helena, MT (2003).

951. California Department of Transportation, "Caltrans-District 3 and North Region: Tahoe Roadwork."http://www.dot.ca.gov/dist3/projects/tahoe/maint.htm.

952. California Department of Transportation, "Caltrans-District 3 and North Region: Tahoe Roadwork."http://www.dot.ca.gov/dist3/projects/tahoe/maint.htm.

953. Nixon, W.A., "The Use of Abrasives in Winter Maintenance." Iowa Department of Transportation and the Iowa Highway Research Board, IIHR Technical Report No. 416 (March, 2001) 28 pp., http://www.sicop.net/Abrasives percent20report.pdf.

954. California Department of Transportation, "The Use of Deicing Chemicals on California State Highways." Caltrans Report to the Legislature in response to Chapter 318. (July, 1992).

955. California Department of Transportation, "Caltrans Snow and Ice Control Operations." (March, 1999) 7 pp., www.dot.ca.gov/hq/roadinfo/snwicecontrol.pdf.

956. Venner and Kober, AASHTO Center for Environmental Excellence, Technical Memorandum for the Kentucky Transportation Cabinet, Winter Operations Benchmarking, November 2003.

957. Pennsylvania Department of Transportation, "PennDOT District 10 Strategic Environmental Management Program Manual," (2002).

958. Pennsylvania Department of Transportation Bureau of Maintenance and Operations, "Maintenance Manual", Pub 23 (7-01) (July 2001) 494 pp., p.4.2.1.

959. Ohio Department of Transportation, "2003 Strategic Initiative Eight: Continue to Improve Snow and Ice Control." http://www.dot.state.oh.us/strategicinitiatives/SI2003/03SI8.asp.

960. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Salt Management Plans." (September, 2003) http://www.tac-atc.ca/english/pdf/saltplan.PDF.

961. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Salt Management Plans." (September, 2003) http://www.tac-atc.ca/english/pdf/saltplan.PDF.

962. Transportation Association of Canada, "Pavements and Salt Management." (September, 2003) http://www.tac-atc.ca/english/pdf/pavement.PDF.

963. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p.18, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

964. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp. p. 3.6.19.

965. Wuori, A.F., "Ice-Pavement Bond Disbonding--Surface Modification and Disbonding." *SHRP Report H-644*, National Research Council, Washington, DC (1993) 213 pp. http://gulliver.trb.org/publications/shrp/SHRP-H-644.pdf.

966. Pell, K.M., "An Improved Displacement Snowplow." *SHRP Report H-673*, National Research Council, Washington, DC (1994) 85 pp.

967. Nixon, W.A., "Improved Cutting Edges for Ice Removal." *SHRP-H-346*, National Research Council, Washington, DC (1993) 98 pp.

968. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p.18, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

969. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Winter Maintenance Equipment and Technologies." (September, 2003) 18 pp. http://www.tac-atc.ca/english/pdf/winter.PDF.

970. Blackburn, R.R., McGrane, E.J., Chappelow, C.C., and Harwood, D.W., "Development of Anti-Icing Technology." Strategic Highway Research Program, *SHRP-H-385*, National Research Council, Washington, DC, (1994) http://www.trb.org/publications/shrp/SHRP-H-385.pdf.

971. Blackburn, R.R., McGrane, E.J., Chappelow, C.C., and Harwood, D.W., "Development of Anti-Icing Technology." Strategic Highway Research Program, *SHRP-H-385*, National Research Council, Washington, DC, (1994) http://www.trb.org/publications/shrp/SHRP-H-385.pdf.

972. Federal Highway Administration, “Snow and Ice Control: The New Generation: New Methods To Prevent Snow And Ice Accumulation Are Making Iowa’s Roads Safer For Motorists.” *Technical Brief*, Washington, DC, http://www.fhwa.dot.gov/winter/roadsvr/CS027.htm.

973. Federal Highway Administration “A Pre-emptive Strike on Ice.” http://www.fhwa.dot.gov/winter/roadsvr/CS010.htm.

974. Federal Highway Administration “Saving Money and the Environment: A New Approach to Winter Maintenance Keeps Oregon Roads Clear of Ice-and Sand.” http://www.fhwa.dot.gov/winter/roadsvr/CS092.htm.

975. Federal Highway Administration, “Anti-icing Techniques Key to Safer Roads in Missouri.” *Technical Brief,* http://www.fhwa.dot.gov/winter/roadsvr/CS028.htm.

976. Federal Highway Administration, “Focus: Reporting on Innovative Products and Strategies for Building Better, Safer Roads.” (October, 2000) http://www.tfhrc.gov/focus/oct00/shrpsuccess.htm.

977. Chang, N., “Cost of Sanding.” *Report CDOT-DTD-R-2002-5*, Colorado Department of Transportation Research (June 2002) 175 pp.

978. Goodwin, L.C., “Best Practices for Road Weather Management.” *FHWA-OP-03-081*, Washington, DC (May, 2003) 131pp. http://ops.fhwa.dot.gov/weather/best_practices/CaseStudiesFINALv2-RPT.pdf.

979. Federal Highway Administration, “Manual of Practice for an Effective Anti-icing Program: A Guide For Highway Winter Maintenance Personnel.” *FHWA-RD-95-202*, Washington, DC (June 1996) http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm#eap24.

980. Federal Highway Administration, “Manual of Practice for an Effective Anti-icing Program: A Guide For Highway Winter Maintenance Personnel.” *FHWA-RD-95-202*, Washington, DC (June 1996) http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm#eap24.

981. Nixon, W.A., “Guide to Selecting Anti-Icing Chemicals and Considering Environmental Impact.” (April, 2002) http://www.anti-ice-guide.com/.

982. Alger, R.G., Adams, E.E. and Beckwith, E.P., Anti-Icing Study: Controlled Chemical Treatments, *SHRP Report H-683*, National Research Council, Washington, DC (1994)145 pp.

983. Brink, M. and Auen, M., “Go Light with the Salt, Please: Developing Information Systems for Winter Roadway Safety.” *TR News,* No. 230 (January-February, 2004), pp. 4-9.

984. Eriksson, Dan, “Reducing Salt Consumption by Using Road Weather Information System and Mesan Data,” *Transportation Research Circular E-C063: Snow Removal and Ice Control Technology,* Transportation Research Board (2004) pp. 278-281, http://trb.org/publications/circulars/ec063.pdf.

985. Federal Highway Administration, “Iowa Gets a Jump on Storms with New Technology.” http://www.fhwa.dot.gov/winter/roadsvr/CS043.htm.

986. Transportation Association of Canada, “Syntheses of Best Practices - Road Salt Management: Winter Maintenance Equipment and Technologies.”(September 2003), http://www.tac-atc.ca/english/pdf/winter.PDF.

987. Federal Highway Administration, “Clearer Roads at Less Cost” http://www.fhwa.dot.gov/winter/roadsvr/CS036.htm.

988. Federal Highway Administration, “Real Time Data Slashes Winter Maintenance Costs.” http://www.fhwa.dot.gov/winter/roadsvr/CS087.htm.

989. Federal Highway Administration, “Winter Monitoring Stations Improve Maintenance Operations.” http://www.fhwa.dot.gov/winter/roadsvr/CS030.htm.

990. Federal Highway Administration, “Monitoring System Gives Highway Crews the Edge in Winter Maintenance.” http://www.fhwa.dot.gov/winter/roadsvr/CS029.htm.

991. Boselly, E. S.,. Thornes, E.J and Ulburg, C. "Road Weather Information Systems Volume 1: Research Report." Strategic Highway Research Program Publication - *SHRP-H-350*, National Research Council, Washington, DC (1993).

992. Boselly, E. S., and D.D. Ernst. Road Weather Information Systems Volume 2: Implementation Guide. Strategic Highway Research Program Publication - *SHRP-H-351*, National Research Council, Washington, DC, 1993.

993. Brink, M. and Auen, M., "Go Light with the Salt, Please: Developing Information Systems for Winter Roadway Safety." *TR News,* No. 230 (January-February, 2004), pp. 4-9.

994. Ketcham, S.A., Minsk, L.D., Blackburn, R.R., and Fleege, E.J., "Manual of Practice for an Effective Anti-Icing Program." *FHWA-RD-95-202*, Turner-Fairbank Highway Research Center, McLean, VA (June, 1996) http://www.fhwa.dot.gov/reports/mopeap/mop0296a.htm#eap24.

995. Al-Qadi, I.L., Loulizi, A., Flintsch, G.W., Roosevelt, D.S., Decker, R., Wambold, J.C. and Nixon, W.A., "Feasibility of Using Friction Indicators to Improve Winter Maintenance Operations and Mobility." Transportation Research Board, 83 Annual Meeting (January, 2004).

996. Garrick, N.W., Nikolaidis. N.P., and Luo, J., "A Portable Method to Determine Chloride Concentration on Roadway Pavements." New England Transportation Consortium (September, 2002) http://docs.trb.org/00939363.pdf.

997. National ITS Architecture: http://www.iteris.com/itsarch.

998. Pincus, M.L. "Feeling a Bit Under the Weather? Get Smart!" *Salt & Highway Deicing for the Winter Maintenance Professional,* Vol. 38, No. 4 (Winter, 2003).

999. Pincus, M.L. "Feeling a Bit Under the Weather? Get Smart!" *Salt & Highway Deicing for the Winter Maintenance Professional,* Vol. 38, No. 4 (Winter, 2003).

1000. Pisano, P.A. and Nelson, G.G. "Advanced Decision Support for Winter Road Maintenance: FHWA Documentation of Requirements for Intelligent Transportation Systems." Transportation Research Record 1741, *Paper No. S00-0018*, pp. 129-136, p. 129.

1001. Pisano, P.A. and Nelson, G.G. "Advanced Decision Support for Winter Road Maintenance: FHWA Documentation of Requirements for Intelligent Transportation Systems." Transportation Research Record 1741, *Paper No. S00-0018*, pp. 129-136, p. 130.

1002 Pisano, P.A. and Nelson, G.G. "Advanced Decision Support for Winter Road Maintenance: FHWA Documentation of Requirements for Intelligent Transportation Systems." Transportation Research Record 1741, *Paper No. S00-001,* pp. 129-136, p. 130.

1003. MDSS Project Description, http://www.rap.ucar.edu/projects/rdwx_mdss/mdss_description.html.

1004. Kroeger, D. and Sinhaa, R. "Business Case for Winter Maintenance Technology Applications Highway Maintenance Concept Vehicle," *Snow Removal and Ice Control Technology*, *Transportation Research Circular E-C063,* p. 323.

1005. Kroeger, D. and Sinhaa, R. "Business Case for Winter Maintenance Technology Applications Highway Maintenance Concept Vehicle," *Transportation Research Circular E-C063: Snow Removal and Ice Control Technology*, p. 331.

1006. Perchanok, M.S., McGillivray, D., and Smith, D. "Snow Removal and Ice Control Technology." *Transportation Research Record 1387*, Transportation Research Board, National Research Council, Washington, DC (1993).

1007. Transportation Association of Canada, "Syntheses of Best Practices - Road Salt Management: Winter Maintenance Equipment and Technologies."(September 2003), http://www.tac-atc.ca/english/pdf/winter.PDF.

1008. Perchanok, M.S., “Evaluation of Methods for High-Speed Application of Road Salt.” Transportation Research Record 1741, *Paper No. S00-0039*, pp. 193-198.

1009. Federal Highway Administration, “Activities by Topic: Equipment.” http://www.fhwa.dot.gov/winter/exchange/topics/equipment.html.

1010. Federal Highway Administration, “Activities by Topic: Equipment.” http://www.fhwa.dot.gov/winter/exchange/topics/equipment.html.

1011. University of New Hampshire Technology Transfer Center, “Pros and Cons of Sand on Ice and Snowpack” (Fall 2001) http://www.t2.unh.edu/fall01/pg6-7.html.

1012. Ljungberg, M. “Expert System for Winter Road Maintenance.” Proceedings of the Ninth Maintenance Management Conference, Center for Transportation Research and Swedish Road and Transport Research Institute (1998) pp. 167-175.

1013. Transportation Association of Canada, “Syntheses of Best Practices - Road Salt Management: Winter Maintenance Equipment and Technologies.”(September 2003), http://www.tac-atc.ca/english/pdf/winter.PDF.

1014. Fonnesbech, J.K., “Ice Control Technology with 20 Percent Brine on Highways.” *Transportation Research Record 1741*, Transportation Research Board, National Research Council, Washington, DC (2001).

1015. AASHTO, “Success Stories - PENNDOT’s Smart Bridges: Winter Finally Meets its Technological Match.” http://www.transportation.org/aashto/success.nsf/allpages/29-PASmartBridges.

1016. Ward, B., “Evaluation of a Fixed Anti-Icing Spray Technology (FAST) System,” New York City DOT, Division of Bridges, presented at the Transportation Research Board (TRB) Annual Meeting, January 2002.

1017. Khattak, A.J., Pesti, G., Kannan, V., “Guidelines for Prioritizing Bridge Deck Anti-Icing System Installations. Phase I and Phase II Report.” Final Report SPR-P1-03-P555, University of Nebraska, Lincoln, NE (March, 2003).

1018. Vonderohe, A.P., “GIS Tool to Measure Performance of Winter Highway Operations.” University of Wisconsin, (September, 2003) http://www.mrutc.org/research/0401/.

1019. Adams, T. M., J. Maloney, A. Vonderohe, and T. Martinelli. Management Decision Tools for Winter Operations. In *Transportation Research Circular E-C052*, TRB, National Research Council, Washington, DC, July 2003, pp. 52–68.

1020. Vonderhoe, A.P., T. Adams, C. Blazquez, J. Maloney, and T. Martinelli, “GIS-Based Analysis of Intelligent Winter Maintenance Vehicle Data,” Transportation Research Circular E-C063: Snow Remove and Ice Control Technology, (June, 2004) p. 347-360.

1021. Welsh, G., “Toronto Salt Management Plan Balances Safety/Environment.” *Salt and Highway Deicing,* Vol. 4, No. 2, (Fall, 2002) http://www.saltinstitute.org/images/shd2-02.pdf.

1022. http://www.gggc.state.pa.us/text/publictn/01GreenPlan/dot.html Scroll down to Winter Roads Maintenance.

1023. John E. Thornes, School of Geography and Environmental Sciences, University of Birmingham, United Kingdom. Contact at J.E.Thornes@bham.ac.uk.

1024. Boselly, E.S. “Performance-Based Assessment of Winter Maintenance Using Level of Service (LOS).” Fifth International Symposium on Snow Removal and Ice Control Technology, National Association of Sciences, Roanoke, Virginia (2000).

1025. Decker, R., Bignell, J.L., Lambertsen, C.M., and Porter, K. “Measuring Efficiency of Winter Maintenance Practices.” Transportation Research Record 1741, *Paper No. S00-0048*, pp. 167-175.

1026. Baroga, E.V., “Performance Measures for Snow- and Ice-Control Activities.” Proceedings of the Ninth Maintenance Management Conference, Juneau, Alaska, (July 16-20, 2000) pp.75-80.

1027. Anderson, E. and Nyman, J., “Southeast Michigan Snow and Ice Management (SEMSIM): Final Evaluation at End of Winter Season Year 2000,” prepared for the Road Commission of FHWA, “Oakland County Michigan – Southeast Michigan Snow and Ice Management (SEMSIM),” ITS Projects Book, (January 2002) http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/13631/ttm-225.html "SEMSIM Web Site," RCOC http://www.rcocweb.org/home/semsim.asp.

1028. Broadbent, T., "Don't Overdo It." *Roads & Bridges* (December, 1999).

1029. Broadbent, T., "Don't Overdo It." *Roads & Bridges* (December, 1999).

1030. Broadbent, T., "Don't Overdo It." *Roads & Bridges* (December, 1999).

1031. Transportation Association of Canada, "Syntheses of Best Practices - Road Salt Management: Winter Maintenance Equipment and Technologies."(September 2003), http://www.tac-atc.ca/english/pdf/winter.PDF.

1032. Transportation Association of Canada, "Syntheses of Best Practices - Road Salt Management: Training" (September 2003) pp. 3-7, http://www.tac-atc.ca/english/pdf/training.PDF.

1033. Harper-Lore, B.L. "Vegetation Management: Trends and Training in Transportation," *in* Williams, J.R., Goodrich-Mahoney, J., Wisniewski, J.R., and Wisniewski, J.(Editors), The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management (1997).

1034. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP-03005*, Federal Highway Administration, Washington, DC (1999) 32 pp.

1035. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP-03005*, Federal Highway Administration, Washington, DC (1999) 32 pp.

1036. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 800-6.

1037. Arner, D. and Jones, J. "Versatile Plant for Multiple Use on Rights-of-Way," Environmental Concerns in Rights-of-Way Management: Seventh International Symposium." *In* Goodrich-Mahoney, J.W., Mutrie, D.F., and Guild, C.A., (Eds.) Elsevier Science Ltd, (2002) p. 57.

1038. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 500-8.

1039. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 34.

1040. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 60.

1041. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 35.

1042. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP*-03005, Federal Highway Administration, Washington, DC (1999) 32 pp.

1043. McLoughlin, K.T., "Application of Integrated Pest Management to Electric Utility Rights-of-Way Vegetation Management in New York State." *In* William, J.R., Goodrich-Mahoney, J. W., Wisniewski, J. R., and Wisniewski, J. (Eds.) New Orleans, Louisiana. Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier Science Ltd., New York (1997) p. 118-126.

1044. McLoughlin, K.T. "Integrated Vegetation Management: The Exploration of a Concept to Application." *In* Goodrich-Mahoney, J. W. Mutrie, D.F. Guild, C.A., (Eds.) Calgary, Alberta, Canada, Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier Science Ltd., New York (2002) p. 29-45.

1045. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management", Minnesota Technology Transfer (T2) LTAP Program, 2000, 132 pp., p. 78.

1046. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 35.

1047. Morrow, S.D., "Effective Integrated Vegetation Management," *In* Williams, J.R., Goodrich-Mahoney, J.W, Wisniewski, J.R., and Wisniewski, J. (Eds.), The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management, (1997).

1048. Nowak, C.A. and Ballard, B.D., "A Framework for Applying Integrated Vegetation Management on Rights-Of-Way." Final Report, Electric Power Research Institute (March, 2004) 18 p.

1049. Nowak, C.A. and Ballard, B.D., “Transferring Knowledge of Shrub Ecology and Management to Promote Integrated Vegetation Management on Powerline Corridors.” Final Report, Electric Power Research Institute (March, 2004), Executive Summary, p. v.

1050. Nowak, C.A. and Ballard, B.D., “A Framework for Applying Integrated Vegetation Management on Rights-Of-Way.” Final Report, Electric Power Research Institute (March, 2004) 18 p.

1051. Nowak, C.A. and Ballard, B.D., “A Framework for Applying Integrated Vegetation Management on Rights-Of-Way.” Final Report, Electric Power Research Institute (March, 2004) 18 p.

1052. McLoughlin, K.T., “Application of Integrated Pest Management to Electric Utility Rights-of-Way Vegetation Management in New York State.” *In* William, J.R., Goodrich-Mahoney, J. W., Wisniewski, J. R., and Wisniewski, J. (Eds.) New Orleans, Louisiana. Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier Science Ltd., New York (1997) p. 118-126.

1053. McLoughlin, K.T. “Integrated Vegetation Management: The Exploration of a Concept to Application.” *In* Goodrich-Mahoney, J. W. Mutrie, D.F. Guild, C.A. (eds.) Calgary, Alberta, Canada, Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier Science Ltd., New York (2002) p. 29-45.

1054. Nowak, C.A. and Abrahamson, L.P., “Vegetation Management on Electric Transmission Line Rights-Of-Way in New York State: The Stability Approach to Reducing Herbicide Use.” *In* D. H. Gjerstad (Ed.) Proceedings of the International Conference on Forest Vegetation Management: Ecology, Practice and Policy Auburn University School of Forestry ReportVol.1. (1993) p. 183-191.

1055. Finch, K.E., and Shupe, S.D., “Nearly Two Decades of Integrated Vegetation Management on Electric Transmission Rights-Of-Way. *In* William, J. R. Goodrich-Mahoney, J. W. Wisniewski, J. R. and Wisniewski, J. (Eds.) Proceedings of the 6th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier Science Ltd., New York. (1997) p. 65-75.

1056. Nowak, C.A., Abrahamson, E.F., Neuhauser, L.P., Foreback, C.G., Freed, H.D., Shaheen, S.B and Stevens, C.H. “Cost-Effective Vegetation Management on a Recently Cleared Electric Transmission Line Right-Of-Way.” *Weed Technology*, Vol. 6 (1992) pp. 828-837.

1057. Abrahamson, L.P., Nowak, C.A., Charlton, P.M., Snyder, P.G., “Cost Effectiveness of Herbicide and Non-Herbicide Vegetation Management Methods for Electric Utility Rights-Of-Way in the Northeast: State-of-the Art Review.” *In* Doucet, G.J., Séguin, C. and Giguère, M. (Eds.) Proceedings of the 5th International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, Quebec (1995) p. 27-43.

1058. Johnstone, R.A. “Vegetation Management: Mowing to Spraying.” *Journal of Arboriculture*, Vol. 16, No.7 (1990) pp. 186-189.

1059. Nowak, C.A., Abrahamson, L.P., Raynal, D.J., and Leopold, D.J. “Selective Vegetation Management on Powerline Corridors in New York State: Tree Density and Species Composition Changes from 1975 to 1991.” *In* Doucet, G.J., Séguin, C. and Giguère, M. (Eds.) Proceedings of the 5th International Symposium on Environmental Concerns in Rights-of-Way Management, Montreal, Quebec (1995) p. 153-158.

1060. Alkiewicz, E., Wingfield, J. Frazier, D. and Khitrik, L., “Using GIS Tools to Conduct Environmental and Asset Analyses Along Rights-of-Way.” *In* Goodrich-Mahoney, J.W., Mutrie, D.F., Guild, C.A. (Eds.) Calgary, Alberta, Canada, Proceedings of the 7th International Symposium on Environmental Concerns in Rights-of-Way Management, Elsevier Science Ltd., New York (2002) p. 29-45.

1061. Florence, R.G., “The Silvicultural Decision.” Forest Ecology and Management Vol.1 (1977) pp. 293-306.

1062. Province of British Columbia. Silviculture Prescription Guidebook. British Columbia Ministry of Forests, Victoria, B.C., Canada (2000).

1063. Baskerville, G., “Adaptive Management: Wood Availability and Habitat Availability.” *Forestry Chronicles* Vol. 61 (1985) pp. 171-175.

1064. Nowak, C.A. and Ballard, B.D., “A Framework for Applying Integrated Vegetation Management on Rights-Of-Way.” Final Report, Electric Power Research Institute (March, 2004) 18 pp.

1065. Iowa Department Of Transportation “Integrated Roadside Vegetation Management Plan.” (February, 1990).

1066. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management", Minnesota Technology Transfer (T^2) LTAP Program, 2000, 132 pp., p. 3.

1067. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management", Minnesota Technology Transfer (T^2) LTAP Program, 2000, 132 pp., p. 4.

1068. Personal communication, Laura Greninger, NYSDOT, June 1, 2004.

1069. Christopher Nowak and Benjamin Ballard, State University of New York, First Interim Report for the project "Assessing New York State DOT's Alternatives to Herbicides, Integrated Vegetation Management, and Related Research Programs" (RF Project No. 1036966; Award No. 31103), for the period November 1, 2003 to April 30th, 2004.

1070. Personal communication, Janice Osadczuk and David Isley, Indiana DOT (April 28, 2004).

1071. Venner, 2002 survey.

1072 NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp.

1073 . Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP-03005*, Federal Highway Administration, Washington, DC, (1999) 32 pp.

1074. Personal communication, Lee Grunau, Colorado Natural Heritage Program, "On-Site Best Management Practices for Rare Plant Species." and "CDOT Shortgrass Prairie Initiative."

1075. Washington State Department of Transportation, 4(d) Maintenance Manual, http://www.wsdot.wa.gov/fossc/maint/4d_rule/PDFs/WSDOT_4d_Manual_new.pdf

1076. Poole, J.M. and Janssen, G.K., "Managing and Monitoring Rare and Endangered Plants on Highway Rights-of-Way in Texas." Forest Service General Technical Report *RM-GTR-283*. pp. 8-12.

1077. Green, K., "Don't Scare the Fish," *Roads & Bridges*, Vol. 39, No. 6, (May 2001)

1078. Transportation Association of Canada, "Syntheses of Best Practices Road Salt Management: Drainage and Stormwater Management." (September, 2003) 9 pp. pp.6-1, 2, http://www.tac-atc.ca/english/pdf/vegetation.PDF.

1079. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 50-52.

1080. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 48.

1081. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP-03005*, Federal Highway Administration, Washington, DC (1999) 32 pp.

1082. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 43.

1083. North Carolina Department of Transportation: Research and Analysis "Application Placement Technologies for Vegetation Management on North Carolina Roadsides." http://www.ncdot.org/planning/development/research/2003-08.html. Contact: Kadibhai, Mustansir A Phone: (919) 715-2467, Email: mkadibhai@dot.state.nc.us.

1084. Wade, A., "Green Landscaping with Native Plants." United States Environmental Protection Agency, http://www.epa.gov/glnpo/greenacres/wildones/handbk/wo21.html.

1085. North Carolina Department of Transportation, "Maintenance Programs, Vegetation Management Section, Wildlife Habitat Areas." http://www.doh.dot.state.nc.us/operations/dp_chief_eng/roadside/vegetation/maintenance/wildlifehabitat.html.

1086. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., page 3.1.9.

1087. NYSDOT presentation at International Conference on Ecology and Transportation, Lake Placid NY (August 2003).

1088. Williams, K. "NYSDOT Draft Conservation Alternative Mowing Plan Guidelines." (May, 2003).

1089. Bedard, Y., Trottier, D., Bélanger, L., Bourassa. J.P., Champayne, N., Gérin-Lajoie, J., Lacroix, G., and Lévesque, E., "Managing the Green Heritage of Highways Rights-of-Way in Southern Quebec: A New Ecological Landscape Approach." *In* Proceedings of the7th International Symposium on Environmental Concerns in Rights-of-Way Management, Calgary, Alberta CANADA (September 9-13, 2000).

1090. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p. 14, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

1091. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 39.

1092. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 39.

1093. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 39.

1094. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management", Minnesota Technology Transfer (T2) LTAP Program, 2000, 132 pp., p. 26.

1095. Wade, A., "Green Landscaping with Native Plants." United States Environmental Protection Agency, http://www.epa.gov/glnpo/greenacres/wildones/handbk/wo21.html.

1096. Pauly, W. R., "How to Manage Small Prairie Fires." Dane County Park Commission, Madison, WI. (1988).

1097. Pauly, W.R., ""Implementing Prescribed Burns: Burn Management as a RoadsideTool." Federal Highway Administration, http://www.fhwa.dot.gov/environment/rdsduse/rd_use14.htm.

1098. Tix, D., Hebberger, A., Vaughan, E., Charvat, I., "The Effects of Fire versus Mowing on Prairie Plant Communities." Final Report MN/RC – 2003-20, Minnesota Transportation Department and the University of Minnesota, (July, 2003) 62 pp. http://www.lrrb.gen.mn.us/pdf/200320.pdf.

1099. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, Federal Highway Administration Publication FWHA –EP-03005 (1999) 32 pp.

1100. Venner, M. and Kober, W., AASHTO Center for Environmental Excellence, Kentucky Transportation Cabinet Division of Operations Routine Highway Operations Environmental Performance Assessment and Implementation Plan, Draft Technical Memorandum #7: Benchmarking Teleconference with the Minnesota, Pennsylvania, Virginia, and Washington State DOTs on Integrated Roadside Vegetation Management and Erosion Control and Drainage Channel Maintenance Practices. (November 7, 2003) 19 pp.

1101. Collins, B.R., and Anderson, K.H. "Plant Communities of New Jersey: A Study in Landscape Diversity" (1994).

1102. Johnson, A., "Best Practices Handbook on Roadside Vegetation Management", Minnesota Technology Transfer (T2) LTAP Program, 2000, 132 pp, p. 33.

1103. Office of Solid Waste and Emergency Response, "Municipal Solid Waste in the United States: 2001 Facts and Figures: Executive Summary" *EPA530-S-03-011* (October 2003) 20 pp. http://www.epa.gov/epaoswer/non-hw/muncpl/pubs/msw-sum01.pdf.

1104. Koob, T.L., Barber, M.E., "WSDOT BMPs for Stormwater Runoff in Confined Spaces", Washington State Transportation Center, *WA-RD 451.1, Final Report*. Pullman, WA (September, 1999) 115 pp. http://www.wsdot.wa.gov/.

1105. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP*-03005,Federal Highway Administration, Washington, DC (1999) 32 pp.

1106. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP*-03005,Federal Highway Administration, Washington, DC (1999) 32 pp.

1107. Federal Highway Administration Guidance on Invasive Species (August 10, 1999) http://www.fhwa.dot.gov/environment/inv_guid.htm.

1108. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 35.

1109. USDOT Volpe Research Center and FHWA (April 2004) "Successes in Streamlining" Newsletter.

1110. Masteller, M., "Roadside Vegetation Maintenance on Iowa's State and County Roadsides: A Cost Analysis begun in 1995." Iowa Department of Transportation.

1111. Illinois Department of Transportation, "First Lady's Wildflower Program" http://dot.state.il.us/wildflower/default1.html.

1112. Texas Transportation Institute Environmental Management Program "A Context-sensitive Design Approach to Natural Landscape Design in the Highway Right-of-Way: A Demonstration Project." http://tti.tamu.edu/enviro_mgmt/projects/mopac.

1113. TxDOT 2003 AASHTO Environmental Excellence Award Application, http://environment.transportation.org/center_products_programs/stewardship/TX_Green_Ribbon_Project.htm.

1114. California Department of Transportation, "Intelligent Herbicide Application System (IHAS II) for Reduced Herbicide Vegetation Control Phase II - Commercialization and Injection Research Study, started in 2002.

1115. Personal communication, David Albright, Phone: (505) 246-6421
Email: david.albright@nmshtd.state.nm.us.

1116. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 50-52.

1117. Commonwealth of Pennsylvania, Department of Transportation, "Roadside Vegetation Management Research Report", Seventh Year Report, *Report # PA-4620+85*-08, Penn State University (1992).

1118. "Weedseeker" Automatic Spot Spray System, website at, www.ntechindustries.com.

1119. Henderson, K., "Roadside Use of Native Plants: Integrating all the Management Tools (IRVM).". Federal Highway Administration, http://www.fhwa.dot.gov/environment/rdsduse/rd_use13.htm.

1120. Minnesota Department of Transportation, "Use of Herbicides: Practices and Responsibilities." Mn/DOT Policy Guideline (February, 2003).

1121. Caltrans Stormwater Compliance Review Task Force "Vegetation Management BMPs." California Department of Transportation Construction Stormwater Pollution Prevention Bulletin, Vol. 3, No. 2 (February 2000) 1 p. http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m2_00.pdf.

1122. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 3.1.9.

1123. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p.15.

1124. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 3.1.9.

1125. Caltrans Stormwater Compliance Review Task Force "Vegetation Management BMPs." California Department of Transportation Construction Stormwater Pollution Prevention Bulletin, Vol. 3, No. 2 (February 2000) 1 p. http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m2_00.pdf.

1126. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p.15, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

1127. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p.15, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

1128. Johnson, A.M., "Best Practices Handbook on Roadside Vegetation Management." Minnesota Department of Transportation, *Report # 2000-19*,University of Minnesota (September, 2000) 132 pp. p. 43.

1129. McClay, A., Bourchier, R.S. Butts, R. and Peschken, D. "Cirsium arvense. Canada Thistle." *In* P. Mason and J. Huber (Eds). Biological Control Programmes against Insect and Weeds in Canada 1981-2000. (2002) Commonwealth Agricultural Bureaux, Slough, UK.

1130. McClay, A.S., "Canada Thistle." *In*: Van Driesche, R., et al., , Biological Control of Invasive Plants in the Eastern United States, USDA Forest Service, *FHTET-2002-04*, (2002) 413 pp. http://www.invasive.org/eastern/biocontrol/17CanadaThistle.html.

1131. NCHRP Project 20-5, Topic 33-04, "Integrated Roadside Vegetation Management." Transportation Research Board, Washington, DC (November, 2003) 104 pp., p. 43.

1132. California Department of Transportation, "Enhanced Biological Control of Yellow Starthistle and Tumbleweed (Russian Thistle)." Transportation Research Board, Research in Progress http://rip.trb.org/browse/dproject.asp?n=7670.

1133. Personal communication, Luke Skinner, Minnesota DNR Coordinator, Purple Loosestrife Program

1134. Johnson, A.M., "Best Practices Handbook on Roadside Vegetation Management." Minnesota Department of Transportation, *Report # 2000-19*, University of Minnesota (September, 2000) 132 pp., p. 78.

1135. Federal Highway Administration, "What Departments of Transportation (DOTS) are Doing about Weeds," Greener Roadsides (Fall 2001) http://www.fhwa.dot.gov/environment/greenerroadsides/fal01p9.htm.

1136. Federal Highway Administration, "What Departments of Transportation (DOTS) are Doing about Weeds," Greener Roadsides (Fall 2001) http://www.fhwa.dot.gov/environment/greenerroadsides/fal01p9.htm.

1137. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP-03005*, Federal Highway Administration, Washington, DC (1999) 32 pp.

1138. Falge, J., Frantz, E., Ambuske, R., "NYS Department of Transportation Response to E.O. 13112 Invasive Plant Species." In 2003 Proceedings of the International Conference of Ecology and Transportation, (Eds.)by Irwin, C.L., Garrett, P., and McDermott. K.P., Raleigh NC Center for Transportation and the Environment, North Carolina State University. Lake Placid, NY (August, 2003).

1139. Federal Highway Administration, "What Departments of Transportation are Doing about Weeds," Greener Roadsides, Fall 2001, http://www.fhwa.dot.gov/environment/greenerroadsides/fal01p9.htm.

1140. Callicot, J.B. and Lore, G.K., "The Nature of Roadsides and the Tools to Work with It." Office of Natural and Human Environment, *FWHA –EP-03005*, Federal Highway Administration, Washington, DC (1999) 32 pp.

1141. Harper-Lore, B.L. "Vegetation Management: Trends and Training in Transportation," *in* Williams, J.R., Goodrich-Mahoney, J., Wisniewski, J.R., and Wisniewski, J.(Editors), The Sixth International Symposium on Environmental Concerns in Rights-of-Way Management (1997).

1142. Nowak, C.A. and Ballard, B.D., "Transferring Knowledge of Shrub Ecology and Management to Promote Integrated Vegetation Management on Powerline Corridors." Final Report, Electric Power Research Institute (March, 2004) http://www.epa.gov/oppbppd1/PESP/regional_grants/2002/r2-2002.htm.

1143. Personal communication, Leroy Irwin, FDOT Environmental Manager, April 2003.

1144. Michael Barber, Shari Schaftlein, Dale Anderson, WSDOT, Stormwater Runoff Cost/Benefit Project Prioritizing Stormwater Outfalls, WA-RD 418.1, (1997) , 99 pp., NTIS publication number PB98-108962.

1145. Turner, J., "PennDOT: Wet'n'Wild," American Federation of State, County and Municipal Employees (January/February 2004) http://www.afscme.org/publications/public_employee/2004/pejf0415.htm.

1146. Bat Conservation International, Inc, "The Bat House Builder's Handbook." (1993,2001).

1147. Williams, K., "Environmental Stewardship in NYSDOT Highway Maintenance," 2003 Proceedings of the International Conference of Ecology and Transportation, Irwin, C.L., Garrett, P., and McDermott, K.P., (Eds.) Raleigh NC Center for Transportation and the Environment, North Carolina State University.

1148. Delaware Department of Transportation, Livable Delaware Highway Maintenance Policy Changes, www.deldot.net/static/pubs_forms/ manuals/livable_delaware/maintenance_policy.pdf

1149. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 2.1.2.

1150. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 420-13.

1151. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 420-13.

1152. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp.

1153. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual" CTSW-RT-02009 (May, 2003) 290 pp., p. 2.10.97.

1154. Evink, Gary. , "Interaction between Roadways and Wildlife Ecology: a Synthesis of Highway Practice." *NCHRP Synthesis 3055*, Transportation Research Board, Washington, DC (2002) http://gulliver.trb.org/publications/nchrp/nchrp_syn_305.pdf

1155. Personal communication, Raja Veermachaneni, Maryland Highway Administration, February 2004.

1156. National Transportation Enhancements Clearinghouse, "Environmental Mitigation Transportation Enhancement Case Studies." http://www.enhancements.org/projectlibrary.htm.

1157. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

1158. California Stormwater Quality Association, "California Municipal BMP Handbook: Road and Street Maintenance SC-70." (January, 2003). www.cabmphandbooks.com.

1159. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p.2.13.110.

1160. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

1161. California Stormwater Municipal BMP Handbook (January 2003) Book 2 of 9 www.cabmphandbooks.com.

1162. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

1163. Personal communication, Skip Outcalt, CDOT Research Branch (February 25, 2004) and Colorado DOT Research Bulletin, CDOT Research Branch (January 2004).

1164. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p. 17, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

1165. Kramer, E.J., "Light the roadway... Not the Neighborhood: Light Trespass, Light Pollution., and the Roadway Lighting in Your Neighborhood." http://www.metrolux.com/roadway.htm.

1166 Prey, SC, "Caltrans Flexes Its Power, *California Department of Transportation Journal*, Vol. 2. Issue 3, (November 2001), 3 pp.

1167. California Department of Transportation Division of Environmental Analysis, "Statewide Stormwater Quality Practice Guidelines, Manual CTSW-RT-02009 (May, 2003) 290 pp., p. 2.29.153.

1168. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999) p. 6, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

1169. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

1170. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., p. 3.1.9.

1171. Cammermayer, J.W., Horner, R.R., Chechowitz, "Vegetated Stormwater Facility Maintenance." *Report No. WA-RD 495.1*, Washington State Transportation Center (TRAC) (December, 2000).

1172. NYSDOT Transportation Maintenance Division, Roadside and Traffic Quality Assurance Condition Assessment http://mrutc.org/outreach/mqa/doclib/docs/NY/RoadsideandTrafficScoringSheet-roadtraf.pdf.

1173. NYSDOT Transportation Maintenance Division, Roadside and Traffic Quality Assurance Condition Assessment. http://mrutc.org/outreach/mqa/doclib/docs/NY/RoadsideandTrafficScoringSheet-roadtraf.pdf.

1174. California Department of Transportation, "Statewide Stormwater Management Plan: CTSW-RT-02-008." State of California Transportation Publication, Sacramento, CA (May, 2003) 291 pp.

1175. National Marine Fisheries Service, Southwest Region, "California Guidelines for Salmonid Passage at Stream Crossings." (September, 2001) p. 9.

1176. University of Alabama Department of Civil and Environmental Engineering, www.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml.

1177. Center for Transportation Research, "Compost and Shredded Brush on ROWs." www.utexas.edu/research/ctr/recycle/compost.html.

1178. Middleton, L. and King, M. "A Natural Choice: Using Compost for Environmentally Sound Roadside Slopes is One Time When Waste Pays Off." *Public Roads*, Vol. 66 , No. 5 (March/April 2003) http://www.tfhrc.gov/pubrds/03mar/01.htm

1179. New York State Department of Transportation, Unpublished paper sent to author 02/09/04.

1180. State of Massachusetts Recycling Reports, http://www.state.ma.us/mhd/recycle/docsframe.htm.

1181. State of Massachusetts Recycling Reports, http://www.state.ma.us/mhd/recycle/docsframe.htm.

1182. AASHTO Environmental Stewardship Demonstration Program, "Building Relationships," http://itre.ncsu.edu/AASHTO/stewardship/buildingrelationships.asp.

1183. New Jersey Ozone Action Partnership, http://www.ridewise.org/ozone/kit01exa.htm.

1184. "Analysis of Potential Area Source RACM Measures for the Metropolitan Washington Region's Severe Area SIP," May 2003, http://www.mde.state.md.us/assets/document/appendixM.pdf.

1185. Klausmeier, R., "Literature and Best Practices Scan: Vehicle Inspection and Maintenance (I/M) Programs," Wisconsin DOT and FHWA (June 2002) 98 pp.

1186. Federal Highway Administration 2001 Environmental Excellence Award: Air Quality Improvements, "Compressed Natural Gas Refueling Station." http://www.fhwa.dot.gov/environment/eea2001/eea01_6.htm.

1187. "Ozone Action Plans Submitted," *Georgia State Personnel News*, Vol. 22, No. 2 (April 1998) pp. 1-2.

1188. Williams, Allen L., Gary J. Stensland, Cathy R. Peters, and Jim Osborne. "Atmospheric Dispersion Study of Deicing Salt Applied to Roads: First Progress Report." *ISWS CR 2000-05* (2000).

1189. Personal communication, Allen Williams, University of Illinois, Urbana-Champaign, project principal investigator for Illinois DOT research study: Atmospheric Dispersion Study of Deicing Salt Applied to Roads (April 14, 2004).

1190. Caltrans Stormwater Compliance Review Task Force, "Painting Operation Stormwater BMPs." *Caltrans Maintenance Stormwater Pollution Prevention Bulletin*, Vol. 3, No. 1 (January, 2000) http://www.dot.ca.gov/hq/env/stormwater/_pdfs/maintain/m1_00.pdf.

1191. Collins, J.T., Moore, J.T., "Roadwaste Management: A Tool for Developing District." Federal Highway Administration, *FHWA-OR-RD-01-07, Phase 3 Final Report* (October, 2000) http://www.odot.state.or.us/tddresearch/reports/pdf/rdwst_tool.pdf.

1192. Collins, J., "Roadwaste: Issues And Options.". *FHWA-OR-RD-99-05*. Federal Highway Administration, Washington, DC (1998) 284 pp.

1193. Ghezzi, M., Collins, J., Moore, J., Bretsch, K., and Hunt, L., "ODOT Roadwaste Research Project: Field Trials." (2001) http://www.odot.state.or.us/tddresearch/reports/pdf/rdwstmng.pdf.

1194. Collins, J.T., Moore, J.T., "Roadwaste Management: A Tool for Developing District." Federal Highway Administration, *FHWA-OR-RD-01-07, Phase 3 Final Report* (October, 2000) http://www.odot.state.or.us/tddresearch/reports/pdf/rdwst_tool.pdf.

1195. City of Portland Sweeper Debris Separation Program, http://www.trans.ci.portland.or.us/services/streetcleaning/recyclin.htm.

1196. Martinelli, T.J., Waschbusch, R., Bannerman, R., Wisner, A., "Pollutant Loadings to Stormwater Runoff from Highways: The Impact of a Freeway Sweeping Program." Wisconsin Department of Transportation, *WI/SPR-11-01, Final Report, WisDOT Study 97-01* (June, 2002) 64pp.

1197. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) 44 pp., section 3-2, p. 18.

1198. New Brunswick, Canada, Department of Transportation, "Environmental Protection Plan." (May, 1998) 147 p. p. 4-26.

1199. Washington State Department of Transportation, "Roadside Manual." (July, 2003) 324 pp., p. 700-13.

1200. Oregon Department of Transportation, "Routine Road Maintenance: Water Quality and Habitat Guide Best Management Practices (July 1999), p. 19, http://www.odot.state.or.us/eshtm/images/4dman.pdf.

1201. New York State Department of Transportation Environmental Analysis Bureau, "Environmental Handbook for Transportation Operations" (July 2001) Section 3-6, p. 20.

1202. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 20.

1203. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 21.

1204. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 22.

1205. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 23.

1206. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 24.

1207. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 25/26.

1208. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 27.

1209. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 28.

1210. Washington State Department of Transportation, "WSDOT MAP Field Data Collection Manual – Volume 1." (September, 2003) p. 29.