United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

General
Technical
Report
FPL-GTR-132

Review of Log Sort Yards

John Rusty Dramm
Gerry L. Jackson
Jenny Wong

Abstract

This report provides a general overview of current log sort yard operations in the United States, including an extensive literature review and information collected during on-site visits to several operations throughout the nation. Log sort yards provide many services in marketing wood and fiber by concentrating, merchandising, processing, sorting, and adding value to logs. Such operations supply forest products firms with desired raw materials, which helps improve their bottom line by reducing the number of marginal logs processed. Ultimately, sorting logs leads to better use of the available timber resources. Successful log sort yards are self-sufficient and have well-established markets and a steady supply of wood. Log sort yard concepts and analyses described in this report have broad applications.

Keywords: log sort yard, small diameter, underutilized species, value-added, sorting, log scaling, log grading, log merchandising

Cover Photograph

Libby Log Sort Yard, Libby, Montana—Logs from small timber producers and private landowners are purchased and sorted for various log products and concentrated for more efficient shipping to mills by truck. The essentials of the small log sort yard are shown: log decks, yard office, and utility hookups. Small log sort yards such as this may hold the key to effective forestland restoration and fuels reduction treatment while providing rural jobs and opportunities for value-added options for small-diameter and underutilized trees.

October 2002

Dramm, John Rusty; Jackson, Gerry L.; Wong, Jenny. 2002. Review of log sort yards. Gen. Tech. Rep. FPL-GTR-132. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 39 p.

A limited number of free copies of this publication are available to the public from the Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53726–2398. This publication is also available online at www.fpl.fs.fed.us. Laboratory publications are sent to hundreds of libraries in the United States and elsewhere.

The Forest Products Laboratory is maintained in cooperation with the University of Wisconsin.

About the Authors

John Rusty Dramm is a Forest Products Utilization Specialist in the Technology Marketing Unit located at the USDA Forest Service, Forest Products Laboratory, Madison, Wisconsin. Current focus of Mr. Dramm's work is on potential applications of log sort yards to improve the viability of forestland restoration and fuels reduction activities on public and private forests. He is a recognized expert in sawmill efficiency and quality and productivity improvement. In addition to his tenure with the USDA Forest Service, he has a total of 20 years experience in lumber manufacturing quality control, hardwood forest management and harvest operations, and wood treating plant management. He holds a Master of Forestry Degree from Oregon State University and a Bachelor of Science Degree in Forest Management, from University of Wisconsin–Stevens Point.

Gerry Jackson is a Forest Products Marketing Specialist with the Technology Marketing Unit in Madison, Wisconsin. Mr. Jackson provides marketing assistance to state and community groups engaged in rural community assistance as well as the forest products industry. His industrial experience includes Weyerhaeuser Company's management trainee program in the southeastern United States. He received his Master's Degree in Forest Products Marketing from Virginia Tech and a Bachelor of Science Degree in Marketing from Alabama A&M University.

Jenny Wong is a summer student with the Forest Products Laboratory. She compiled the extensive literature review of log sort yards. She is working toward a pre-law undergraduate degree at the University of Minnesota.

Acknowledgments

Coordination of log sort yard site visits was made possible by efforts of Federal and state utilization and marketing specialists throughout the country. We especially recognize the efforts by Peter Lammert, Maine Department of Conservation; Dean Huber, USDA Forest Service, Northeastern Area; and Bill von Segen, USDA Forest Service, Region 6, State & Private Forestry. The authors also thank several individuals, companies, and organizations who contributed their insights into log sort yard operations. We are most grateful for contributions from the following individuals and organizations:

Terry Larimer, Libby Log Yard; **Roger Jaegel**, Watershed Research and Training Center; **Mark Stella**, Rogue Institute; **Terry Mace**, Wisconsin Department of Natural Resources; **Dr. Robert Govett**, University of Wisconsin–Stevens Point; **Chris Edwards**, Western Wood Products, Inc.; **Bob McCarty**, Weyerhaeuser Company; **Carl Henderson**, Huber Resources Corporation; **Peter Honey**, Champion International; **Norm Steve**, Prentiss and Carlisle; **Ed Kimball**, Penley Corporation; **George Parke**, Northeast Bio Recovery, Inc.; **Ray Emery**, Emery Forest Products; **Earl Pelletier**, Oak Brokers, Inc.; **Dick Pierce**, Timber Resources Group, LLC; **Scott Thomas**, GT&S Logging, Inc.; **Howard Miller**, Jackman Lumber—Somerset Log Yard; **Bruce Edwards**, E.D. Besse & Son; **Peter Holman**, Maxiwood; **Reiny Krause**, Algoma Lumber Company; **Byron Hawkins**, Webster Lumber Company; **Jamie Barbour**, USDA Forest Service, Pacific Northwest Research Station; **Dean L. Parry**, USDA Forest Service, Pacific Northwest Research Station; **Steve Schmieding**, USDA Forest Service, Forest Products Laboratory.

Contents

Review of Log Sort Yards

John Rusty Dramm, Forest Products Utilization Specialist
Gerry L. Jackson, Forest Products Marketing Specialist
Jenny Wong, Summer Student
Forest Products Laboratory, Madison, Wisconsin

Introduction

The forest products industry's interest in log sort yards has increased during the past several years in response to a decline in timber resource quality and availability, changes in wood and fiber markets, and the need to recover more value from available resources. In addition, forest-dependent rural communities, affected by changes in the timber supply situation, are searching for ways to build diversified and sustainable local forest products businesses. For this to happen, a dependable supply of raw material is crucial.

At the same time, land managers need economical ways to reduce the forest fuel load in the West and must find ways to market low value material from thinning operations and forest restoration projects. Furthermore, current land management strategies indicate that the USDA Forest Service will harvest significant amounts of small-diameter material and biomass during the next several decades. Dense, overstocked small-diameter stands require mechanical treatment (that is, thinning), followed by prescribed burning to reduce the fuel load, improve forest vigor, and restore landscapes to desired presettlement conditions. Because of insufficient funding to achieve wide-scale forest restoration and fuel reduction, an economical outlet (or market) for small-diameter material and biomass is needed. These changes in land management strategies, primarily from watershed restoration projects and fuel reduction work, will result in small-diameter mixed species sales, which will differ from the large-diameter, single species commercial timber sales of the past.

In addition to the traditional commercially run log sort yard, possible log sort yard scenarios include small community-based and government-run log yards. In general, yards operating other than for profit (for example, community and government-run yards) have not had much success (marginal at best) for a number of reasons. In Canada, however, the Ministry of Forestry has successfully operated a government log sort and sales yard since 1995 in Lumby, British Columbia (Wallowa Resources 1997). Similar pilot projects could be pursued in the United States. The Watershed Research and Training Center in Hayfork, California, is also pursuing a community-based log sort yard project to help overcome previous barriers to success (Roger Jaegel, Watershed Research and Training Center, personal communication, 1999).

Log sort yards could potentially improve utilization and value recovery of underutilized species, small-diameter material, and biomass resources. Consequently, the USDA Forest Service is investigating opportunities for using log sort yards to improve raw material supply for small wood, specifically for businesses in rural community economies (Dramm and Jackson 2000). This report reviews several points about successful log sort yard operations. Selected log sort yard and related references with abstracts (where available) are listed in the Appendix.

Log Sort Yard Project

The USDA Forest Service log sort yard project (Dramm and Jackson 2000) seeks to identify and overcome barriers to successful operations and to improve utilization and marketing of logs. This project will help sustain timber-dependent rural communities by improving the supply of small quantities of logs for local businesses. Also, providing viable outlets (markets) for the material produced from forest restoration projects will facilitate these restoration efforts, thereby assisting in the decrease of forest fuels and biomass. Project findings are applicable to a wide range of situations from the traditional commercially run log sort yard to new concepts in community and government-run yards.

In researching log sort yards, the authors visited 18 log sort yard (and related) operations in the United States. Visits ranged from traditional commercially operated log sort yards to community and government-run yards. Related site visits included concentration and mill log yard operations and a business that makes soil amendment products from log sort yard debris. The site visits provided valuable insights into log sort yard design, operation (for example, log sorting and transporting), log procurement, and marketing.

An extensive literature search uncovered additional sources of log sort yard information. This report covers the basic concepts and general information discovered during site visits and in researching the extensive literature review. (Log sort yard identification and specific operations, marketing information, photographs, and especially sensitive business information are confidential, and direct reference to them has not been included in this report.)

Background

Beginning in the mid-1990s, the USDA Forest Service, Forest Products Laboratory (FPL), and State and Private Forestry (S&PF) conducted a series of technical assistance visits to various USDA Forest Service regions throughout the nation. The primary purpose of the visits was to learn the issues affecting the National Forests and their forest-dependent rural communities and industries (Dramm 1999). Key needs identified during these visits include the following:

- Stable and consistent timber supply to sustain a viable forest products industry
- Alternative methods to Federal timber sales to sustain small local wood-using businesses
- Value-added options for small-diameter trees and underutilized hardwoods
- Economical small-diameter thinning and harvesting systems, including design and layout
- Economical stand treatments for ecosystem management and watershed restoration
- Long-term contracts to encourage business investment in small-diameter utilization opportunities
- Economical utilization and marketing of small-diameter timber

During the past several decades, Federal fire suppression efforts implemented to provide public safety and protect our nation's natural resources as well as personal property (for example, homes in the wildland–urban interface) have contributed to excessive forest fuel buildup. In addition, limited funding for forest management, such as forestland restoration and timber stand improvement projects, and reductions in timber sales on public lands during the last decade have contributed to the forest fuel buildup, leading to dangerously high levels.

Poor timber harvest strategies (for example, selectively cutting and removing the best trees in a stand) and lack of good forest management practices have contributed to less desirable species with poorer stand quality and composition. Log quality has generally declined, especially in the hardwood timber resource of nonindustrial forestlands, found primarily in the eastern United States.

Consequently, millions of forest acres are at risk from wildfire, disease, and insect attack. Lack of adequate forest management (silvicultural operations) and lack of sufficient funding for forest fire prevention efforts (fuel reduction work) have resulted in many acres of western forests changing from open or moderately well stocked stands of large conifer trees (for example, ponderosa pine) to dense stands with overstocked, mixed species of small-diameter trees. Similarly, the quality and composition of forest stands has declined because of lack of disturbance (fire) and lack of good land management practice. Many stands at risk require treatments such as thinning to help reduce the fuel load and restore forests to a healthy vigor. The types of materials to be removed are currently of little or no value, and thinning operations are costly; therefore, restoration and forest management activities are limited (Dramm 1999).

Creating economic incentives and readily available markets for low-value small-diameter material would help return our public and private forests to healthy conditions. Incentives might be achieved through improved utilization and marketing of material from thinning operations and fuel reduction projects. This in turn could supplement limited funding for forest and watershed restoration, fuel reduction, and forest management prescriptions.

Increasing the industrial capacity for these forest products could provide the necessary outlet for small-diameter material and underutilized species. Industrial capacity also provides manufacturing jobs, an important economic engine for rural communities.

Unfortunately, the kinds and quality of the material available possess severe utilization and marketing challenges. The small size and low grade of such material results in greater manufacturing costs and decreased wood product market values compared with the more traditional large-diameter, high-quality logs. In some regions in the United States, the forest products industry lacks the appropriate technology necessary to achieve the highest value from this traditionally low- to no-value resource.

There is a declining outlet (market) for Forest Service timber and biomass in some parts of the Intermountain West as a result of closures of forest product plants. The current timber supply situation is causing a shift to fewer, smaller, and less permanent plants. In some areas of the West, distance from large markets and lack of infrastructure are problems. In the eastern United States, where forest product infrastructure still exists, the need is to retool the industry to economically handle a low-value resource.

Currently, we need to focus on the existing industry so that it remains viable. Establishing new mills in today's competitive forest products industry requires heavy capital investment. Such investment is unlikely given the uncertainty of a continuous and consistent timber supply. For existing sawmills, capital investment and improved log conversion efficiency are needed to remain competitive in the market place as well as in procuring logs. However, it is unlikely that current mill owners will make further heavy capital investment until there is a more secure and stable timber supply (Dramm 1999).

Poor transportation infrastructure also limits economical options to move wood products to market. Proper plant siting is vital to successfully establishing and maintaining a forest products industry, of which transportation infrastructure is a crucial consideration. Transportation corridors, terminal facilities (rail reload facilities), and processing centers (sawmills) need to be identified. For underutilized species and small-diameter material, raw material transportation costs would be minimized by first using the material in areas as close as possible to potential manufacturing facilities.

Locally run small wood products firms typically depend on a secure supply of small quantities of logs with special characteristics. Ways to consistently offer these types of logs in small volume to small operators are needed. Similarly, larger primary mills (for example, softwood dimension sawmills) depend on a specific log mix to maximize mill efficiency and remain viable. The forest products industry's log specifications and required log mix continue to tighten as log-processing requirements become more demanding. Sometimes, high-quality logs are not processed to achieve their full value. This happens in pulpmill operations, where a wide range of logs (including sawlogs and veneer peeler blocks as well as pulpwood) are often needed to meet pulpwood procurement demands. These examples show the need for better log utilization and marketing. Log sort yard operations could accomplish this.

Log Sort Yard Concept

The log sort yard concept may provide an economical way to supply wood and fiber. Log sort yards (1) process, merchandise, and sort logs into higher value products, (2) provide a market for multiple log products for both large and small timber producers, and (3) supply primary processing forest products firms with desired raw materials, thereby improving their log mix.

Log sort yards may provide options for effective marketing of underutilized and small-diameter material. The goal for this project is to improve rural economies and ecosystem recovery by providing utilization options and identifying potential market opportunities for forest products using log sort yards. This goal would contribute to the rebuilding and retooling of forest products infrastructure and to the use of small-diameter softwoods as well as low-quality underutilized hardwoods.

The benefits of sorting logs may include the following:

- Higher prices and less fluctuation in prices for log sales can be generated through a strategically positioned log sort and sales yard.
- The desired log mix (species, grade, and length) that will best meet processing needs can be supplied to individual wood-using businesses, instead of the broad mix (woods run) of logs typically supplied from a timber sale.
- Specialty and character wood logs could be sold when markets exist.
- The small timber producer could sell small quantities, regardless of grade.
- The small wood-using business could purchase small quantities, regardless of grade.
- Log inventory control and fiscal accounting of available log resource would be improved.

There are also opportunities for log merchandising at the log sort yard, for example, upgrading sawlogs to veneer or bucking for grade and products from long logs, rather than bucking at the landing. This helps reduce site disturbance at the landing, reduces landing size requirements, and provides for more sorting opportunities not otherwise possible when bucking occurs at the landing.

One advantage of using log sort yards rather than other sorting schemes (for example, sorting logs at the landing) is that at yards, logs can be more easily merchandised (bucked for best available markets) and sorted by quality characteristics (species, size, and grade) for allocation to their highest value use. Mill operators and forest products industries can bid on logs in small (truckload or even individual logs) to large lots (entire log decks), purchasing those logs best suited for their mill design and reducing the number of marginal logs (logs whose value is equal to or less than their cost) processed.

Types of Log Yards

There are several different types of log yards serving many purposes, including mill yards, concentration yards, log reload yards, remote log processing yards, and log sort yards. The traditional mill log yard receives and stores logs for several weeks or months of inventory to feed the mill. Concentration log yards provide a central point for accumulating logs for long-distance shipment to mill yards (Wallowa Resources 1997). Log reload yards provide transfer points between truck, rail, or barge transportation. Remote processing log yards feed satellite chip mill and log merchandiser operations. A log sort yard takes advantage of a diversified log market and serves several objectives by sorting logs for the available markets. To some extent, all types of log yards do some log sorting for various reasons such as to improve log procurement, increase log value, take advantage of available log markets, and provide a better log mix to consuming mills.

Origins of the Log Sort Yard

Sorting logs is not new. Hampton (1981) reports that log sort yards trace their history back to river log drives of the white pine era in New England and the Lakes States. Lumbering companies cut and skid white pine logs, storing them at landings or skidways on riverbanks during winter months. Mill stamps, identifying log ownership were hammered into the ends of each log (Fig. 1). Logs were dumped into the rivers after spring thaw and driven downriver (Rosholt 1980). Later, logging railroads transported logs directly to

Figure 1—A mill stamp (near the scaler's forehead) was hammered into the ends of logs to identify log ownership at water sorting grounds.

Figure 2—Water sorting logs was done manually using a pike pole.

Figure 3—Scaling logs in a log raft ready for shipment down river to the mill.

water sorting grounds. Logs were accumulated downstream in booming grounds (water sorting yards) and sorted by log ownership (Fig. 2). Sorted logs were built into rafts, scaled (Fig. 3), and shipped by water to the mill, typically pulled by a tugboat. Dryland log sort yards were first used in the 1960s in the Pacific Northwest and British Columbia. Sinclair and Wellburn (1984) reported that development of dryland sort yards resulted from the need to reduce log losses in water sorting grounds because of sinkers (water-logged logs); the need for more accurate grading, scaling, and sorting; and the need to reduce environmental impact to wetlands and waterways used in water transportation and sorting. Log sort yards have gained in popularity in other parts of the United States in more recent years.

Benefits of Sorting Logs

High log cost, changing resource (large old growth to small second growth to even smaller thinnings), and increased competition for available timber resource has resulted in increased specialization of solid wood processing equipment and mill design. Today's softwood sawmills are specialized and generally not designed to handle a wide range of mixed species and products from timber sales, commercial thinning operations, and forest restoration projects. The typical softwood mill operates with a low profit margin and high volume throughput. Processing lines are designed to handle a nearly uniform wood resource and need specific log requirements to be efficient and profitable. Consequently, the manufacture of primary softwood products requires tight raw material specifications to optimize log utilization. Control of the log mix feeding a sawmill operation is crucial.

For the hardwood sawmill and pine board mill, lumber appearance (that is, appearance grades for factory lumber) determines lumber value. A general decline in log quality challenges the ability of these mills to economically use the available timber resource from thinnings and harvest operations. To remain competitive, mills must forego processing marginal logs unsuited to their operations and then sell or trade them in the log market (Hallock 1964). Having a uniform log resource (quality and size distribution) to supply today's forest products industry would be of great advantage. This could be partially achieved by log sorting.

Sorting logs prior to processing helps ensure that each log is used for its most economical use. Logs can then be marketed to diverse markets rather than to a single use. For example, more value can be obtained by sorting out sawlogs and veneer peelers from a pulpmill's wood supply under the right market conditions (pulp market prices and demand are lower than lumber and veneer market prices and demand).

Log scanning and computer optimization processing equipment has dramatically increased product recovery from logs during the last several decades (Forest Products Laboratory 2000). The Forest Products Laboratory pioneered the Best Opening Face (BOF) computer-optimized log breakdown technology in the early 1970s and continues to provide the basis for geometric sawing solutions to optimize lumber recovery from small softwood logs. Such optimization technology is relatively expensive and has been adopted by large forest products firms that capitalize on high production rates (economies of scale) to recover equipment costs. This leaves the small sawmill at a disadvantage with lower lumber recovery and production rates. Based on the author's experience and that of others (Terry Mace, Wisconsin Department of Natural Resources, 2001, personal communication) in sawmill efficiency, such small mills may be 10% to 20% less efficient in converting logs than large optimized computer sawmills. Therefore, sorting is necessary to improve utilization of logs at small sawmills.

An alternative to expensive optimization equipment is to sort logs prior to processing into diameter classes based on optimal sawing patterns. This method has been employed in Scandinavian countries for several decades to process small-diameter material (Williston 1988). In this alternative, like-sized logs are first sorted and then processed in batches. Log breakdown systems (sawing machine centers) use fixed set saws to process logs efficiently (that is, higher production rate with good lumber recovery). Similar approaches are being explored in the United States (Roger Jaegel, Watershed Research and Training Center, personal communication, 1999). This simplifies and reduces the time required for log breakdown decision making (for example, what sawing pattern to use) as well as the time to reset saws. Increased sawmill efficiency results from presorting logs.

Log Sorting Alternatives

Log sorting alternatives should also be considered (Dramm and Jackson 2000). Economics and processing limitations should be considered for each alternative. Alternatives include (1) using a log sort yard, (2) sorting at the landing, (3) presorting, (4) sorting at the mill log yard, and (5) not sorting.

Log Sort Yards

Log sort yards capture more log value than other sorting alternatives. They are efficient at processing logs of varying quality and products for various markets (for example, sawlogs, hardwood veneer logs, softwood peelers, poles, and pulpwood). This can help the primary manufacturer (sawmill) recover more value per unit, with an improved log mix, and improve business performance. Log sort yards encourage more accurate grading, scaling, and sorting and offer an opportunity to merchandise logs into higher value products (bucking long logs into various short log products like sawlogs, peelers, poles, and pulpwood).

Sorting at the Landing

An alternative is sorting at the woods landing. Sorting at the landing is justified when there are few sorts (for example, species and products) and a large percentage of high-value logs in the harvest operation. In this case, the logger can afford to take extra effort to sort logs to increase revenue from sale of logs to the mill. Limitations include lack of space at the landing to sort and not enough high-quality logs (volume or percentage wise) to justify sorting at the landing. Logs are sorted by log loaders, skidders, pulpwood forwarders, or log trucks with hydraulic loaders at the landing.

Presorting

A variation of sorting at the landing is presorting where only major sorts are pulled at the landing. This helps reduce extra handling at the sort yard of large-volume sorts. Presorting generally works to the benefit of the log sort yard when harvesting and log sort yard operations are integrated, such as when a logging company owns a log sort yard. With independent operations, major sorts are moved from the landing to the consuming mill. Unsorted material can then be processed at a log sort yard more efficiently.

Sorting at the Mill

Low volumes of high-value logs are often sorted at the mill yard. This is true in both the softwood and hardwood industries. A classic example of this is the sorting out of veneer logs from factory lumber logs at hardwood sawmills (Fig. 4). The low volume and high value of these sorts cannot justify a log sort yard alone. Generally, a hardwood veneer log has substantially more value than the factory lumber that could be produced from it. Simply put, a hardwood sawmill cannot afford to saw expensive veneer logs. Veneer logs are sold to a veneer buyer. Mill yards whose primary purpose is to store log inventory for processing can bear the cost of making low-volume sorts and selling logs to high-value markets.

No Sorting

As with any set of alternatives, one option is to do nothing. Any log sorting is predicated on multiple markets for the available log resource. This generally means that a diversified forest products infrastructure is available within the working circle. Without diversified industrial infrastructure

Figure 4—Hardwood sawmill's log yard with logs outspread. Veneer buyer is marking and scaling logs.

and markets, there is little need to sort logs. No sorting is a viable option when (1) there is only a single market for logs; (2) no markets exist for high-quality logs; (3) logs are of uniform quality, size, and value; (4) there is too little overall value to justify sorting; (5) not enough high-quality logs are in the log mix to justify sorting; or (6) high-value logs need to be diverted to low-value uses to meet contractual obligations (for example, a timber producer's pulpwood contract to deliver specified monthly volumes).

Advantages of Log Sort Yards

Log sort yards provide better utilization and marketing with improved value recovery of currently available timber resources in North America (Dramm and Jackson 2000). There are perhaps several specific reasons to build a log sort yard. These might be generalized into the following:

1. Improve log procurement
2. Improve resource utilization
3. Improve log grading, scaling, and sorting
4. Improve log merchandising
5. Capture additional value at satellite processing yards
6. Concentrate logs for shipment

Log Procurement

Log sort yards can help supplement a timber harvesting program of a wood-using business helping to smooth out log supply flow to larger mills. Procuring a wood supply from small, fragmented, nonindustrial private forestland (primarily the case in eastern United States) provides considerable challenges. Sort yards can also provide smaller quantities of logs to small businesses that are not able to purchase large volumes of timber. A good example of this type of yard is the Canadian Ministry of Forestry's log sort yard in Lumby, British Columbia (Wallowa Resources 1997).

Resource Utilization

Sorting logs is a crucial process in Scandinavian small log sawmill operations. Logs are sorted into specified diameter classes and then sawn with the best sawing pattern to optimize lumber volume recovery for each diameter class. Sorting helps Scandinavian sawmills achieve better lumber recovery from a given log resource. North American small sawmill designs also require presorting logs by diameter and length to take full advantage of optimal sawing patterns for high-volume recovery of lumber. The Watershed Research and Training Center in Hayfork, California, is developing small-scale mechanized log sorting systems to help reach higher lumber recovery rates (Roger Jaegel, Watershed Research and Training Center, personal communication, 1999).

Log Grading, Scaling, and Sorting

Proper log grading and scaling are important so that the right logs get to the right mill. This is also necessary for selling logs in the log market. Grading and scaling logs before sorting improves the accuracy of sorting (Sinclair and Wellburn 1984). When log grading, scaling, and sorting are improved, mills require fewer logs to produce the same economic return. Improved utilization and product recovery are also possible.

Log Merchandising

Bucking long logs into multiple high-value log products (called merchandising) is an important function of some log sort yards. The log sort yard can merchandise logs into higher quality products more efficiently than the logger can at the landing. However, as log market prices fluctuate, merchandising may or may not increase the value of tree-length or long logs. If for example, pulp logs are only slightly less valuable per unit than sawlogs, recovering the cost of bucking and sorting sawlogs from the pulpwood would be difficult. In other cases, as with veneer logs, it is critical to merchandise high-value products from quality hardwood timber.

Value-Added Satellite Processing

Log sorting is sometimes incorporated with satellite primary processing yards. For example, the trend to incorporate sorting with satellite chipmills (Fig. 5) offers opportunities to merchandise high-value logs (sawlogs and peelers) from low-grade long logs (pulpwood). Other value-added log sort yard operations include post and pole peeling mills (Fig. 6), where sawlogs and pulpwood are sorted out and sold to other primary processors. With a trend toward smaller sawlogs, some operators have captured a unique market opportunity in debarking stud logs (Fig. 7) in the log sort yard (Chris Edwards, Western Wood Products, personal communication, 1999). In a studmill (a small log sawmill producing

Figure 5—Satellite chipmill yard chips low-grade pulpwood into higher value chips for shipment to pulpmill by chip van.

Figure 6—Utility pole yard and peeling mill provides another value-added option.

Figure 7—Douglas-fir debarked stud logs loaded and ready for shipping, but no market for hemlock blocks.

nominal 2- by 4-in. (standard 38- by 89-mm) studs), debarking is often a processing bottleneck. A supply of debarked logs helps the sawmill operator reduce this bottleneck and smooth out production flow, thereby improving mill productivity (Chris Edwards, Western Wood Products, personal communication, 1999). Similar reasons are given for satellite chipmills, which improve pulpmill raw material flow and reduce processing noise (noise pollution) at the pulpmill site.

Logs Concentrated for Shipment

Efficiency in transporting log products to multiple markets is improved by concentrating and shipping larger quantities of logs for more cost-efficient transport by truck, rail, or barge. A modification of the log sort yard is the concentration yard where mixed loads of logs are sorted by products. This helps reduce overall log transportation costs by moving logs to various users directly rather than reloading at the primary manufacturer's (sawmill, plywood plant) mill yard. Concentration yards serve as a central satellite terminal for logs consolidating loads to take advantage of transportation efficiencies.

Log Sort Yard Goals and Objectives

The goal of a log sort yard is the efficient procurement, concentration, sorting, utilization, marketing, and distribution of logs. Log sort yards should be established using clear, well-defined log procurement, processing, marketing, and financial objectives (Sinclair and Wellburn 1984). Log procurement objectives most often aim to secure a stable log supply at a reasonable cost. Processing objectives of a log sort yard are generally to improve the productivity and quality of log sorting. Log sort yard marketing objectives center around improving the movement (or distribution) of sorted logs to the best available markets to realize the best price for the available log resource. A log sort yard must also be justified on a financial basis. Financial objectives are to achieve cost savings or additional value (that is, profit center) from the available log supply.

Log procurement, processing, marketing, and financial objectives must be balanced to achieve good overall log sort yard performance. The authors cannot overstress the importance of meeting these objectives. Failure in one or more of these areas often leads to failure of the venture. Log sort yards must pay their way by economically supplying a ready market with the additional value captured by log sorting. Meeting all four objectives is challenging.

Trying to achieve only financial objectives (for example, cutting log procurement and operational costs or increasing log production through the yard) may result in poorer scaling and grading quality. While reduced operating costs and increased production rates might be achieved, lost revenue may be experienced through lost market share as a result of inaccurate grading and scaling. Overall financial performance then also suffers. Similarly, focusing on only processing objectives may lead to poor financial performance. For example, while stick scaling may help improve log scaling accuracy, the additional yard costs associated with stick scaling could easily outweigh any additional value realized (for example, stick scaling low-value small-diameter logs rather than weight scaling). Ultimately, all four objectives are bound by the economics of log sort yard operations and the character of the available log resource. (Refer to the section on log sort yard economics for more information.)

Log Sort Yard Operations

Sinclair and Wellburn (1984) and Hampton (1981) provide good discussions of log sort yard operations and productivity principles and general recommendations. All log sort yards share the same basic operational functions. These are materials handling (unload–reload and transport), log processing (for example, log grading, scaling, and sorting), and log storage–inventory. Additional value-added processing (for example, log merchandising, debarking, and peeling) is also found in some yards.

Materials Handling

A log sort yard involves material handling (that is, unload–reload and transport) with inspection, processing, and inventory functions. Every material-handling move involves a "pick" where a load is picked up, transported, and then set down (Mason 1998). There are two prime rules in material handling: (1) the shorter the distance traveled, the cheaper the cost, and (2) the greater the weight per move, the cheaper the cost per unit.

The principles of material handling applied to log sort yards are (Sinclair and Wellburn 1984) as follows:

- Reduce or eliminate unnecessary movements and combine movements
- Increase the size, weight, or quantity of material moved wherever possible
- Standardize types and sizes of equipment
- Use equipment that can perform multiple tasks unless specialized equipment is needed
- Select equipment to match all aspects of material and flow in the system
- Minimize the ratio of dead weight to total weight on all moves
- Maximize the load and minimize the distance on high-intensity moves
- Make low-intensity moves, if long distances must be covered
- Pick up and set down whole loads

A heavy load moved a short distance is the least expensive move. The most expensive move is a light load moved a long distance. Log sort yard layout should focus on maximizing loads transported within the yard and minimizing distances they are moved. Light loads should be combined if possible. Frequency of light loads transported long distances should be minimized.

Extra handling decreases log sort yard productivity and increases costs and risks of log degrade and damage. Handling does nothing to add value to logs. Unnecessary picks (that is, process of picking up, transporting, and setting down a log or load of logs) and handling of low-value material should be minimized. Logs should be handled in bunched loads to take full advantage of log handling machine capacity. The section on log sort yard equipment and sorting systems discusses more details on materials handling equipment.

Figure 8—Rubber-tire-mounted hydraulic loader unloading and spreading logs for grading and scaling.

Unload–Reload

Logs are generally transported to and from log sort yards by log trucks. To a lesser degree, rail and barge transportation are also used. In small log sort yards, front-end loaders with lifting capacity of 30,000 to 50,000 lb (13.6 to 22.7 Mg) do all the functions and truck unloading is generally by multipass lift unloading. In the Northeast and the Lake States, self-contained, rubber-tire mounted hydraulic log loaders are used in smaller log sort yards (Fig. 8) for unloading, reloading, spreading logs for grading and scaling, and sorting. In large log sort yards, log stackers with lifting capacity of 80,000 to 110,000 lb (36.3 to 50.0 Mg) are most often used for transporting and unloading trucks in one pass, where the whole load is lifted off the log truck or rail car. Logs are transported and spread out in a sorting bay or inventoried in a temporary storage deck. This greatly reduces the truck waiting time during unloading compared with multipass methods. Other unloading methods include pushing and pulling the loads off trucks. Large log sort yards and yards serviced by barges incorporate log cranes for unloading. The same equipment is used to reload trucks, rail cars, and barges for shipment to the mill.

Transport

Logs are handled and transported between each of the other yard functions. In general, log handling and transportation occur between (1) unloading, (2) grading and scaling, (3) sorting, (4) storage, and (5) reloading. It is most efficient to transport logs using the full capacity of forwarding machines (Fig. 9). Logs are sometimes transported a few at a time or individually. While this is inefficient use of machine availability, at times it is unavoidable. A successful log sort yard often depends on using the right machine for the type, weight, size, and production rates of logs processed.

Figure 9—Front-end loader using full machine capacity to transport logs in the yard. Front-end loaders are good multipurpose machines for unloading and reloading, transporting, spreading, and sorting logs.

Log Processing

Processing functions in a log sort yard include log grading, scaling, and sorting activities. Efforts are concentrated on improving log value at minimum cost. While other functions such as materials handling and log storage are necessary costs, the success of a log sort yard falls on its ability to increase log value during grading, scaling, and sorting production phases. Additional processing functions may include log merchandising and value-added operations (previously described).

Grading

In log sort yards, grading or marking a log designates what sort the log should be put into. This differs somewhat from the traditional sense of log grading, where logs are assigned a log grade for commodity markets. Logs are spread out in a sorting bay (Fig. 4) for efficient grading and scaling. Graders mark logs for sorting by product or market. Graders may also indicate logs to be upgraded by bucking back (cutting back the length of a high-quality sawlog to veneer log specifications (Fig. 10). The sort and where to buck logs are usually indicated on the log with spray paint, a paint gun, or a log marking stick. Other marking systems include color tags or crayon marks. Graders also assume quality control duties for the log sort yard, watching for mismanufactured logs (Fig. 11) and excessive log damage (Figs. 12 and 13).

Scaling

Two methods of scaling are generally used in log sort yards, stick scaling and weight scaling. Two other possible scaling methods for low-value material (such as pulpwood) are cords and cunits. Scalers normally stick scale logs after grading and bucking but before sorting. Several basic manual and computerized log scale accounting and inventory systems are available. Log tag or deck cutoff inventory systems are typically used when logs are sold in the open log market (Sinclair and Wellburn 1984). High-value logs (for example, hardwood veneer logs) may be individually tagged, and grade and scale information is recorded for each log. Many log sort yards use a log deck cutoff inventory system. In this system, sorted logs are accumulated in storage decks. When a deck is full, it is closed or “cutoff” and the accumulated scale tickets are tallied to show the total volume (or estimated volume if weight scaled) and grade of logs in the deck.

Figure 10—Workers determining whether birch sawlog could be upgraded to a veneer log if it were bucked.

Stick scaling uses a log rule to determine the net volume after deductions for defects and grade of the log. Measures include board foot log scale, cubic log scale, and cubic meters. The accuracy associated with stick scaling is important for high-value logs such as veneer peelers and high-quality sawlogs. Because stick scaling is relatively expensive, it is not recommended for low-value material such as pulpwood. Exceptions to this are when there are no other scaling alternatives (for example, small log sort yard without a truck scale) or when required by log buyers. The log scale

Figure 11—Pistol butt—a poor log-making practice. Proper log making in the woods goes a long way to recovering highest value for the log sort yard operator. This log may be no value because it was mismanufactured.

Figure 12—Log fork damage from a front-end loader caused by carelessness or excessive log handling.

Figure 13—Timber processor damage on a sawlog. Harvesting damage such as splits results in poorer lumber recovery and loss of log value.

Figure 14—Loaded truck at a large sort yard gets weighed in. After unloading, the truck is reweighed empty and the net log weight is calculated.

and grade of each log are recorded for accounting purposes (Fig. 4). Data can be recorded manually with a hand-held data recorder or computer.

Weight scaling is preferred for material handling efficiency and productivity because it greatly reduces scaling time compared with stick scaling. Check scaling (stick scaling a sample of a weight-scaled load of logs) is often used to determine volume-to-weight ratios and provide an estimate of grade mix. Weight scaling involves weighing a loaded truck on a truck scale (Fig. 14), then unloading and reweighing the empty truck. The tare weight (empty truck weight) is subtracted from the loaded truck weight to determine weight of the load.

For low-value logs, using weight scaling rather than stick scaling increases productivity and reduces costs of operating a log sort yard. Efficiency is improved by processing logs in bulk rather than individually. With weight scaling, only a small portion of log loads are check scaled (sample stick scaling) to confirm log volume and quality. Stick scaling should be reserved for high-value logs such as hardwood veneer logs (Fig. 4), softwood peelers, and high-quality sawlogs.

While more efficient than stick scaling, weight scaling has some disadvantages—primarily that weight varies with log moisture content and species density and logs will also vary to some degree from season to season. Logs stored on the landing for a period of time weigh less per volume (due to moisture loss) than logs recently harvested. To overcome these problems, a sample of the load may be check scaled (stick scaled) to estimate grade mix and establish a weight-to-volume relationship.

Measuring in cords is a popular alternative for scaling pulpwood and saw bolts in the Lakes States. One cord equals 4 by 4 by 8 ft or 128 ft^3 (3.62 m^3) of wood, bark, and air space. Although the authors are not aware of any log sort yards using cords, this scaling scheme would be of benefit for low-value, high piece counts per volume logs (for example, small-diameter material). Other measures of logs (for example, cunits, cubic feet, cubic meters) can also be used as scaling systems.

Cords are calculated from the average load height and length. Using cords as a measure results in similar problems as weight scaling. Here, the problem is that of accurately estimating the solid wood volume in a load. Pulpwood is often transported by truck or open top railcar loads. As in weight scaling, check scaling is used to determine the volume of wood in a measured cord, which averages about 79 ft^3 (2.24 m^3) for pulpwood in the Lakes States (Terry Mace, Wisconsin Department of Natural Resources, personal communication, 2001).

Sorting

Log sorting accuracy is improved when logs are graded and marked prior to sorting. Sorting involves separating individually graded and scaled logs into groups of logs with the same end-use. Logs are generally sorted by species, product (for example, pulpwood, sawlogs, peelers), and market. Logs are then bunched (accumulated) and transported to sorted log inventory decks or reloaded directly.

The number of sorts may vary from just a few to perhaps 40 or more. Log size distribution, daily production rate, and number of sorts determine the type and number of sorting machines required for sorting logs. These same factors affect log sort yard productivity. The number of sorts also influences the choice of sorting system.

Determining the number and types of log sorts is an economic problem. Given available markets, log sorting improves the overall value of the log resource. This is realized by the sale of logs in a diversified log market. However, the fewer the number of sorts made in the log sort yard, the lower the cost per unit (fewer sorts decreases costs and volume of logs in inventory). There must be a sufficient added benefit (that is, increased log value created by the sorting) to justify each sort. When considering additional sorts, the added benefits must offset added costs. Refer to the section Log Sort Yard Equipment and Sorting Systems for a detailed discussion of log sorting equipment and systems.

Log Storage and Inventory

Inventories perform four functions to improve the efficiency of log sort yards (Sinclair and Wellburn 1984):

- Provide surge leveler or buffer
- Decouple log yard functions
- Smooth out fluctuations in log flow through the yard
- Accumulate loads

While log inventory should be kept to a minimum, it may be necessary to temporarily store unsorted and sorted logs. Most log sort yards do not store sorted logs unless they must be accumulated for reload. Unsorted storage is used to decouple production phases in a log sort yard to improve work flow. Decoupling means to separate production flow from one process to the next. This is accomplished by providing temporary storage or a surge area in the log sort yard. Decoupling through storage also improves safety by separating mobile equipment away from graders, scalers, and other yard workers (Sinclair and Wellburn 1984). Some log sort yards store unsorted logs to balance daily and seasonal surges in log production. This may reduce investment in equipment and overtime costs and increase the working year of the crew, but it may also reduce efficiency, increase investment in land, and subject the logs to degrade. Some log storage is unavoidable, but the inventory should be controlled. Large log inventories in log sort yards are a concern, and every effort should be made to reduce the inventory.

Log storage also reduces productivity, increases costs, and increases log damage (as caused by log forks and breakage) (Fig. 12) and loss from insects and stain. Sometimes, there is no alternative to log storage, and without it, productivity would be lower and costs higher. Yards with extreme variations in log input require log storage–surge areas to smooth out log yard flow. Yards that store a large amount of logs have lower productivity than yards that store smaller amounts. Minimizing log inventories and shortening turnaround times help reduce log yard costs and improve productivity. Every effort should be made to minimize unnecessary log storage. First in–first out (FIFO) inventory control should be used to reduce losses from degrade.

Log Sort Yard Equipment and Sorting Systems

Material-handling equipment can be divided into transport and sorting functions (Sinclair and Wellburn 1984). In large log sort yards, crawler-mounted heel-boom log loaders are used primarily for sorting and log stackers and large front-end loaders are used for transporting. In small log sort yards, front-end loaders are used for both sorting and transporting logs. Wherever possible, logs should be bunched before they are moved to use the full capacity of the transport machines. It is inefficient to use a front-end loader or log stacker to transport just a few logs from one end of the yard to the other. Other types of equipment (for example, forklifts and skid steer type farm loaders) are not well suited to log sort yard requirements for performance and efficiency (Hampton 1981).

There are several basic sorting systems (Sinclair and Wellburn 1984, Hampton 1981). Front-end loaders and both mobile and stationary log loaders are the primary machines used for sorting. Sorting tables, linear log-sorting systems, and log merchandisers are also used to a lesser extent but are gaining in popularity. Small yards use front-end loaders or rubber-tire truck-mounted hydraulic loaders to perform all machine functions. Sorting systems with front-end loaders have more flexibility than other sorting systems because front-end loaders can perform many log sort yard functions (such as unloading, spreading, reclaiming, sorting, transporting). Large log sort yards use log stackers, front-end loaders, and log loaders in various combinations; specific job functions are often assigned to each machine. Log loaders can sort small pieces and build a better bundle of logs than can front-end loaders. Stationary log loaders achieve high sorting production rates, but more time is needed for handling (transporting) material compared with that required by mobile log loaders.

Front-End Loaders

The front-end loader with a log fork (Fig. 9) is a general purpose machine used in log sort yards. The front-end loader performs unloading, transporting, and sorting functions but is not as efficient as other specialized log handling machines (for example, log stackers, log loaders, sorting tables, merchandising systems) in performing any of these functions.

The front-end loader performs well for sorting large logs and transporting them short distances. For the small yard, front-end loaders unload and reload trucks. Because the front-end loader can do several functions, it is a good backup machine. A small front-end loader is good for sorting because of its size, speed, and capacity, but its load and lifting capacity limits its suitability for efficiently transporting logs in the yard. A large front-end loader is best for transporting bunched logs and truck unloading and reloading. A medium-sized loader is a good multipurpose machine for sorting, transporting, loading, and unloading. This loader is a good backup machine.

Two systems are used when sorting logs with front-end loaders. The first is where a front-end loader works from the end of the grading and scaling bay and sorts the logs into piles. In the other system, the front-end loader moves along the side of the deck and pulls out the logs, generally pulling the large-volume sorts first. Sorted logs are bunched and forwarded to sorting bunks or storage bays or reloaded directly onto trucks.

Log Stackers

Large West Coast and southeastern U.S. mill log yards and medium to large log sort yards use log stackers (Fig. 15) for unloading and transporting large loads. Log stacker lifting

Figure 15—Overview of a paved log sort yard. Note sorting bay, log truck approaching truck scale, and log stacker ready to unload the truck in a single pass, lifting the entire load off.

capacity ranges from about 80,000 to 110,000 lb (36.4 to 50.0 Mg). These machines are capable of unloading a log truck and over-the-road semitrucks in a single pass. Railcar and off-highway truckloads can be unloaded in two or three passes. Log stackers efficiently spread logs for scaling and grading and stack logs in storage decks.

Log Loaders

Hydraulic log loaders are used for sorting logs. Other uses include unloading and reloading trucks and building log storage decks. Mobile log loaders range from heel-boom crawler-mounted loaders and rubber-tired knuckle-boom machines to log-truck-mounted loaders. Stationary log loaders are also used for sorting or in combination with a sorting table or log-merchandising system. The sorting system (that is, mobile equipment and sorting procedures) used will depend on the log size, number of sorts, and time available for transporting logs in the yard.

On the West Coast and in the southeast United States, high-capacity mobile crawler-mounted heel-boom log loaders sort logs in the yard. A crawler-mounted mobile log loader typically works its way in a travel corridor adjacent to a grading and sorting bay of spread logs. The loader sorts and bunches logs of the same grade, placing them in the travel corridor behind the machine as it works its way along the sorting bay. A front-end loader will then accumulate the sorted logs and transport to the sorting bunks, sorted log storage, or reload directly onto trucks.

Less expensive rubber-tire-mounted (Fig. 8) or log-truck-mounted (Fig. 16) knuckle-boom loaders are used predominately in the hardwood industry in the northeastern United States. These machines are well adapted to 8- to 16-ft-(2.44- to 4.88-m-) long logs of a wide range of diameters (4 to 32 in. (10 to 81 cm) or more) and may have good potential for small log sort yards in the West. Logs are unloaded and spread for grading directly from the log truck. Logs are graded, sorted, and bunched by the mobile loader or a front-end loader. Pregraded logs (for example, veneer and sawlogs graded at the landing) coming into the yard may be sorted by the truck driver as logs are off loaded.

Stationary hydraulic loaders are also used in some large yards. Logs are fed by a front-end loader or log stacker. Unsorted logs are spread out in front of the loader on one side. The stationary loader then sorts the logs into six to nine bunks located around the other three sides of the loader (Fig. 17). Sorted logs are accumulated and moved to a storage deck or reloaded on trucks. This system works best when the average log size is relatively large and there are few sorts. Stationary log loaders are also used in conjunction with mechanical log sorting tables and log merchandisers (Fig. 18). Generally, these are crawler-mounted. However, pedestal-mounted loaders are also used in some large yards

Figure 16—Log-truck-mounted loader typical of hardwood logging trucks.

Figure 17—Stationary log loader with sorts laid out on three sides of a square for efficient sorting. Front-end loaders feed logs to the loader for sorting on the fourth side of the square.

that employ a sorting table or log merchandiser system for processing small-diameter logs.

Sorting Systems and Log Merchandisers

Log-sorting tables and linear systems were pioneered in Scandinavia for sorting logs into diameter classes at small log sawmills (Williston 1988, Sinclair and Wellburn 1984). Such systems consist of stationary log transport chains and transfer chains moving each log to one of several sorting bays. Sorting tables transport logs transversely, whereas linear systems move logs end to end. These systems have gained in popularity in North America. For system efficiency and high production rates, logs must be relatively small and uniform with little sweep. Under the right conditions, log-sorting tables and linear systems improve productivity in large log sort yards (Hampton 1981).

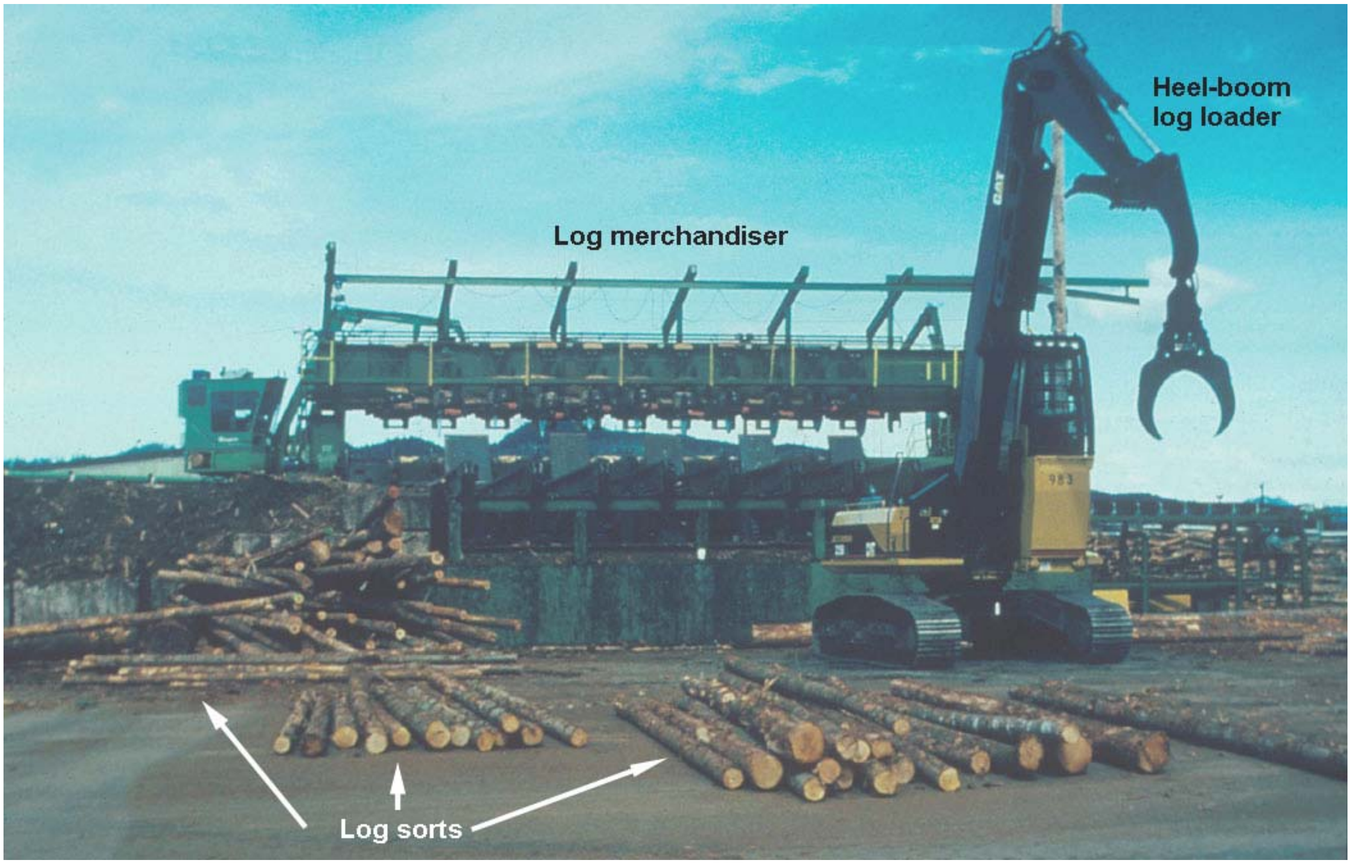

Figure 18—Log loader sorting sawlogs and stud bolts from a transverse log merchandiser. Note the typical layout of sorts within easy reach of the loader's boom and grapple.

Log merchandisers were first pioneered by Weyerhaeuser Company (Tacoma, Washington) in the 1970s as a result of the need to recover more value from tree length and long logs (Hollis McNully, Perceptron, Inc., personal communication, 1996). These systems are similar to log-sorting tables and linear systems with the addition of a bucking saw. Originally used at large softwood sawmills, merchandisers buck tree length and long logs into various short log products (for example, veneer peelers, grade saw-logs, small sawlogs, pulpwood) for recovering higher value. When first introduced, the merchandiser operator determined bucking decisions. Today's merchandisers incorporate log scanning and optimization technology (Fig. 19) to determine the best utilization of long logs. From an infeed deck, logs are scanned and the optimal bucking solution and product designation are determined by optimization software. Next, the optimized bucking solution bucks the log into products and routes to appropriate sorted log bay (Figs. 20 and 21) where logs accumulate for transport to temporary storage or reloading. Log merchandisers have been adapted to log sort yards in the last 10 years to efficiently process small-diameter logs.

Timber Processors and Cut-To-Length Systems

As an alternative to large log merchandisers, mechanized logging equipment has been incorporated in some small- to medium-sized sort yards. This equipment is helping these yards to handle small-diameter logs with success. Tree length logs are bucked accurately with computer-controlled processing heads. Such equipment provides flexibility for the logger-operated log sort yard, where such equipment is also used in harvest and thinning operations. Logs are sorted and transported with front-end loaders or rubber-tire mounted hydraulic loaders.

Sorting Bunks

Sorting bunks are used to accumulate sorted logs (Fig. 22) for transport by large-capacity machines (for example, a log stacker) to reload trucks or log storage decks. The designs and materials used for bunks depend on the volume of logs processed through the yard. Bunks are generally made of I-beams, steel plates, pipe, reinforced concrete, or wood pilings.

Figure 19—Laser scanning and computer-controlled bucking at a high production log sort yard. The merchandiser bucks logs into various sawlog products, railroad tie logs, and pulpwood.

Figure 20—After it leaves the bucking station, pulpwood is routed by chain conveyor to the satellite chipmill (left). Cross-tie logs and sawlogs are transported to the grading station by transverse chain (building on right). Logs are then sorted by product into four sorts where a hydraulic loader bunches logs for transport for loading or temporary storage. Photo taken from the operator's station.

Selection of Log Sort Yard Equipment

The log-sorting system influences the type and size of machines needed (Sinclair and Wellburn 1984, Hampton 1981). The type and size of equipment employed is influenced by log sort yard size and production rate (that is, number of pieces processed per day). Each sorting system and layout requires certain machine performance for various log sort yard functions described earlier. One way to determine whether a machine will satisfy the demands is to visit existing log sort yard operations. Log-handling equipment manufacturers also supply information on machine specifications and performance. Table 1 is a guide to selection of log sort yard equipment.

Figure 21—The four sorted log bays as viewed from the log merchandiser grading station.

Figure 22—Log sorting bunks to accumulate sort logs for transport by larger machines like a large-capacity front-end loader.

Log Sort Yard Layout

The best log sort yard design depends on the volume of logs to be processed, site restrictions, and capital available for material-handling systems (Hampton 1981). Figure 23 shows one example log sort yard layout. Large log sort yards have flexibility in their design. Three grading, scaling, and sorting bays should be able to handle most surges and should protect yard workers from mobile equipment by separating grading and scaling functions from transport functions. A large log sort yard can be 10 or more acres in size. For the small log sort yard, high construction costs and low log volume dictate that these yards be as simple and small as possible. Typically, in medium-sized log sort yards (Fig. 15), the area for sorting will be 5 acres, and in some small yards, the sorting area might only be a half acre. Log storage is limited to accumulating enough logs to make loads to be reloaded on trailers.

Table 1— Log sort yard equipment selection guide[a]

	Function and yard size[b]								
	Load and unload logs			Transport and spread logs			Sort logs		
	Large	Medium	Small	Large	Medium	Small	Large	Medium	Small
Machine equipment									
Front-end loader, large[c]	—	●	●	1	●	●	—	—	—
Front-end loader, medium[d]	—	—	1	—	—	1	—	—	1
Front-end loader, small[e]	—	—	1	—	—	1	—	1	●
Log stacker	●	1	—	●	1	—	—	—	—
Log loader, tracked	—	—	1	—	—	—	●	●	1
Stationary log loader	—	—	—	—	—	—	●	●	—
Log loader, wheeled	—	—	●[f]	—	—	—	—	—	●
Log loader, truck mounted	—	—	1	—	—	—	—	—	●
Sorting system									
Linear sorting system[g]	—	—	—	—	—	—	●	●	1 [h]
Transverse sorting table[i]	—	—	—	—	—	—	●	●	1
Log merchandiser, linear	—	—	—	—	—	—	●[j]	●[j]	1 [k]
Log merchandiser, transverse	—	—	—	—	—	—	●[l]	1	●[m]

[a]Adapted from Sinclair and Wellburn (1984) and Hampton (1981), and information collected from interviews with log sort yard operators.
[b]● recommended equipment or system; 1 acceptable equipment or system; — unsuitable equipment or system or not applicable. Small yard is <25 million board feet (MMBF)/year; medium is 25 to 100 MMBF/year; large is >100 MMBF/year.
[c]For example, CAT988G with log forks (Caterpillar Corp., Peoria, IL).
[d]For example, CAT980G with log forks, good backup machine (Caterpillar Corp., Peoria, IL).
[e]For example, CAT966G with log forks (Caterpillar Corp., Peoria, IL).
[f]In the eastern United States, rubber-tire-mounted log loaders are preferred machines (For example, Prentice 210).
[g]Generally for small-diameter, straight, and uniformly sized logs only.
[h]Less expensive linear sorting systems are available for low volume log sort yards.
[i]Typically for larger grade logs in combination with a stationary grapple boom loader to pull sorts from table.
[j]Typically employs optical or laser scanning with computer-optimized bucking systems.
[k]Less expensive manual merchandising (that is, manual bucking decisions) systems for small uniform logs.
[l]Very high production small-log softwood computer-optimized merchandising.
[m]Smaller hardwood log merchandising generally with manual bucking decisionmaking.

The area required for sorting logs increases with the volume sorted, the number of sorts, and the number of pieces processed per shift. Small log sort yards with fewer sorts and minimal log storage have high machine productivity, the lowest capital investment per unit, and lower than average total costs per unit and piece. Small yards achieve some efficiencies with reduced transport distances and lower construction costs compared with larger yards. Large yards that have the most sorts and little log storage have the highest machine productivity, higher than average productivity, the lowest total cost per unit and piece, and lower than average investment costs per unit. Large yards have an advantage with economies of scale.

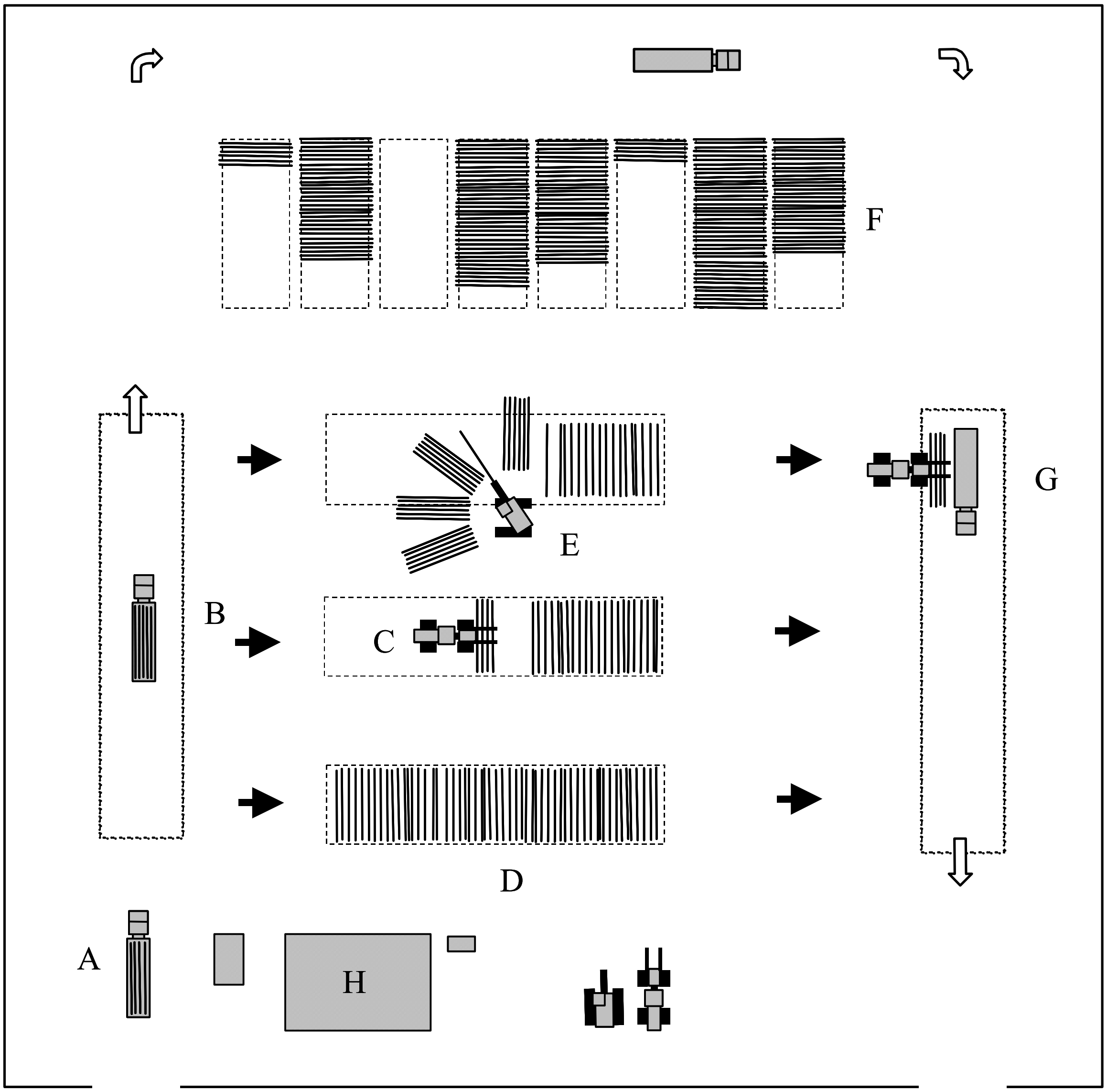

Figure 23—Example of a basic log sort yard layout: (A) log truck waiting in the queue for unloading; (B) log truck unloading with a front-end loader or log stacker; (C) spreading logs in the sorting bay for grading and scaling; (D) grading and scaling functions are decoupled from mobile equipment operations (for example, spreading and sorting logs) for safety; (E) sorting logs with a heel-boom loader—logs are accumulated and transported to temporary storage or reloaded directly onto trucks; (F) temporary sorted log storage for accumulating full truck loads; (G) truck loading with a front-end loader; (H) office, shops, fuel, and mobile equipment deadline.

Log Sort Yard Economics and Productivity

Economics

Assuming a good supply of logs and markets, the economics of log sort yards is determined by

- log procurement costs (as reflected by stumpage, harvest, and haul costs),
- log market prices (freight on board (FOB)),
- per unit (volume) yard processing costs,
- dollar value recovery of log products sold (as a function of raw material cost), and
- log yard inventory cost, overhead charges, depreciation, and business taxes and fees.

Every consideration should be driven by the need to procure logs and process them at the lowest unit cost possible and minimize inventory and overhead costs (Mason 1998). At the same time, it is essential to recover the highest value from the logs processed in the yard. Focus should be on merchandising and sorting logs for highest net value products and negotiating the highest possible product prices in the log market to obtain the highest value.

Optimizing log making and sorting are keys to achieving the greatest overall potential value for logs. Consequently, optimizing overall potential value requires a sufficient volume of high-value logs in the total log mix processed through a log sort yard. The submarginal log is an economic problem for log sort yards (Hallock 1964). A submarginal log is one whose value is less than log procurement and variable processing costs. This is a major stumbling block in using small-diameter trees from forest fuels reduction and restoration projects proposed by the USDA Forest Service.

Effort expended processing logs should be in proportion to the value of the product. It makes no sense to spend $5 grading, scaling, and sorting a $4 log. Low-value, small-diameter logs need to be handled and processed quickly and efficiently. It is not critical that individual low-value logs be graded and scaled with great accuracy. Weight scaling (Fig. 14) and scaling stacked wood by cords is much less expensive than individually stick scaling (Fig. 4) every log. This helps control unit processing costs of low-value, high-piece-count, small-diameter wood, leading to improved efficiency and productivity.

Sorting tables, linear sorting systems, and log merchandisers in large log sort yards have also been effective in reducing unit cost of grading, scaling, and sorting low-value logs. Presorting low-value logs before they reach the log sort yard (for example, truckloads of pulpwood) also helps improve a yard's productivity and efficiency. Tracking measurement costs and productivity by piece rather than by volume further helps identify the marginal log.

For high-quality large logs, the opposite is true. Too often, too little time is spent grading, scaling, and sorting high-value logs. Value is lost at the expense of cost control to improve log sort yard operational efficiency. Opportunities to remanufacture and upgrade high-quality sawlogs (for example, merchandising sawlogs by bucking them into veneer logs) (Fig. 10) are also lost when insufficient effort is spent. This is even more important in specialty logs (for example, Sitka spruce music wood log and bird's eye and tiger stripe maple logs) whose value may be from one to several thousand dollars each.

The key to minimizing costs and recovering the highest value is log sort yard efficiency. The most important factor to reducing log-handling costs is to reduce the number of unnecessary moves in the log sort yard (Mason 1998).

Productivity

The log sort yard must carefully choose the measurement units that reflect log sort yard performance. Industry's traditional measure of log sort yard performance has been volume production. However, log sort yard productivity is much more sensitive to the number of pieces processed per day than the volume of logs processed per day. Volume production is really a function of log sort yard system design and materials-handling machine capacity. Performance should be based on the number of pieces processed per machine hour rather than on volume production.

Consequently, processing small logs (small diameter and short lengths) results in substantially lower volumes per day than larger and longer logs given the same log sort yard design and equipment. For example, it takes about four times as many 6-in. (15.2-cm) small end diameter (SED) logs to equal the same volume found in 12-in. (30.5-cm) SED logs of the same length (Barbour 1999).

A log sort yard that processes short small-diameter logs will be less productive than one of similar design processing longer large-diameter logs. Machinery requirements and number of employees are determined by the number of logs to be processed through a log sort yard. Volume as it relates to weight of logs processed per day identifies lifting and transporting capacity requirements of log handling equipment. Volume of wood is important for accounting purposes and valuation but is not a good measure for tracking log sort yard productivity.

Keys to a Successful Log Sort Yard

A successful log sort yard must not only meet its quality and productivity goals but always be striving to improve them. At the same time, the successful log sort yard must pay its way and be justified on a financial basis operating within available markets.

Establishing a successful log sort yard venture requires a well-conceived and researched business plan. One of the benefits of the business planning process is developing the strategic thinking used to determine the various controlling criteria and purposes of log sort yard functions. It furthers the thought process and helps make decisions about the goals of the log sort yard and how they will be achieved. The business plan includes a market and financial feasibility analysis, which helps avoid marginal investments and helps the prospective business owner carefully consider a number of critical factors for success. Effort here is well spent because it will reduce the risk of failure in the long term. Success also depends on a reliable source of raw material, product diversity, matching product to markets, and transportation infrastructure.

Log Sort Yard Business Plan

A business plan is essential for a log sort yard to gain financing, and it greatly increases the chances of success. Prior to a business plan, a feasibility study is done to look at potential viable business opportunities. Business plan development starts with a well-executed marketing and financial feasibility analysis to identify viable log sort yard opportunities. A business plan is generally required to secure venture capital.

Several critical factors deserve consideration in formulating the business plan (Eugene Davis, International Resources Unlimited, personal communication, 1995):

- Raw material resource (availability, price, location, quality, mix)
- Products (mix, differentiation, added value)
- Markets (share, competition, distance to markets, projected growth, specialty and commodity markets)
- Processing (technology, equipment, physical plant, automation, and manufacturing methods)
- Community (business-friendly, workforce skills, work ethic, school system, quality of life)
- Management (experience, knowledge, and understanding of business of log sort yards)
- Financing (financial statements, venture capital, fees, business taxes, incentives)
- Environment, health, and safety (regulations and licensing)

Raw Material Resource

Of primary interest to forest industry is raw material availability. Such things as the timber resource inventory, stumpage price, location in relation to manufacturing facilities, transportation infrastructure, availability of a sufficient and consistent timber supply, quality, and quantity of raw material (logs), the physical properties of the material, as well as any unique attributes can influence the product and its markets.

Products

Material properties help determine suitable products. In addition, such things as trends in the market place for various products, existing product shortages, (as well as resource shortages of a desired quality), and new technological developments can also provide options for potential products. An important consideration for a product is to meet the end-use performance requirements. Careful consideration of product mix and differentiation are crucial in today's markets.

Markets

In addition to raw material supply, markets, marketing, and market feasibility are important considerations to be looked at when evaluating business investment opportunities. Such things as market size and segmentation, as well as trends, competition, potential customers, potential market share, projected growth, specialty compared with commodity markets, and pricing all need to be carefully analyzed and evaluated. Market considerations also include a critical look at the industry itself: type of industry, competitors, wages and number of jobs, growth, and stability. Critical to the log sort yard is a diversified log market for consuming the various products produced from the available timber resource. Transportation infrastructure (truck, rail, and barge) as well as distance to markets are also crucial considerations.

Processing

Material processing is also a critical consideration for successful ventures. This includes available technology and equipment, physical plant and automation with high piece counts. In many cases, different raw materials have different processing technology requirements. In addition, appropriately scaled technologies for a particular product and application will be important for economic considerations. Some cases may require application of entirely new technologies.

Community

Community and workforce deserve some consideration in siting a log sort yard. Considerations include zoning, taxes, licenses, and tax incentives. Workforce aspects to consider include skills, school system–training, related experience (for example, heavy equipment or logging equipment operation), and work ethic.

Management

As with any business venture, the management team's abilities, knowledge, and practical experience are crucial. Individuals considering a log sort yard should take inventory of their own personal abilities as well as those of their management team with respect to running a log sort yard. This begins with an honest assessment of assumptions used in developing the business plan and carries through to the day-to-day operations.

Financing

In addition to a market feasibility study, a financial analysis of the potential business investment will assess profitability. The financial feasibility of the business investment involves the preparation of financial statements that cover all aspects of the financials, such as working capital requirements and after tax net cash flow (Robert Govett, University of Wisconsin–Stevens Point, personal communication, 2001).

Figure 24—Log sort yard debris makes up about 5% of the log volume processed. The problem of accumulation of log debris cannot be understated. Note the good log sort yard practice of placing decked logs on stringers and off the mineral soil.

Environment, Health, and Safety

Environmental, health, or safety issues could limit an otherwise successful venture. For example, concerns could arise about log yard debris (Fig. 24), log yard surface water runoff, safety issues, meeting standards and codes, etc. Regulations and permits are also important considerations.

All these factors are critical to successful log sort yard business ventures. The business plan must address all these factors before a venture capitalist will even consider investing in a business. The business plan provides your banker with a basis to evaluate your venture startup or expansion plans. Weaknesses and deficiencies will be pointed out in the business plan. A business plan is essential for a firm to gain financing, and it greatly increases the odds of success. The process begins with a well-executed feasibility analysis to identify viable opportunities for economic development.

Barriers to Successful Log Sort Yard Operations

In addition to lack of a well-conceived business plan and poor log yard management, there are four main challenges facing log sort yards. These are lack of (1) reliable source of raw material, (2) diversity of log products from woods-run logs, (3) diversified log markets, and (4) good transportation infrastructure.

Reliable Source of Raw Material

Guarantee of consistent timber supply is the long-term major overriding issue for establishing and maintaining a sustainable forest products industry. One primary objective of a log sort yard is to help smooth out log flow problems for consuming mills by providing a more consistent supply of desired log supply. This means that the log sort yard itself must have a good consistent supply of logs moving through its operations.

Log Product Diversity

The available log supply must have enough value in a diversity of log products from woods-run logs. For example, there must be enough high-value logs mixed with the low-value pulpwood to financially warrant sorting. A certain percentage of high-quality logs is required in the general supply of logs available to the log sort yard. A log sort yard takes advantage of sorting that is not possible at the log landing in the woods. The opportunity for a log sort yard lies somewhere in between having enough value in woods-run logs to justify a log sort yard and the motivation of the logger to sort logs at the landing. For example, the Lumby log sort yard (Wallowa Resources 1997) found that woods-run logs must contain 20% to 35% high-value logs to justify a log sort yard. This of course varies with economic conditions and markets.

Diversified Forest Products Industry Log Market

A diversified forest products industry, with the ability to utilize and market a variety of species and size classes, is key to successful log sort yards. This includes markets for disposing of residues like yard debris. Successful log yards service a range of forest products businesses using a variety of log products from veneer peelers to pulpwood. Success is predicated on getting logs to the best available market and realizing the most net value from those logs. The purpose of the log sort yard is to provide a more stable wood supply of the right product mix to many industries. Markets must also be matched up with products from the available timber resources.

Transportation Infrastructure

Distance to markets and lack of transportation infrastructure are barriers to success. Transportation infrastructure is a crucial consideration in siting a log sort yard. Today, logs are being moved greater distances from forest to mill. Poor transportation infrastructure and high transportation costs limit options to move products to market. Terminal facilities (such as truck and rail log-reload facilities) need to be identified and established to improve transportation of logs to market.

Concluding Remarks

While commercial log sort yards both large and small have enjoyed success, sort yards operating other than for profit or as a commercial venture (for example, community and government run yards) have not had much success for a number of reasons. The Libby, Montana, log sort yard struggled with low log procurement volumes, and the Rogue Institute in southern Oregon was unable to get sufficient support for their proposed nonprofit log sort yard. Beyond the four specific barriers mentioned, additional specific barriers confront applications of the log sort yard concept. There are perhaps several resource supply, technical, marketing, financial, and Forest Service policy barriers to overcome. At this time, not much is known about these barriers. Some examples of these barriers are poor market prices, poor log quality, and too expensive to process. The USDA Forest Service policies include chain of custody issues, inability to guarantee a long-term supply, and issues regarding stewardship contracting (that is, combined forest restoration with timber sale authorities).

In Canada however, the Ministry of Forestry has successfully operated a government log sort and sales yard since 1995 in Lumby, British Columbia. Similar pilot projects could be pursued in the United States. The Watershed Research and Training Center in Hayfork, California, is also pursuing a community-based log sort yard project. They are working to overcome barriers to success for this project.

While the USDA Forest Service project is oriented toward the small log sort yard to help timber-dependent rural communities recover from changes in timber supply, the information will apply to large commercial log sort yard operations as well. Our log sort yard project seeks to identify and overcome barriers and document successes in an effort to help meet the needs described in this report. Findings presented in this report have broad application to industry, community, and government-run log sort yards. Future publications will include a report on determining log sort yard feasibility and another on the design, layout, construction, and operation of small-scale log sort yards.

Log sort yards should provide better utilization and marketing with improved value recovery of currently available timber resources in North America. Log sort yards provide many services in utilization and marketing wood and fiber by concentrating, merchandising, sorting, and adding value to logs. Such operations supply forest products firms with a more desirable log mix suited to their operations. This can help the sawmill and plywood plant reduce the number of marginal logs processed in their operations, recover higher value per unit, and improve bottom line performance. Benefits of log sort yards include the potential for more accurate grading, scaling, and sorting; the opportunity to merchandise logs into higher value products; and the opportunity to capture a higher value from otherwise low-grade woods-run logs.

The goal of a log sort yard is to improve the quality and productivity of log sorting and distribution through improved utilization and marketing. Ultimately, improvement results in better timber resource utilization and better bottom line business performance. The objective of a log sort yard is to help maximize the return of the investment through improved log merchandising, grading, scaling, sorting, adding value, marketing, and distribution. When this objective is met, the log sort yard achieves increased log value. Improved efficiency produces cost savings and results in increased value per volume. Improved utilization and efficiency lead to improved productivity and quality in the forest products industry.

References

Barbour, J.R. 1999. Relationship between diameter and gross product value for small trees. In: Proceedings from Wood Technology Clinic and Show Conference, Portland, OR. San Francisco, CA: Miller Freeman Publications.

Dramm, J.R. 1999. Small-diameter issues and opportunities. In: Proceedings from Wood Technology Clinic and Show Conference, Portland, OR. , San Francisco, CA: Miller Freeman Publications.

Dramm, J.R.; Jackson, G. 2000. Is it time to revisit the log-sort yard? In: Proceedings from Wood Technology Clinic and Show Conference, Portland, OR. , San Francisco, CA: Miller Freeman Publications.

Forest Products Laboratory. 2000. Forest Products Laboratory research program on small-diameter material. Gen. Tech. Rep. FPL–GTR–110 (rev.). Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 31 p.

Hallock, H. 1964. Some thoughts on marginal sawlogs. Forest Products Journal. 14(11): 535–539.

Hampton, C.M. 1981. Dry land log handling and sorting: Planning, constructing, and operation of log yards. San Francisco, CA: Miller Freeman Publications, Inc. 215 p.

Mason, H.C. 1998. Small log processing. In: Proceedings from Wood Technology Clinic and Show Conference, Portland, OR. San Francisco, CA: Miller Freeman Publications.

Rosholt, M. 1980. The Wisconsin logging book, 1839–1939. Rosholt, WI: Rosholt House. 300 p.

Sinclair, A.W.J.; Wellburn, G.V. 1984. A handbook for designing, building, and operating: a log sort yard. Vancouver, B.C., Canada: Forest Engineering Research Institute of Canada. 285 p.

Wallowa Resources. 1997. The potential of log sort yards: Lessons from Libby, Montana and British Columbia. Wallowa Resources Rep. 2. Enterprise, OR: Wallowa Resources.

Williston, E.M. 1988. Lumber manufacturing: The design and operation of sawmills and planer mills (rev.). San Francisco, CA: Miller Freeman Publications, Inc. 486 p.

Appendix: Selected Bibliography of Log Sort Yard and Related References

Categories

Log Sort Yards

Log Rules and Scaling

Log Grading

Economics–Costs–Productivity

Marketing

Exporting

Debris–Disposal and Use of Residues

Bucking and Merchandising–General

Optimal Softwood Bucking

Hardwood Bucking

Log Manufacture

Harvest–Logging–Timber Sales

Transportation–Loading and Unloading

Log Allocation

Log Procurement

Inventory Control and Storage

Protection and Insect Control

Debarking, Chipping, Hogging, and Grinding

Miscellaneous

Log Sort Yards

Broad, L.R. 1989. Note on log sort yard location problems. Forest Science. 35(2): 640–645.

> Sort yards placed either at forest locations or at locations between forest and utilization sites may be used to sort logs into log types that are more consistent with their final form of utilization. This sorting procedure has the potential to increase returns from log scales. A formulation of the inherent location problem as a Mixed Integer Linear Program (MILP) is presented.

Grace, L.A. 1993. Evaluating a prototype log sorting system for use in pine sawmills. Rep. 237. Uppsala, Sweden: Sveriges Lantbruksuniversitet. Institutionen for virkeslara, 43 p.

Hampton, C.M. 1981. Dry land log handling and sorting: planning, construction, and operation of log yards. San Francisco, CA: Miller Freeman. 215 p.

Oregon State University. 1977. Sort yards of the Northwest. Proceedings of a conference, Forestry Program, Oregon State University; 1977 April 4–6; Corvallis, OR. Corvallis, OR: Oregon State University, Forestry Extension: 250 p.

Paredes, G.; Sessions, J. 1988. A solution method for the transfer yard location problem. Forest Products Journal. 38(3): 53–58.

> A procedure is presented to solve for the most efficient forest transportation system given alternative modes of wood transportation and choices in the location of wood transfer yards. The transfer yard location problem is a special case of the facilities location problem. It is generally solved for as a linear mixed-integer problem, but for large problems, that approach presents computational difficulties because of the many integer variables required to model yard locations. The procedure proposed here consist of a screening of the feasible location nodes, followed by a breakdown of the problem that exploits its structure, and an efficient heuristic to solve for fixed charge problems. The procedure greatly reduces the computational complexity of the problem and makes it possible to solve for the most efficient design in large-scale networks and transportation plans.

Sessions, J.; Garland, J.J.; Paredes, G. 1988. Identifying sort yard locations with size dependent processing costs. In: Kent, B.M.; Davis, L.S., eds. The 1988 symposium on systems analysis in forest resources; 1988 March 29–April 1; Pacific Grove, CA. Gen. Tech. Rep. RM–161. Fort Collins, CO: Rocky Mountain Forest and Range Experiment Station: 245–250.

> Sort yards placed at selected intermediate points between timber cutting sites and mills have the potential for increasing the value of logs or trees destined for processing into different products. A two-phase modeling procedure is presented for identifying the efficient placement of sort yards using computations much simpler than those in standard linear mixed-integer programming methods.

Sinclair, A.W.J.; Wellburn, G.V. 1984. A handbook for designing, building and operating a log sortyard. Vancouver, BC: Forest Engineering Research Institute of Canada. Ch. 7. 285 p.

Winzler and Kelley Consulting Engineers. 1978. Tribal log sorting facility and forest regeneration complex. Tech. Assistance Rep. for the Hoopa Valley Business Council. Hoopa, CA: Hoopa Valley Business Council. Eda Title IX Project No. 07–19–01796. Bibliography, P. (C11–C12). 253 p.

Log Rules and Scaling

Anderson, B. 1990. Video-assisted log scaling. Field Note, General 14. Vancouver, BC: Forest Engineering Research Institute of Canada, Western Division. 2 p.

Dilworth, J.R. 1981. Log scaling and timber cruising. Corvallis, OR: Oregon State University. 468 p.

Fahey, T.D.; Snellgrove, T.A.; Cahill, J.M.; Max, T.A. 1981. Evaluating scaling systems. Journal of Forestry. 79(11): 745–748.

A proposed method of analyzing scaling systems consists of two parts. Part I applies only to sound logs and compares the precision of scaling systems using the relationship between lumber recovery and scaled volume. Part II uses only defective logs to compare the abilities of scaling systems to adjust volume for defect.

Freese, F. 1974. A collection of log rules. Gen. Tech. Rep. FPL–1. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 65 p.

Presents a brief description of a number of log rules that have been used in the United States and Canada. Also describes some general volume formulae, lumber measures, and foreign log rules.

Markstrom, D.C.; King, R.M. 1993. Cubic foot/weight scaling of Rocky Mountain area sawtimber. Res. Pap. RM–31. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 9 p.

Cubic-foot/weight scaling of short ponderosa pine and white spruce logs required less than half the number of truckloads to be both weighed and stick scaled as compared with the number required for Scribner board-foot/weight scaling. Cubic-foot/weight scaling of long Engelmann spruce and white fir logs resulted in 19% fewer loads to be weighed and stick scaled as compared with the number required for Scribner board-foot/weight scaling. The study showed that ratio weights need to be recalculated depending upon changes in timber size and woods storage time.

McKinney, C.; Lenhart, J.D.; Cook, D.F. 1992. Topwood component of truckloads of tree-length pine stems in east Texas. Forest Products Journal. 42(7/8): 29–30.

The expected weight of the topwood component of truckloads of tree-length southern pine stems can be calculated using observed total weight of stems, observed total number of stems, and predicted weight of the sawlog proportion of the stems. By subtracting the predicted weight of the sawlog portion of the stems from the observed weight of the total stems, the expected weight of the topwood component of the stems can be obtained.

Plank, M.E.; Cahill, J.M. 1984. Estimating cubic volume of small diameter tree-length logs from ponderosa and lodgepole pine. Res. Note PNW–417. Portland, OR: Pacific Northwest Forest and Range Experiment Station. 7 p.

A sample of 351 ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and 509 lodgepole pine (*Pinus contorta* Dougl. ex Loud.) logs were used to evaluate the performance of three commonly used formulas for estimating cubic volume. Smalian's formula, Bruce's formula, and Huber's formula were tested to determine which would provide the best estimate of cubic volume when it was applied to tree-length logs. Smalian's formula overestimated the volume by 19%, Bruce's formula underestimated by 16%, and Huber's formula underestimated by 2%. Huber's formula provided the closest estimate and is recommended. Accuracy and bias tests are shown.

United States Forest Service. 1970. Log volume tables. Scribner decimal C log rule, maximum scaling length 20 ft. Tabulations include 2 to 21 ft logs, Diameters 3 to 120 in., 22 to 80 ft logs, diameters 6 to 65 in. San Francisco, CA: U.S. Forest Service, Region 5, Division of Timber Management. 62 p.

United States Forest Service. 1973 National forest log scaling handbook. Washington, DC: U.S. Government Printing Office. 184 p.

Van Deusen, P.; Watson, W.F.; Evans, J. 1981.Predicting board foot volume from the weight of a load of logs. Mississippi State, MS: Mississippi Agricultural and Forestry Experiment Station. 14 p.

Wiant, H.V. 1992. An inexpensive computer system for estimating the volume and value of logs. West Virginia Forestry Notes. Circular 155. 14: 18–19.

Log Grading

Anderson, I.V. 1934. Log grades for ponderosa pine; a statement of specifications describing the four log grades and illustrated by photographs. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Rocky Mountain Forest and Range Experiment Station. 14 p.

Hanks, L.F.; Gammon, G.L.; Brisbin, R.L.; Rast, E.D. 1980. Hardwood log grades and lumber grade yields for factory lumber logs. Res. Pap. NE–RP–468. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 92 p.

The U.S. Department of Agriculture Forest Service Standard Grades for Hardwood Factory Lumber Logs are described, and lumber grade yields for 16 species and 2 species groups are presented by log grade and diameter. The grades enable foresters, log buyers, and log sellers to select and grade those logs suitable for conversion into standard factory grade lumber. By using the appropriate lumber grade yields, log buyers and sellers can appraise the logs in terms of expected lumber grade volume and value. This report supersedes an earlier report on hardwood log grading, Forest Research Paper FPL–63.

Kenna, K.M. (ed.) 1981.Grading hardwood logs for standard lumber: Forest Service standard grades for hardwood factory lumber logs (Rev.). Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 19 p. (Originally published as Publication D1737 — At Forest Products Laboratory, U.S. Department of Agriculture, Forest Service.)

Kenna, K.M. 1991. Hardwood log grades. Management Bull. R8. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region, Cooperative Forestry. 2 p.

Land, P.H.; Woodfin, R.O., Jr. 1977. Guidelines for log grading coast Douglas-Fir. Res. Pap. PNW–218. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest.14 p.

This report is a photographic guide to the application of the new four-grade system for cruising Coast Douglas-fir. It is intended as both a training aid and illustration of features that lower grades.

Northeastern Loggers' Association. 1991. Log rules and other useful information. Old Forge, NY: Northeastern Loggers' Association. 28 p.

Judging by the number of calls that the Northeastern Loggers' Association has received in recent years regarding log scaling rules and conversions from English to metric, there is a vacuum in the information available to people in the logging and lumber business. We consulted a number of sources and have attempted to put a lot of good information under this one cover.

Rast, E.D. 1973. A guide to hardwood log grading (Rev.). Upper Darby, PA: Northeastern Forest Experiment Station. 32 p.

Stump, W.G.; Ralston, R.A.; Arend, J.L. 1953. Log grading starts in the woods. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Lake States Forest Experiment Station. 1 p.

Wengert, E.M.; Meyer, D.A. 1994. Guidelines for grading hardwood logs. Madison, WI: University of Wisconsin-Extension, Cooperative Extension Programs. 5 p.

Economics–Costs–Productivity

Berndt, E.R. 1979. Estimation of logging costs and timber supply curves from forestry inventory data. Resources Pap. 39. Vancouver, BC: University of British Columbia. Department of Economics, 15 p.

Bushman, S.P.; Olsen, E.D. 1988. Determining costs of logging-crew labor and equipment. OSU Forest Research Laboratory Res. Bull. 63. Corvallis, OR: Oregon State University. 22 p.

Gingras, J.–F. 1996. The cost of product sorting during harvesting. In: Proceedings of the meeting on planning and implementing forest operations to achieve sustainable forests. Gen. Tech. Rep. NC–186. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 130–135.

Integrating harvesting with the sorting of multiple products is a reality that many companies and their contractors must adapt to. This separation of products can be performed at several stages during harvesting. This report combines the results of published and unpublished studies to describe the advantages and disadvantages of separating two or more products using the various machines in full-tree, tree-length and cut-to-length harvesting systems. The cost of separating six products is simulated with three different harvesting systems.

Heaps, T. 1988. Econometric analysis of log production in coastal British Columbia. Forest Economics and Policy Analysis Project FEPA. FEPA Working Pap. 108. Vancouver, BC: University of British Columbia. 41 p.

Sinclair, A.W.J. 1980. Evaluation and economic analysis of 26 log-sorting operations on the coast of British Columbia. Vancouver, BC: Forest Engineering Research Institute of Canada. 47 p.

Sinclair, A.W.J. 1982. Productivity of five coastal B.C. log sorting systems. FERIC Technical Note TN–64. Pointe Claire, QC: Forest Engineering Research Institute of Canada 37 p.

Withycombe, R.P. 1982. Estimating costs of collecting and transporting forest residues in the Northern Rocky Mountain Region. Gen. Tech. Rep. INT–GTR–81. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 12 p.

A model is presented for computing the costs of harvesting forest residues, based on several key characteristics of the residues and the logging area. Costs per unit are presented in tabular form for several alternative harvesting methods.

Marketing

Anderson, S.; O'Hara, T.J. 1995. Timber marketing 101: the basics. Forest Farmer. 54(3): 42–48.

> Selling timber can be a rewarding experience for some timberland owners while a traumatic experience for others. Landowners who do a thorough job of planning, preparation and marketing usually are satisfied with a timber harvest from their property; and those who did not prepare for a timber sale are likely to be dissatisfied with the harvest. They may receive a fraction of the timber's true value because they did not know what volumes or products they had or they did not market it effectively. Many problems encountered by landowners during a timber harvest can often be avoided by obtaining assistance from a professional forester. This article presents guidelines to assist individuals in marketing timber from their woodlands. It should not be a substitute for advice and assistance provided by a professional forester.

Berg, D.R.; Schiess, P. 1994. A procedure for estimating logging costs associated with structural retention: a market analysis approach. In: Proceedings of the meeting on advanced technology in forest operations: Applied ecology in action; 1994 July 24–29;Corvallis, OR. Portland–Corvallis, OR: Oregon State University: 58–69.

Constantino, L.F. 1988. Sawlog prices and quality differences in Canadian and United States coastal log markets. Canadian Journal of Forest Research. 18(5): 540–544.

> This paper introduces a methodology grounded on economic theory for comparing wood quality between regions. The methodology, which is based on index numbers, is applied to data on volumes and prices of sawlogs traded in the Canadian and United States Pacific Coastal Log Markets from 1957 through 1982. The quality of sawlogs traded was found to be higher on average in the United States than in Canada, but the U.S. advantage declined over time. The measure of wood quality is then used to adjust average log market prices for quality differences. Contrary to U.S. claims, the U.S. industry enjoyed a wood cost advantage during most of the sample period. The lower price of wood in Canada could be explained by its lower quality.

Kenna, K. 1994. Product quality and marketing. In: Southern hardwood management. Management Bull. R8; 67. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region, Cooperative Extension Services: 87–101.

> It is not the intent here to detail explicitly all hardwood product grading systems. Such a task could cover volumes in itself. Since over half of all hardwood log production is destined for factory lumber, this chapter will concentrate on describing a system of grading for this product alone. This type of log is adapted to the production of boards that later can be remanufactured so as to remove defects and yield smaller strips of clear wood. An examination of almost any piece of solid hardwood furniture will demonstrate how these strips have been further utilized by edge-gluing to produce drawer fronts, table tops, chair seats and bed rails. It is important to note that any log suitable for sawing into factory lumber may also be suitable for firewood, pulpwood, veneer, or specialty products. It cannot be emphasized enough that a thorough investigation of local market conditions is necessary in order to know which log classification will generate the highest income and return on investment.

Olsen, R.A.; Terpstra, R.H. 1981. An application of capital asset pricing to the spot market for softwood logs in Oregon. Forest Science. 27(1): 215–223.

> This study utilizes the Capital Asset Pricing Model to analyze risk, return, and competition in a major spot log market in Oregon for 1968–1978. Holding period returns on thirteen individual log species and grades were calculated using actual log sales prices and storage costs. In general, the results suggest that the market is competitive and that log investors earn a return, which approximates the yield on U.S. Treasury bills. In addition, log returns do not appear to exhibit any significant amount of systematic or "market related" risk.

Tooch, D.E. 1995. Create a market and then corner it. Northern Logger and Timber Processor. 44(4): 20–22.

Van Goethem, L. 1995. What happened to the markets? What happened to the prices? Northern Logger and Timber Processor. 44(3): 28–29.

> The logging industry got a nasty surprise from the Easter Bunny last spring. After sailing along on the crest of historic high prices for pulpwood and sawlogs, the market got squishy and began to sink. It happened fast and has led to curtailed production and layoffs. The crunch was triggered by a glut of sawlogs and pulpwood, but it's worse than that. While pulp prices held fairly steady, the mills cut back on purchases while stumpage, at least in the Lake States, remain high.

Zhang, D.; Binkley, C.S. 1994. The informational efficiency of the Vancouver Log Market and the financial risk of holding logs in storage. Canadian Journal of Forest Research. 24(3): 550–557.

> Viewed on an annual or quarterly basis, the Vancouver Log Market appears to process price information efficiently, but apparently does not do so for monthly trading intervals. For the longer holding periods the Vancouver Log Market passes one of the fundamental tests for an efficient market, and as a consequence

there are few gains to make by speculating in this market on the basis of technical analysis of past price movements. Explanations for lack of information efficiency in the monthly returns requires further study. Holding logs does not appear to entail a significant amount of systematic or market risk if the holding periods are one quarter or less. Producers can hold log inventories in the Vancouver Log Market without increasing the financial risk of their enterprises.

Exporting

Dean, W. 1993. Log exports: is the tide turning? American Forests. 99(3/4): 49–52.

Even after a century of intensive logging, the forests of the Pacific Northwest contained astronomical volumes of old-growth timber in the 1950s. Large landowners, wanting to capture the value of the resource and restart the growing cycle with vigorous young trees, found their best market in the export of logs, initially to Japan. For more than 30 years, log exports have been an important source of revenue for the landowners, and integral part of U.S. foreign trade policy, and a source of often bitter controversy because many in this country believe the logs should be processed in the U.S. The importing nations were willing to pay 25% to 30% more for the logs than U.S. mills would. In recent years, this premium has often been around $150 per thousand board-feet. There was even a brief period when the export price was over 66% more than domestic mills would pay. Since markets for western timber are driven by price, the logs flowed naturally toward the fleets of ships specially designed and built to carry them across the Pacific. In most years, the log volume shipped across the Pacific exceeded 3 billion board-feet. It reached more than 4.5 billion board feet in both 1988 and 1989. However, exports began to decline in 1990 and continued to slip through 1992 as high U.S. prices drove the importing nations to other suppliers. Meanwhile, restrictions on logging in the federal forests imposed to protect the habitat of endangered species, most notably the spotted owl-have resulted in severe wood shortages among domestic mills. As a result, sawlog prices are 35% to 50% higher than at the end of the 1980s, creating a domestic market that competes effectively with overseas buyers. In short, the northern spotted owl and market forces may be achieving what decades of political activism could not.

Flora, D.F.; Anderson, A.L.; McGinnis, W.J. 1991. Future Pacific Rim flows and prices of softwood logs, differentiated by grade. Res. Pap. PNW–RP–433. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

By 2000, prices are expected to rise significantly for medium-grade logs and modestly for low-grade logs. World economic cycles may obscure, however, the upward price trends. Exports from the United States of medium grades are expected to remain stable, while volumes of lower grades are projected to remain level through 1995 and then decline because of competition.

Flora, D.F.; Anderson, A.L.; McGinnis, W.J. 1991. Pacific Rim log trade: determinants and trends. Res. Pap. PNW–RP–432. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 72 p.

Pacific Rim trade in softwood logs amounts to about $3 billion annually, of which the U.S. share is about $2 billion. Log exporting is a significant part of the forest economy in the Pacific Northwest. The 10 major Pacific Rim log-trading client and competitor countries differ widely in their roles in trade and in their policies affecting the industry.

Flora, D.F.; McGinnis, W.J.; Lane, C.L. 1993. The export premium: why some logs are worth more abroad. Res. Pap. PNW–RP–462. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 18 p.

For as long as logs have been exported from the Pacific Northwest, they seem to have been worth more offshore than in the domestic market. Five reasons for the export premium are the inconvenience of trade, quality, extra "haul and hassle," continuity in export arrangements, and export embargoes. A large and increasing differential remains between export and domestic prices for comparable logs in high grades. Logs of lower quality do not seem to have a dual price structure, and there appears to be a declining premium for logs overall. Year-to-year fluctuations in the premium can be considerable, however, and trade policy changes typically affect the export premium more, proportionately, than they affect export volumes.

Gruenfeld, J.; Flynn, B. 1990. Log exports: an update. American Forests. 96(9–10): 50–53, 74–76.

Exporting unprocessed logs has been controversial in the United States since the early 1960s. As timber-supply shortages force some mills in the Pacific Northwest to close because of higher log prices, the controversy grows even more rancorous. Are log exports to blame for the timber shortage? Does exporting logs equate to exporting jobs, or are log exports an important part of this nation's timber industry? Here, in addition to explaining some of the characteristics of the log-export industry, we'll discuss some of the arguments for and against allowing this practice to continue.

Luppold, W.G. 1994. The U.S. hardwood log export situation: what is the problem? Forest Products Journal. 44(9): 63–67.

The export of domestically produced hardwood logs continues to be a divisive issue within the U.S. hardwood industry. Although many sawmill and veneer mill operators feel that log exports have increased log prices to unacceptable levels, others within the industry feel logs should continue to be sold to the highest bidder. This paper discusses the hardwood log export issue by examining changes in exports and the factors that have caused these changes.

Luppold, W.G.; Thomas, R.E. 1991. New estimates of hardwood-log exports to Europe and Asia. Res. Pap. NE–659. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 24 p.

Current and historic estimates of hardwood log exports to Europe and Asia are in error because of a combination of reporting errors and computer programming problems at the U.S. Department of Commerce. This paper discusses past problems with log export data, explains how a new set of hardwood-log export statistics were developed, and provides a detailed set of new hardwood-log export estimates for European and Asian markets.

USDA. 1994. Importation of logs, lumber, and other unmanufactured wood articles. Washington, DC: United States Department of Agriculture. Animal and Plant Health Inspection Service Federal Register. 28 p.

Warren, D.D. 1989. Log exports by port, 1987. Res. Note PNW–RN–492. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 26 p.

Volumes and average values of log exports by port have been compiled by quarter for 1987. The tables show the four Northwest customs districts by ports, species, and destinations. These data were received from the U.S. Department of Commerce too late to be published in the 1987 quarterly reports, "Production, Prices, Employment, and Trade in Northwest Forest Industries."

Debris–Disposal and Use of Residues

Adams, T.C.; Smith., R.C. 1976. Review of the logging residue problem and its reduction through marketing practices. Gen. Tech. Rep. PNW –48. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 22 p.

This study notes the increasing concern over logging residue in forestland management and describes the various administrative and technological means for accomplishing reductions of logging residue. Alternative sales arrangements can include such things as reduction of stumpage charges for low quality logs or required yarding on utilized material to the landing or to some stockpiling or disposal point. Improvements in materials handling can include use of logging systems that create less breakage or that can handle small pieces more efficiently. Specialized chip mills and increased chip markets, including chip exports, can give added incentive for removal of formerly unutilized material. Other potentials for utilization are also indicated.

Campbell, A.G.; Tripepi, R.R. 1992. Logyard residues: products, markets, and research needs. Forest Products Journal. 42(9): 60–64.

Disposal of log yard residues is a critical problem facing the forest products industry, and new uses should be examined. In the future, screening and classification of residues will commonly separate the rock, bark, and fines (organic matter and soil) into useful fractions. Composting processes will likely be used to reduce volume and mass while creating a more stable material for horticultural and agricultural applications. Composted and uncomposted residues could be used as cover for revegetating landfills, as soil amendments to enhance productivity of marginal farmland, as mulch for landscape beds and walkways, and as soil cover for mud and erosion control. Research is needed to develop a composting process, establish compost quality standards, and create markets for classified residue products. Research involving greenhouse and field growth of plants should evaluate composted and uncomposted residues as a substitute for bark and peat moss in container media and as a mulch or soil amendment for heavy-metal-contaminated soils and marginal farmland.

Forrester, P.D. 1991. Potential for separating logyard debris in Alberta. FERIC Special Rep. SR–80.Vancouver, BC: Forest Engineering Research Institute of Canada. 20 p.

In November 1990, logyard debris at Weldwood Canada Limited's operation at Hinton, Alberta, was assessed to determine the type and quantity of the material being generated. This report documents the results, quantifies the amounts of reclaimable fibre and rock, and outlines the potential costs involved in reclaiming, rather than landfilling, the debris. This project was funded by: Forest Industry Development Division of Alberta Forestry, Lands and Wildlife; Weldwood of Canada Limited (Hinton Division); and the Forest Engineering Research Institute of Canada (FERIC).

Forrester, P.D. 1992. Systems for logyard debris separation and product reclamation. Field Note General–25.Vancouver, BC: Forest Engineering Research Institute of Canada. 2 p.

Forrester, P.D. 1998. Observations of a Morbark Model 1200 tub grinder processing log sortyard residues for composting. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 4 p.

During April of 1997 the Forest Engineering Research Institute of Canada (FERIC) observed a portable tub grinder processing log sortyard residues in British Columbia on the west coast of Vancouver Island. The resulting material was composted with fish-processing residues and will be used in the rehabilitation of deactivated forest roads. FERIC observed the productivity and costs associated with the grinding operation and transportation of the ground wood to the composting site.

McWilliams, J. 1992. Log yard debris: the ultimate solution. Canadian Forest Industries. p. 16, 18. (Jan./Feb.).

Mitchell, P.; Spitler, M.; Buder, M. 1996. Description and performance of log yard debris separation systems. In: Proceedings of the 1994 Forest Products Society Southeastern Section workshop on environmental quality in wood processing. Proceedings 7295. Madison, WI: Forest Products Society: 102–114.

Sinclair, A.W.J. 1981. Utilization of coastal British Columbia log sortyard debris. Vancouver, BC: Forest Engineering Research Institute of Canada. 68 p.

Sinclair, A.W.J.; Goater, G.H.; Wakefield, D.C. 1988. Disposal of logyard waste in a high-pressure, underfire pit burner. Tech. Rep. TR–78. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 18 p.

Smith, D.G. 1977. Log-sort yard debris: composition and source. FERIC Tech. Rep. TR–14. Vancouver, BC: Forest Engineering Research Institute of Canada. 14 p.

Bucking and Merchandising—General

Grace, L.A. 1993. Exploring the potential of using optical log scanners for predicting lumber grade. Forest Products Journal. 43(10): 45–50.

Swedish softwood sawmills have traditionally sorted logs into relatively homogeneous size classes to facilitate downstream production processes. Sorting is normally based on top-end diameter classes as determined by optical log scanners. The purpose of this study was to determine the feasibility of using conventional optical log scanners to determine log quality. A total of 300 debarked Scots pine (*Pinus sylvestris*) sawlogs delivered to a large sawmill in northern Sweden were scanned using the dual-axis scanner installed at the mill. Log profiles, consisting of diameters measured in two directions to the nearest millimeter every second centimeter along the log diskette. The scanned logs were sawn and the resulting lumber graded. The scanned profile data were used to develop computer algorithms describing various parameters of log geometry including: taper in different sections of the log, surface roughness, sweep, and eccentricity. Parameters describing the shape of each log were combined with the lumber grade information to determine which parameters indicated lumber quality. Taper in the large end was found to be a good indicator of log position, which can indicate lumber within position classes, but neither sweep nor eccentricity demonstrated any relationship with lumber grade. These results have been used to develop a log sorting algorithm to automatically identify and sort logs with the geometric features associated with grade recovery.

Grondin, F. 1998. Improvements of the dynamic programming algorithm for tree bucking Wood and Fiber Science. 30(1): 91–104.

Log bucking is one of the most important operations in the transformation of trees into lumber. A bad decision at this stage can jeopardize the optimal recovery in volume or in value. The problem of optimizing the recovery during the bucking process has been solved using, among other things, dynamic programming. This article describes the main approaches and suggests some improvements to the dynamic programming approach. By introducing certain assumptions into the dynamic programming algorithm formulation, this approach becomes both more realistic and more efficient. The algorithm defined here is used in an integrated bucking-breakdown model. Example simulations demonstrate the computational speed improvements that result from the introduction of the assumptions.

Hardison, L.D. 1995. Bucking takes on high-tech perspective. Southern Lumberman. 256(5): 31–37.

Koch, C. 1978. Improving volume recovery in logging operations using felling and bucking evaluations from the improved harvesting program. Phoenix, AZ: Arizona State Land Department. Arizona Landmarks. Vol. 8, Book 4. 49 p.

Maness, T.C.; Adams, D.M. 1991. The combined optimization of log bucking and sawing strategies. Wood and Fiber Science. 23(2): 296–314.

Determination of optimal bucking and sawing policies is linked in a common model. The core of this model is a linear program (LP) that selects stem bucking and log sawing policies to maximize profits given an input distribution of raw material. Product output is controlled by price–volume relationships that simulate product demand curves. The model uses a three stage solution process performed iteratively until identical solution bases are obtained. A variation of the Dantzig–Wolfe decomposition principle is used, linking the three models through the use of the

Lagrange multipliers from the LP. The procedure is demonstrated for a sample sawmill. The revenue gain from using the policies suggested by the integrated model over those found by the bucking and sawing programs working separately was found to be 26% to 36%.

Olsen, E.D. 1991. Evaluating timber sale bids using optimal bucking technology. Corvallis, OR: Oregon State University. Forest Engineering Department. 5 p. (Reprint from Applied Engineering in Agriculture 7(1): 131–136).

This study documented and field tested a method of using optimal bucking procedures to aid in cruising and stand value appraisals. The CRUISE/BUCK method can estimate the type of logs which should be cut from a stand and evaluate the potential revenue if different sets of mills are chosen as the purchasers. This type of pre-harvest analysis can aid managers in how to "merchandize" the stand. Alternative methods of collecting diameter measurements were compared.

Olsen, E.D.; Pilkerton, S.; Garland, J. 1991. Questions about optimal bucking. Res. Bull. 71. Corvallis, OR: Oregon State University, College of Forestry, Forest Research Laboratory. 18 p.

Optimal Softwood Bucking

Bowers, S. 1998. Increased value through optimal bucking. Western Journal of Applied Forestry. 13(3): 85–89.

Garland, J.; Sessions J.; Olsen, E.D. 1988. Optimal bucking at the stump. High technology in forest engineering. In: Proceedings of the Council on Forest Engineering, 10th annual meeting; 1987 August 3 to August 6; Syracuse, NY. Syracuse, NY: College of Environmental Science and Forestry: p. 239–247.

Garland, J.; Sessions J.; Olsen, E.D. 1989. Manufacturing logs with computer-aided bucking at the stump. Forest Products Journal. 39(3): 62–66.

Computer-aided bucking of western Oregon old-growth and second-growth Douglas-fir (*Pseudotsuga meziesii* [Mirb.] Franco) was tested for the ability of the computer to determine various log mixes. Techniques were developed to predict log grades from observed surface characteristics. The increase in log volume was negligible, but the computer solution shifted a large percentage of volume from low-value to high-value logs. Value increases were 14.2% for 50 old-growth trees and 11.9% for 100 second-growth trees. Values were decreased by preferred-length restrictions.

Murphy, G.E.; Olsen, E.D. 1988. Value recovery from trees bucked on a landing and at the stump. Forest Products Journal. 38(9): p. 49–52.

Comparison of the value of logs from a radiata pine (*Pinus raditata* D. Don) plantation in steep terrain in New Zealand indicated a significant difference in the performance of log manufacturers working at the stump, but no difference in their performance on a landing. Value recovery on the landing was significantly better than value recovery at the stump for one log manufacturer. A major source of value loss came from downgrading potential peeler logs to sawlog grades, and sawlogs to pulpwood. Log manufacturers working on the landing produced more logs that met specifications than did those working at the stump. Much of the reduction in out-of-specification logs resulted from improved accuracy in judging length.

Olsen, E.; Stringham, B.; Pilkerton, S. 1997. Optimal bucking : two trials with commercial OSU BUCK software. Corvallis, OR: Oregon State University, College of Forestry, Forest Research Laboratory. 32 p.

Olsen, E.; and others. 1991. Computer aided bucking on a mechanized harvester. Journal of Forest Engineering. 2(2): 25–32. (Jan.)

Sessions, J. 1988. Making better tree-bucking decisions in the woods. Journal of Forestry. 86(10): 43–45.

Sessions J.; Garland, J.; Olsen, E.D. 1989. Testing computer-aided bucking at the stump. Journal of Forestry. 87(4): 43–46.

The possibility of improving log-value recovery through improved bucking practices has motivated much recent research (Briggs 1980, Geerts and Twaddle 1985, Lembersky and Chi 1987, Murphy 1987, Prevmaticos and Mann 1972, Threadgill and Twaddle 1986). Weyerhaeuser has claimed to have saved more than $100 million over a 7-year period through more efficient bucking. Improvements in the processing speed and memory capability of handheld computers raises the possibility of these computers being used to help make bucking at the stump more productive. In 1987, Oregon State University tested the potential gains in value with computer-assisted bucking in old-growth and second-growth Douglas-fir timber stands, and then added the cost of using a computer. Both types of stands were investigated because old-growth and second-growth stands have wide differences in potential value. The old growth has more marketing options and potential bucking patterns.

Sessions, J.; Olsen, E.D.; Garland, J. 1989. Tree bucking for optimal stand value with log allocation constraints. Forest Science. 35(1): p. 271–276. (Mar.)

Many log sellers in the western United States face price schedules requiring that a given percentage of the volume be delivered in logs of a specified length. A simple heuristic procedure was developed for

deriving a set of log prices which, when used in making decisions for bucking individual trees, provides nearly optimal stand value while meeting volume–length restrictions.

Wang, S.J.; Giles, D.R. 1989. Effects of various factors on computer-optimized bucking system performance. Vancouver, BC: Forintek Canada Corporation. 4 p. (Reprint from Forest Products Journal 39(11/12): 33–36).

A simulation study of a computer-optimized transverse bucking system with a perfectly accurate scanner found that computer-optimized bucking with sweep scanned in two planes outperformed that without scanning for sweep by 7.3% in terms of total product value recovery. For one-plane sweep scanning, this uplift was reduced to 3.6%. For the same sweep option, the value recovery uplift decreased as the scanner error increased. With 0.25-in. scanning error, two-plane sweep scanning did not result in statistically higher value recovery over single-plane sweep scanning. Inclusion of downstream log processing costs and a minimum 12-ft log segment length recovery and number of log segments generated. Reduction of saw spacing from nominal 4 ft to 2 ft increased value recovery by 1.4% when diameter scanning error was 0.15 in. and two-plane sweep was considered. The increase was insignificant when the scanner error increased to 0.25 in.

Hardwood Bucking

May, D.M. and others. 1994. Impact of in-woods product merchandizing on profitable logging opportunities in southern upland hardwood forests. Res. Pap. SO–282. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.11 p.

Procedures developed to assess available timber supplies from upland hardwood forest statistics reported by the U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis (FIA) units, were modified to demonstrate the impact of three in-woods product-merchandizing options on profitable logging opportunities in upland hardwood forests in 14 Southern States. Product-merchandizing options ranged from harvesting a single, lower valued product to harvesting multiple higher valued products. Under the specific assumptions and conditions of the demonstration, two-fifths of the South's reported upland hardwood forest, containing about three-fifths of the reported inventory, was estimated to be profitable logging opportunities and profit margins. However, in specific situations defined by product prices, market locations, and stand characteristics, merchandizing options harvesting fewer and lower valued products were shown too be most profitable, demonstrating that multi-product harvesting cannot always be assumed to be an optimal merchandizing alternative.

Pickens, J.B. 1996. Methods to customize the HW–BUCK software. In: Putting research to work for the hardwood industry: new technology available today. Proceedings of the 24th annual hardwood symposium. Memphis, TN: National Hardwood Lumber Association: 141–147.

The HW–BUCK decision simulator is a computerized training tool designed to help hardwood log buckers improve value recovery. The trainee plays the bucking "game" by observing one of 150 actual hardwood stems, then selects their bucking cuts. The picture includes defects and sweep, and can be rotated to see stem shape and hidden defects. After the trainee has selected cuts, the software presents their results beside the optimal bucking pattern for comparison. This paper emphasizes the flexibility of the system to use different prices and veneer grading rules, and presents the process for including a user's trees.

Pickens, J.B. and others. 1991. HW–Buck: a computerized hardwood bucking decision simulator. In: Proceedings of the 1991 symposium on systems analysis in forest resource; 1991 March 3–6; Charleston, South Carolina. Gen. Tech. Rep. SE–74. Asheville, NC: Southeastern Forest Experiment Station: 213–216.

Recent research indicates that current field bucking practices in the Upper Peninsula of Michigan underachieve the possible value of hardwood logs produced by 39% to 55%. This paper describes a computerized decision simulator for training buckers to improve value recovery when bucking hardwood stems. The program presents the trainee with a picture of the hardwood log to be bucked, allows the trainee to select the sequence of cuts to buck the tree, and then presents a side-by-side comparison of the trainee's bucking choices and the optimal bucking cuts.

Pickens, J.B.; Lee, A.; Lyon, G.W. 1992. Optimal bucking of northern hardwoods. Northern Journal of Applied Forestry. 9(4): 149–152.

This paper describes the development and application of a bucking (cross-cutting) optimization model developed for use with northern hardwood species. The model evaluates feasible bucking solutions using computer log grading and scaling procedures that closely reflect industry-established rules. Optimal solutions are found using dynamic programming. A study of 166 trees bucked in Michigan indicates that the gross delivered values of optimal solutions are 39% to 55% higher than those chosen by the buckers. Possible approaches to improve value recovery during bucking are discussed.

Pickens, J.B.; Lyon, G.W.; Lee, A.; Frayer, W.E. 1993. HW–BUCK game improves hardwood bucking skills. Journal of Forestry. 91(8): 42–45.

Several bucking optimization models have been developed to maximize the total value of logs produced from an individual tree, stand, or planning period. However, all are for softwood species. This article describes a computerized bucking decision simulator that has been developed at Michigan Technological University specifically to improve hardwood log bucking skills.

Pickens, J.B.; Throop, S.A.; Frendewey, J.O. 1997. Choosing prices to optimally buck hardwood logs with multiple log-length demand restrictions. Forest Science. 43(3): 403–413.

The purpose of this article is to present a hierarchical optimization approach that selects prices which, when used in a single stem bucking optimization model, produce a specified mix of logs by grade and length. The model is developed to address the demand constrained optimal bucking situation for northern hardwoods. The demand constraints are minimum percentages needed in four log lengths [3.0 m (10 ft), 3.7 m (12 ft), 4.3 m (14 ft), and 4.9 m (16 ft)] to meet order requirements from veneer buyers. There are two levels in the hierarchical optimization system: at the lower level, a dynamic programming model is used to optimize the value of each individual tree, while the upper level is a linear programming model which finds one or more sets of prices, each used some portion of the time, that produce the required product mix in the lower level model. The hierarchical model is solved iteratively until a single set of prices satisfies all demand constraints. This approach is distinctly different than traditional approaches, which pass different information between the upper and lower level models to solve two-level optimization problems. The parameters passed in traditional approaches are shadow prices in one direction and production levels in the reverse direction. The model developed could be adapted to other species and log grading rules whenever several competing demand constraints exist. Furthermore, the approach could be adapted to a wide range of hierarchical planning applications where inputs, and therefore the production possibilities curve, are fixed and constraints apply.

Log Manufacture

Carino, H.F.; Foronda, S.U. 1987. Determining optimum log requirements in lumber manufacturing. Forest Products Journal. 37(11/12): 8–14.

A systematic approach to the problem of determining optimum log requirements in sawmilling is presented. Linear programming is used to analyze various log input size distributions, and profit contribution is used as the measure of effectiveness. The analytical approach was explained through the discussion of a case study involving a southern pine dimension mill. The analysis indicated that this mill would realize greater profits by processing relatively smaller diameter logs. It was found that the mill could attain the highest profit contribution ($1,285/hr.) from a sawlog distribution that included only those logs with top or small-end diameters of 8 in. to 16 in. inclusive.

Young, G.G. 1998. Mechanical and manual log manufacturing in coastal second-growth forests: a comparison of recovered value. Pointe Claire, QC : Forest Engineering Research Institute of Canada. 12 p.

In 1996 the Forest Engineering Research Institute of Canada compared the value of logs manufactured by various systems at two sites in coastal second-growth forests in British Columbia. At Site 1, the value recovered by a Timberjack 1270 single-grip harvester manufacturing short logs at the stump was compared to the theoretical maximum value as predicted by a grader. Also, the log value recovered by a conventional manual falling and bucking system was compared to that of a grader. At Site 2, the value recovered by a Steyr KP60 processor manufacturing conventional length logs from tree lengths at roadside was compared to the values as predicted by a grader, and by a bucker at roadside.

Harvesting–Logging–Timber Sales

Conway, S. 1976. Logging practices: principles of timber harvesting systems. San Francisco, CA: Miller Freeman. 416 p.

Logging Practices not only shows what happens during timber harvesting but also how and why it happens. The book gives an overall view of the systems, equipment, and practices used in North America to harvest timber crops. Its thorough coverage includes such essential subjects as forest resources, woods labor, operations planning, ground skidding, cable and aerial logging, safety management, and production control. In addition it gives the small practical details the industry needs in order to obtain maximum value from timber and land resources. One of the major contributions of this book is its emphasis on the "systems" approach. To understand timber harvesting systems it is necessary to see that they are made up of smaller systems called components, and that these in turn are made up of subsystems called elements. It is also necessary to realize that timber harvesting is itself part of the larger, dominant system, which includes manufacturing, marketing, transportation, sales and much else. The book describes the basic components and elements and makes it clear that only by comprehending

the various hierarchical relationships among them will it be possible to meet both the short- and long-term goals of the dominant system.

Ewart, J.M. 1990. Development of the west coast log processor. Special Rep. SR–71. Vancouver, B.C. Forest Engineering Research Institute of Canada. 7 p.

Garland, J.; Jackson, D. 1997. Felling and bucking techniques for woodland owners (rev. ed.). Corvallis, OR: Oregon State University Extension Service. 15 p.

Gingras, J.–F.; Godin, A. 1997. Sorting for quality with a cut-to-length system. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 6 p.

This study compared the productivity, cost and efficiency of a single-grip harvester and a shortwood forwarder for sorting pulpwood. Three methods were analyzed: in the first, two pulpwood grades were separated by the forwarder; in the second, this separation was conducted by the harvester; and in the third, the harvester did a three-way pulpwood sort (for grade and species).

Hartsough, B.R.; Stokes, B.J. 1990. Comparison and feasibility of North American methods for harvesting small trees and residues for energy. In: Harvesting small trees and forest residues. Proceedings of the International Energy Agency, Task VI, Activity 3 Workshop; 1990 May 28; Copenhagen, Denmark. Auburn, AL: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 31–40.

Hoffman, B. 1991. How to improve logging profits. Old Forge, NY: Northeastern Logger's Association. 60 p.

International Organization for Standardization. 1987. Logging industry: products, terms and definitions. International standard ISO 8966. Geneva, CH: International Organization for Standardization. 7 p.

Johnson, L.R. 1989. Recovery of wood residues in the intermountain region. In: Harvesting small trees and forest residues. Proceedings of an international symposium, International Energy Agency/Bioenergy Agreement Task VI–Activity 3; 1989 June 5–7; Auburn University, AL. Auburn, AL: U.S. Department of Agriculture, Forest Service: 11–31.

Macklin, R.R. 1982. The logging business management handbook. San Francisco, CA: Miller Freeman Publications. 176 p.

Miyata, E.S. How to calculate costs of operating logging equipment. St. Paul: North Central Forest Experiment Station. 6 p.

Pacific Logging Congress. 1977. Loggers handbook. Vol. 37. Logging: a look at realities. Portland, OR: Pacific Logging Congress. 163, 78, 37 p.

Shaver, J.R. 1994. What current harvest technologies are available to meet IRMP concerns and market economics? Or, small log harvesting for future forests. In: Indian forestry: changing perspectives of resource management. Final proceedings, 18th annual national Indian timber symposium; 1994 April 25–29; Polson, MT. Portland, OR: Intertribal Timber Council: 108–115.

Stokes, B.C. 1992. Harvesting small trees and forest residues. In: Reports and reviews summarized from proceedings, International Symposium; 1992 June 5–7; Auburn, AL. Biomass and Bioenergy. 2(1/6): 131–147.

Eight countries collaborated and shared technical information on the harvesting of small trees and forest residues in a three year program. Proceedings and reports from workshops and reviews are summarized in a review of activities and harvesting systems of the participating countries. Four databases were developed for harvesting and transportation of these materials.

Wilton, W.C. 1981. Integrated logging for production of pulpwood and hog fue. Ottawa, ON: Northland Associates Ltd. Canadian Forestry Service. (ENFOR project P–143 DSS Contract 07SC.KL001–9–0057).

Workers' Compensation Board of British Columbia. 1990. Fallers' & buckers' handbook: practical methods for falling and bucking timber safely. Richmond, BC: Workers' Compensation Board of British Columbia. (9th ed. (rev.) 1998.)

Transportation—Loading and Unloading

Barnes, B.; Sullivan, E.C. 1980. Timber transport model, version 2.0. Berkeley, CA: University of California, Institute of Transportation Studies. 277 p.

Bradford, H.D. 1970. Log truck traffic generation analysis. San Francisco, CA: U.S. Department of Agriculture, Forest Service, Transportation System Planning Project. 29 p.

Bradley, D.P. 1988. When you say harvest and transport costs, you've said it all (or nearly all)! In: Minnesota's timber supply: perspectives and analysis. Proceedings of conference; St. Paul, MN. St. Paul, MN: University of Minnesota, Department of Forest Resources. Staff paper series no. 64: 145–152.

Bridge, D.R. 1989. Soft ground crossing. Washington, DC: American Pulpwood Association, 2 p.

Clark, C.J. 1977. A case study of the influence of log deck configurations on loading with a self-loading log truck. Thesis (Master of Forestry). Corvallis, OR: Oregon State University. 83 p.

Clark, M.L. 1986. Highway hauling of tree-length logs in the B.C. Cariboo. FERIC Tech. Rep. TR–66. Pointe Claire, QC. Forest Engineering Research Institute of Canada. 46 p.

Clark, M.; Giles, D.R. 1988. Orientation of log butts on highway trucks: an economic analysis. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 2: 34 p.

Cox, B. 1992. Swedish style shortwood logging truck. Vancouver, BC: Forest Engineering Research Institute of Canada, Western Division. Field note. Loading and trucking. 30. 2 p.

Cox, W.R.; Wong, P. 1977. A mathematical programming approach for the analysis of transport-logging systems for timber sale. (U.S. Forest Service. Engineering Technical Information System. Field Notes. 9(5): 3–12).

Forest Engineering Research Institute of Canada. 1978. Long-distance off- and on-road transport. Vancouver, BC: Forest Engineering Research Institute of Canada. 2: 46 p.

Jokai, R. 1994. A comparison of actual vs. simulated logging truck performance using OTTO software. Vancouver, BC: Forest Engineering Research Institute of Canada, Western Division. Field note. Loading and trucking. 34. 2 p.

Koger, J.L.; Tenn, N. 1981. Transportation methods and costs for sawlogs, pulpwood bolts, and longwood: TVA/ONR/LFR–81/4. Tennessee Valley Authority, Division of Land and Forest Resources. 34 p.

Ljubic, D.A. 1985. Analysis of productivity and cost of forestry transportation: Pt. 3. Theoretical analysis of the impact of vehicle operating conditions. Tech. Rep. TR–61. Pointe Claire, QC: Forest Engineering Research Institute of Canada, 71 p.

Long, J. 1977. Computer-aided timber transportation analysis, five case studies. Berkeley, CA: University of California, Institute of Transportation Studies. 49 p.

McMorland, B. 1983. Truck unloading in coastal B.C. dryland sortyards. Tech. Note. TN–70. Vancouver, BC: Forest Engineering Research Institute of Canada. 5: 21 p.

Meyer, R.L. 1990. Nordic logging machinery transport truck. Washington, DC: American Pulpwood Association, 1 p.

Moll, J.E.; Copstead, R. 1996. Travel time models for forest roads: a verification of the Forest Service logging road handbook. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology and Development Program. 40 p.

Oakley, P.; Marshall, N.G. 1989. Optimal sizing of off-highway logging trucks. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 20 p.

Overbee, P.D.; Shaffer, R.M.; Stuart, W.B. 1988. A low-cost program to improve log truck weight control. Forest Products Journal. 38(6): 51–54.

Truck weights are a focal point in log hauling. Loggers are penalized by the state, and sometimes by the receiving mill, for overweight loads. But excessively underweight loads lose revenue for the logger. Mechanical and electrical devices are available for in-woods weighing, but these devices are expensive. A low-cost method utilizing feedback on load weights to heighten the awareness of loader operators regarding weight control was tested by loggers at two southern papermills. The majority of loggers at both sites slightly improved their loading performance, resulting in increased profits.

Parker, S.P.S. 1995. Log-transportation requirements in western Canada, 1992–2002 : a survey. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 13 p.

Poulton, M.C.; Hughes, J.R. 1980. Minimizing the costs associated with sawlog transportation to the lower Fraser River. Vancouver, BC: Centre for Transportation Studies, University of British Columbia. 80 p.

Salm, D. [and others]. 1988. Harvest scheduling and transportation analysis for an area of the Allegheny National Forest using the Integrated Resources Planning Model. TRANSHIP. In: High technology in forest engineering. Proceedings of the Council on Forest Engineering, 10th annual meeting; 1987 August 3 to August 6; Syracuse, New York. Syracuse, NY: College of Environmental Science and Forestry: 127–147.

Shaffer, R.M.; Keesee, J.M. 1991. Keeping mud off the highway during wet-weather logging. Southern Journal of Applied Forestry. 15(1): 50–53. (Feb.)

Sinclair, A.W.J. 1984. Recovery and transport of forest biomass in mountainous terrain. Victoria, BC: Environment Canada, Pacific Forest Research Centre. 31 p.

Smith, D.G.; Tse, P.P. 1977. Logging trucks: comparison of productivity and costs. FERIC Tech. Rep. TR–18. Pointe Claire, QC: Forest Engineering Institute of Canada. 43 p.

Wong; T.B. 1990. REVHAUL: a revenue-tracking program for log-hauling contractors. Pointe Claire, QC: Forest Engineering Research Institute of Canada. 13 p.

Log Allocation

American Institute of Industrial Engineers. 1974. LOCAL: location-allocation models for establishing facilities. In: Proceedings 1974 spring conference American Institute of Industrial Engineers. Norcross, GA: American Institute of Industrial Engineers: 391–400.

Bare, B.B.; Briggs, D.G.; Mendoza, G.A. 1989. Log allocation and soft optimization: a de novo programming approach. Forest Products Journal. 39(9): 39–44.

Describes how to efficiently allocate logs to a set of interdependent utilization facilities while simultaneously designing the optimal characteristics of the production system. Using the external reconstruction algorithm (a de novo algorithm), selected resource constraints are considered “soft” and are determined through analysis.

This procedure facilitates the design of an optimal production system and is not limited to the solution of a prespecified problem wherein all constraints are taken as fixed. The procedure is demonstrated by applying it to a representative log allocation problem facing owners of a vertically integrated utilization complex. Results illustrate the range of increased profits that can be expected when the optimal set of resource inputs is available.

Goetz, H.L. 1981. Allocation of raw materials to alternative products. In: Harvesting and utilization opportunities for forest residues in the Northern Rocky Mountains. Gen. Tech. Rep. INT–110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 251–257.

In traditional timber harvesting operations, the allocation of raw material to alternative products is most often made at the mill. However, in western Montana, because there are no processing facilities equipped to utilize the full range of residue material, the landowner or land manager must make the allocation decision. The allocation process should also be an integral part of sale preparation and not occur as an afterthought at the conclusion of harvest. This paper discusses the utilization of ponderosa pine residue created by a locally severe outbreak of mountain pine beetle in the Blackfoot River drainage northeast of Missoula, Montana.

Mendoza, G.A. 1980. Integrating stem conversion and log allocation models for wood utilization planning. Seattle, WA: University of Washington. Ph. D. dissertation.

Mercado, J.S.; Carino, H.F.; Biblis, E.J.; White, C.R. 1990. Optimizing log procurement and allocation in southern pine dimension lumber manufacturing. Forest Products Journal. 40(5): 31–36.

The profitability of a southern pine dimension mill operation was analyzed using linear programming. Results indicate that the mill can maximize profit by producing lumber from logs with a small-end diameter ranging lumber from 6 to 21 in. and by selling small-sized logs as pulpwood. A maximum profit contribution of $564 per hour is attainable under current conditions. Parametric analysis indicates that log and lumber prices significantly impact profit contribution and log input mix. For example, a 10% price increase for large-sized (e.g., 2 by 10’s and 2 by 12’s) lumber would result in a 20% increase in profit contribution with the optimum log input mix changing significantly. Also, if there is an increase in log prices, the result would be a significant reduction in profit contribution accompanied by a decrease in the sizes of input logs profitable to process into lumber. The study also shows how a rational log pricing strategy in dimension lumber manufacturing can be developed within the framework of maximizing profit.

Stokes, B.J.; Watson, W.F. 1988. Recovery efficiency of whole-tree harvesting. In: Harvesting whole trees with processing and log allocation in the forest to conventional and energy products. Proceedings of an A-1 technical group meeting; 1988 June 6–10; Garpenberg, Sweden. Rotorua, New Zealand: Forest Research Institute, Forest Management and Resources Division. Rep. 6: 186–200.

Westerkamp, G.L. 1978. A linear programming approach to log allocation. Seattle, WA: University of Washington, College of Forest Resources. 74 p.

Log Procurement

Ahrens, G.W. 1988. Sawmill procurement and harvesting. In: Hamel, M.P. ed. Current challenges to traditional wood procurement practices. 1987 September 20–30; Atlanta, GA. Proc. 47353. Forest Products Research Society: 33–37.

Brinker, R.W.; Jackson, B.D. 1991. Using a geographic information system to study a regional wood procurement problem. Forest Science. 37(6): 1614–1631.

Burger, D.H.; Jamnick, M.S. 1991. Analysis of wood procurement strategies: supplying multiple mills from multiple sources. In: Proceedings of the 1991 symposium on systems analysis in forest resources; 1991 March 3–6; Charleston, South Carolina. Gen. Tech. Rep. SE–74. Asheville, NC: Southeastern Forest Experiment Station: 17–23.

A linear programming wood procurement and distribution model was developed to analyze a complex wood distribution system. The model can be used to measure trade-offs between the conflicting objectives of minimizing total wood cost and maximizing profit for a woodlands division that is a profit center. The model considers mill requirements, product revenues, and harvest, transportation and wood purchasing costs.

Davis, S.R. 1988. Microcomputer software for timber procurement and harvest scheduling. In: Hamel, M.P. ed. Current challenges to traditional wood procurement practices. 1987 September 20–30; Atlanta, GA. Proc. 47353. Madison, WI: Forest Products Research Society: 95–96.

Fortson, J.C. 1988. Harvest scheduling/wood procurement modeling using linear programming. In: Hamel, M.P. ed. Current challenges to traditional wood procurement practices. 1987 September 20–30; Atlanta, GA. Proc. 47353. Madison, WI: Forest Products Research Society: 85–86.

Hokans, R.H.; Stuart, W.B. 1983. Yard-to-mill woodflow scheduling by microcomputer. Southern Journal of Applied Forestry. 7(1): 50–53.

Scheduling yard-to-mill woodflows requires the regular attention of wood procurement managers. While the calculations are routine, they are sufficiently time consuming to preclude evaluation of more than a first-guess schedule. A computer program implemented on a microcomputer provides a cost-effective means of doing the calculations and choosing an operationally feasible least-cost solution to the scheduling problem.

Lee, E.C. 1988. Procurement strategies without land ownership. In: Hamel, M.P. ed. Current challenges to traditional wood procurement practices. 1987 September 20–30; Atlanta, GA. Proc. 47353. Forest Products Research Society: 38–39.

Maass, D. 1991. Wood procurement strategies for the 1990s. Tappi Journal. 74(11): 66–67.

Inventory Control and Storage

De Groot, R.C. 1978. Save wood: end-treat stored maple and birch logs. Research and Application Series. Madison, WI: U.S. Department of Agriculture, Forest Service Forest Products Laboratory. 5 p.

Important factors involved in storing bark and bark-free, whole log, and whole-tree chips. In: Proceedings 7th International FPRS industrial wood energy forum '83; 1983 September 19–21; Nashville, Tennessee. Proc. 47337. Madison, WI: Forest Products Research Society: 189–202.

Ellisor, J. 1981. Log inventory controls. OSUSOB monograph 14. Corvallis, OR: Oregon State University. 8 p.

Yerkes, V.P. 1967. Effect of seasonal stem moisture variation and log storage on weight of Black Hills ponderosa pine. Res. Note RM–96. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 8 p.

The moisture content of ponderosa pine trees in the Black Hills fluctuated enough from season to season to account for a significant portion of the variability that might be experienced in weight scaling. A difference in moisture content of trees on different growing sites was also noted. Weight loss from logs left in woods storage for up to 108 days was not great and could largely be ignored in weight scaling. Lumber degrade during storage would probably be a more serious problem, and normally would be the main concern in log storage.

Zhang, D.; Binkley, C.S. 1994. The informational efficiency of the Vancouver log market and the financial risk of holding logs in storage. Canadian Journal of Forest Research. 24(3): 550–557.

Viewed on an annual or quarterly basis, the Vancouver Log Market appears to process price information efficiently, but apparently does not do so for monthly trading intervals. For the longer holding periods the Vancouver Log Market passes one of the fundamental tests for an efficient market, and as a consequence there are few gains to make by speculating in this market on the basis of technical analysis of past price movements. Explanations for lack of information efficiency in the monthly returns requires further study. Holding logs does not appear to entail a significant amount of systematic or market risk if the holding periods are one quarter or less. Producers can hold log inventories in the Vancouver Log Market without increasing the financial risk of their enterprises.

Protection and Insect Control

Canadian Forestry Service. 1972. Water misting for log protection from ambrosia beetles in B.C. Victoria, BC: Pacific Forest Research Center, Canadian Forestry Service. 34 p.

Ambrosia beetles have long been a problem in coastal British Columbia. Climate, extensive stands of mature coniferous forests and methods of harvesting them all favor these insects. Logging debris and stumps provide good beetle breeding sites, as do right-of-way logs and other timber left too long after felling. One species, *Trypodendron lineatum* (Oliv.), which attacks all commercial softwood species in this area, is by far the most abundant and damaging. The export of beetle-damaged lumber to certain overseas markets is restricted because of the possibility of accidental introduction of these insects. Logs felled during spring are relatively immune to attack; those felled the previous autumn and winter are preferred by the beetles. Prevention of beetle damage by insecticide application is not economically feasible. A serious problem remains at times and under some conditions, particularly at dry-land log sorting and storage areas. Water sprinkling has been found to reduce deterioration of stored logs and was recently tested in British Columbia. Discussions of the Pest Control Committee of the Council of the Forest Industries of British Columbia led to a cooperative project to test the cost and effectiveness of water spray for preventing ambrosia beetle damage to logs in dry-land storage.

Elowsson, T.; Liukko, K. 1995. How to achieve effective wet storage of pine logs (*Pinus sylvestris*) with a minimum amount of water. Forest Products Journal. 45(11/12): 36–42.

Logs stored on land are protected by sprinkling with water. It is important to minimize the period between felling and the start of sprinkling. In Sweden, generous sprinkling has resulted in damage to the groundwater. Thus, it is necessary for the sprinkling program too be designed in such a way as to prevent negative effects on the environment. Three types of sprinkling experiments were conducted: intensive (recirculation), normal, and controlled sprinkling with successively reduced amounts of water. Measurements were made of the moisture content, waste-water flow, and the actual evaporation. A theoretical evaporation was calculated and a correlation was made between measured and calculated evaporation. The results reveal that (1) there was a rapid drying process before the start of the sprinkling; (2) reduced sprinkling that is adapted to evaporation results in the same moisture content development as intensive sprinkling; and (3) the buffering capacity in a log pile is low. Evaporation calculated in accordance with the Penman–Monteith formula correlates with the measured evaporation at the 0.1% level. Controlled sprinkling using this formula will offer reliable protection to the logs while reducing the amount of waste-water.

Feighl, O. 1978. Protection of veneer logs in storage in eastern Canada (a survey of the literature). Inf. Rep. OP–X–196. Ottawa, ON: Canada Department of Forestry. Forest Products Research Laboratory. 20 p.

Gray, D.R.; Borden, J.H. 1985. Ambrosia beetle attack on logs before and after processing through a dryland sorting area. Forestry Chronicle. 61(4): p. 299–302.

Damage by ambrosia beetles was assessed on logs arriving at and leaving a northern Vancouver Island dryland sort. Damage on incoming logs was severe, indicating a high population of attacking beetles in the forest. Although logs were processed rapidly through the dryland sort, exposed portions of logs in booms were subjected to additional attack by resident dryland sort beetles, causing additional damage. Value lost to degrade equaled \$0.89/m^3 processed during the seven weeks of the study, 44.9% from attack by beetles in the woods, and an additional 55.1% by beetles in the sort.

Kreber, B.; Byrne, A. 1996. Production of brown stain in hemlock logs and lumber during storage. Forest Products Journal. 46(4): 53–58.

Hemlock brown stain is a discoloration that can develop in unseasoned logs and lumber of western hemlock and amabilis fir. This discoloration is a serious problem for producers of high-value Canadian lumber. Production of hemlock brown stain was monitored in freshly felled western hemlock trees and after storing the logs for 2 and 9 months. Saltwater and dry land storage of logs were evaluated as conditions that influence colorations. Lumber sawn from the 9-month-old logs was also evaluated for color change following storage for 2 months. This study demonstrated that brown stain was associated with extended log storage, particularly in saltwater. Fungi were isolated from freshly felled trees and from logs after 2 months of storage. Dark-pigmented hyphae were associated particularly with areas showing brown stain. Information gained from this study suggested that faster processing of western hemlock logs into lumber could lessen the extent of brown stain problems.

Lindgren, B.S.; Fraser, R.G.1994. Control of ambrosia beetle damage by mass trapping at a dryland log sorting area in British Columbia. The Forestry Chronicle. 70(2):159–163.

A mass trapping program for ambrosia beetles at the Sooke dryland sorting area of Canadian Pacific Forest Products in British Columbia captured close to 16.5 million beetles over 12 years. Spring weather conditions influenced trapping of the main pest species, *Trypodendron lineatum*, the populations of which fluctuated considerably. *Gnathotrichus sulcatus* populations declined gradually, presumably because of the trapping and improvements in inventory management. A benefit/cost estimate, based on the assumption that the number of beetles removed can be correlated with degrade losses, yielded a benefit of 5 to 1 and an estimated saving of \$400,000 over the 12 years. The trapping program was concluded to have been operationally and economically successful.

McMullen, L.H.; Betts, R.E. 1982. Water sprinkling of log decks to reduce emergence of mountain pine beetle in lodgepole pine. Forestry Chronicle. 58(5): 205–206.

Water sprinkling of lodgepole pine logs infested by mountain pine beetle with soaker-hoses on the surface of log decks, reduced survival of pupae and young adults to 5% compared with 93% in control decks. The technique provides a useful alternative to other methods of reducing hazard from the insect to pine stands surrounding log storage areas.

Miller, D.J. 1979. Deterioration of logs in cold decks—a survey of information applying to the Pacific Northwest. Forest Products Journal. 29(1): 34–40.

Logs left lying in the woods during warm weather are vulnerable to attack by insects and to infection by stain decay fungi. As a result, infected logs may deteriorate sooner than expected during later storage in dry decks, or that may appear to have deteriorated while wet-decked under protective water sprays. In dry storage damage from stain, insects, and drying stress (checks) may appear in a few months or less during warm weather; decay usually is not evident until after a year or more of unprotected storage. The usual procedures for protecting logs are to process them as

quickly as possible or to sprinkle them with water if decked storage is necessary. Sprinkling provides protection against insect, fungal, and drying damage if water coverage is adequate to keep the log surfaces wet—particularly the ends, which may be less accessible to wetting. Short on-off sprinkling cycles seem as effective as continuous spraying. Sprinkling may increase the permeability of sapwood but causes no important change in its strength or durability. Environmental restrictions on runoff water from wet decks usually have not prevented operators in the Pacific Northwest from sprinkling decked logs. There is little information on the amount and value of losses incurred during storage in log decks.

Miller, D.J.; Swan, S. 1980. Blue stain in sprinkled log decks and lumber piles of ponderosa pine. Forest Products Journal. 30(2): 42–48.

Ponderosa pine (*Pinus ponderosa* Laws.) logs decked under various water-spray conditions during summer in central Oregon soon changed appearance. Sapwood of log ends sprayed with clean river water darkened within a few weeks; white resinous bloom and green slime appeared later. Logs sprayed with warmer, turbid pond water were quickly covered with dark slime. Sapwood tended to be ~10°F warmer than sprayed water, usually ranging from 50°F to 66°F during warm summer days, and in top logs, cooling 5°F to 10°F during the night. Sapwood MC was usually >150% in logs sprayed continuously or by brief on and off cycles, but fell to levels suitable for fungal growth if the "spray-off" part of the cycle was prolonged (6 min. on, 34 min. off). Intermittently sprinkled logs also developed increasing amounts of blue stain from prolonged "spray-off" periods. Blue stain in logs amounted to <1% of surfaced lumber tally if spray was continuous or brief and intermittent (6 min. on, less than or equal to 10 min. off); however, the longest "spray-off" (34 min.) cycle increased log stain to 3.6%. The amount of additional blue stain which developed in lumber close-piled outdoors for 4 weeks during November and December, despite cool air temperatures (highs usually 40°F to 55°F, lows usually 25°F to 40°F), seemed unrelated to sprinkling practices. Staining in lumber piles amounted to <2% of board footage. In some cases, more stain developed in lumber than in decked logs. Total downgrade by blue stain in both logs and piled lumber was greatest in logs sprinkled the least (34 min. "spray-off" period); 5.7% downgrade and a loss of $11.75 per thousand board feet. No loss resulted when logs were sprayed 6 min on, 6 off, but absence of stain in that piled lumber probably occurred by chance. Less than half the stained surfaced lumber was actually downgraded, except if sprays were off 34 min.

Ostaff, D.; Shields, J.K. 1978. Reduction of losses to logs and lumber caused by wood-boring insects. Inf. Rep. OP–X–218. Ottawa, ON: Canada Forest Products Research Laboratory. Eastern Forest Products Laboratory. 15 p.

Rice, J.A.; Anderson, H.W.; Nyland, R.D.; Dey, D.C., eds. 1994. Logging damage: the problems and practical solutions. Forest Research Inf. Pap. 117. Sault Ste. Marie, ON: Ontario Forest Research Institute. 70 p.

Scheffer, T.C. 1969. Protecting stored logs and pulpwood in North America. Material und Organismen. 167–199.

Debarking, Chipping, Hogging and Grinding

Host, J.R. 1970. Portable debarking and chipping machines can improve forest practices. Res. Note INT–112. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 4 p.

Use of portable debarking and chipping machines may be a suitable means of disposing thinnings, defective overmature trees, and logging residues. Trial chipping under five different field conditions produced chips suitable for pulping. Chip output per day varied considerably, depending upon the size of the average piece, stand volume per acre, and upon skidding conditions.

Pottie, M. 1981. A way to make pulp chips from logging debris using a small drum debarker. FERIC Tech. Note TN–49. Pointe Claire, QC: Forest Engineering Research Institute of Canada 18 p.

Thompson, M.A.; Sturos, J.A. 1991. Performance of a portable chain flail delimber/debarker processing northern hardwoods. Res. Pap. NC–297. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 14 p.

Whole-tree chipping in the woods is a cost-effective method of producing chips for the forest products industry. A major disadvantage of this system, however, is the poor chip quality that results when leaves, bark, branchwood, and grit are included with the chipped stem. The chain flail delimber/debarker is a recently reintroduced technology being used to improve the quality of whole-tree chips. This machine consists of two or more parallel shafts with many chains mounted on the periphery of integral drums. The shafts are run at high speed as the whole tree is passed through the field of rotating chains. Bark and limbs are removed by the resulting mechanical interaction. This provides relatively clean stems to the chipper, resulting in less bark and grit in the furnish. An assessment of the performance and cost of flail debarking was needed to determine the viability of using this concept to improve the quality of chips produced in the woods. A survey

of roundwood chipping facilities throughout the southeastern United States was undertaken, and the results pertaining to information collected on drum debarkers were summarized. The survey covered 76 roundwood chipping installations including 53 mill yards and 23 satellite mills. Drum debarkers are summarized by features such as drum size, rotation speeds, and manufacturer. Southern hardwoods did not debark as well as pines. Drum volume had an impact on hardwood debarking quality.

Twaddle, A.A.; Watson, W.F. 1992. Survey of drum debarkers in roundwood chipping yards of southeastern United States. Tappi Journal. 75(11): 105–107.

Miscellaneous

Arola, R.A.; Sturos, J.B. 1982. A portable chunking machine. Res. Note WO–11. Washington, DC: U.S. Department of Agriculture, Forest Service. 4 p.

A prototype, portable spiral-head shearing machine, designed to operate from the power take-off of an agricultural tractor, was fabricated. This spiral-head chunking concept offers an alternative to regular chipping, enhancing the prospect of using small-diameter wood for fiber or fuel. The potential exists for producing a commercial spiral-head chunking device patterned very closely after the prototype unit.

Bassel, J.R. 1996. Voice data logger. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Technology and Development Program. Vol. 1.

Cahill, J.M.; Cegelka, V.S. 1989. Effects of log defects on lumber recovery. Res. Note PNW–RN–479. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 10 p.

The impact of log defects on lumber recovery and the accuracy of cubic log scale deductions were evaluated from log scale and product recovery data for more than 3,000 logs. Lumber tally loss was estimated by comparing the lumber yield of sound logs to that of logs containing defects. The data were collected at several product recovery studies; they represent most of the major commercial softwood species in the Western United States. Defects listed in order of decreasing effect on lumber recovery are: multiple defects, ring shake, soft rot and voids, weather check, firm rot, breakage, crook and sweep, and heart check. The accuracy of cubic log scale deductions was also analyzed. The rules were considered accurate for heart check, breakage, and crook and sweep; they underestimated the impact of ring shake and soft rots and voids on lumber tally, and overestimated the impact of weather checks, firm rot, and multiple defects.

Copithorne, R.; Young, G.; McNeel, J. 1994. Applying statistical quality concepts to control log value recovery. In: Proceedings of the meeting on advanced technology in forest operations: applied ecology in action; 1994 July 24–29; Portland–Corvallis, OR. Corvallis, OR: Oregon State University: 256–263.

Huyler, N.K.; Turner, T.L. 1993. Quality wood from underutilized trees. Northern Journal of Applied Forestry. 10(2): 95–97.

Stand condition and current logging practices support the idea that improved tree utilization, yielding more high value material, could be attained through the use of sawbolt marketing. However, to assess the feasibility of such marketing and utilization practices, it is necessary to estimate the potential volume of sawbolts under various cutting methods and the associated costs and added value of incorporating this product into the market place. The purpose of this study was to establish preliminary estimates of sawbolt volume and quality on logging contracts in Vermont. Reported are volumes and quality of sawbolts observed at the landings on six harvesting sites in Vermont.

LeDoux, C.B. 1988. Impact of timber production and transport costs on stand management. Res. Pap. NE–612 Broomall, PA: Northeastern Forest Experiment Station. 5 p.

Decisions to manage immature eastern hardwood stands on steep terrain must be based on an understanding of the impact of timber production costs on optimal rotation length and present net worth. Planners and managers can make improved decision by knowing how the interaction of timber production and transportation costs affect individual stand management. Simulations with a complete systems model indicate that managers and planners must consider cable logging technology, transportation network standards, and transport vehicles.

McCall, J.H. 1993.In the yard: log loaders and fork lifts cross market lines. Southern Lumberman. 254(4): 21–28.

Buying heavy equipment for in-yard use requires the commitment of a considerable amount of money, and mill owners, particularly those with lower profit margins-plan carefully for the wisest use of their dollars. Does it matter whether you buy a log loader of a forklift? Should you buy attachments for either piece of equipment: Whatever your need, most industry experts agree there is a place in the market for the variety of equipment presently available.

Parrish, R. 1991. The changing resource, new technology, and market opportunities for wood products. In: Waverly, S., ed. Proceedings of engineered wood products, processing and design; 1991 March 26–27; Atlanta, GA. Atlanta, GA: Forest Products Research Society: 1–8.

Ringe, J.M.; Hoover, W.L. 1987. Value added analysis: a method of technological assessment in the U.S. forest products industry. Forest Products Journal. 37(11/12): 51–54.

In recent decades, rising price differentials between timber grades, relative to structural product prices, have reduced the profit margin on traditional conversion processes, contributing to the development of new technologies. Value added analysis assesses the difference between log costs and the value of the resulting products. Assessments were projected over time for different log grades used to produce structural products through alternative conversion methods. The results obtained indicate that resource scarcity (as reflected by log prices) provides a strong impetus for development and adoption of improvements in log conversion processes. For the traditional conversion processes of sawing and peeling, in which product size and quality depends on log size and quality, value added projections decreased. Although improvements in these processes to increase yields resulted in higher value added figures, they still decreased with time. The value added in producing reconstituted panels, where size and quality do not depend on log size and quality, was projected to increase. Because value added analysis enables the identification of marginal log grades, it shows significant potential as a tool for assessing resource-driven technological change. The difficulties involved in basing decisions on trend extrapolations, however, indicate that this technique is most useful when incorporated in a market model containing a feedback mechanism for trend line updating. In such an application, value added analysis can aid in predicting regional industry migrations caused by resource-driven technological change.

Ross, R.J.; Green, D.W.; McDonald, K.A.; Schad, K.C. 1996. NDE of logs with longitudinal stress waves. In: Sandoz, J.L., ed. Proceedings, 10th international symposium on nondestructive testing of wood; 1996 August 26–28; Lausanne, Switzerland. Lausanne, Switzerland: Presses Polytechniques et Universitaires Romandes: 117–123.

Past nondestructive evaluation (NDE) research efforts have paved the way for the successful use of NDE for determining the quality of finished wood products. However, little effort has been expended on developing NDE techniques for use in grading or sorting logs for internal soundness and structural quality. We recently conducted a study using longitudinal stress wave NDE techniques to evaluate the quality of approximately 193 balsam fir and eastern spruce logs prior to processing into lumber. Longitudinal stress wave speed was used to determine the modulus of elasticity (MOE) for each log. The MOE of each piece of structural lumber cut from the logs was then determined using transverse vibration NDE techniques. A strong relationship was observed between the MOE of the logs and the lumber obtained from the logs.

Schuytema, G.S.; Shankland, R.D. 1976. Effects of log handling and storage on water quality. Cincinnati, OH: Industrial Environmental Research Laboratory. 75 p.

Wong, T. 1984. Dryland sortyard illumination with the Vortek high intensity argon lamp. Tech. Note TN–78. Vancouver, BC: Forest Engineering Research Institute of Canada. 14 p.