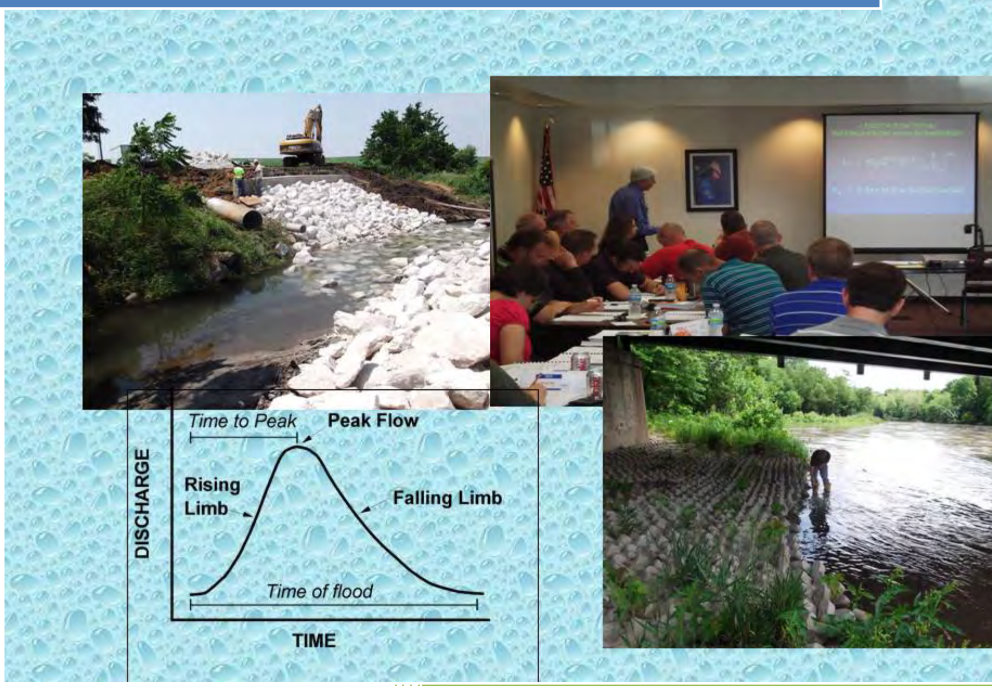
January 2012

Highway Hydraulics State of Practices



FHWA Resource Center

Hydraulics Technical Service Team

1/1/2012

Highway Hydraulics

State of Practices Report

50 US States and Puerto Rico

January 2012

FHWA Resource Center
Hydraulics Technical Service Team

Executive Summary

The Federal Highway Administration (FHWA) Resource Center has compiled a report on the current hydraulic practices of state highway agencies. This activity was performed by the Resource Center Hydraulics Technical Service Team (RC TST HYD) in coordination with the FHWA National Hydraulics Team (NHT). Information was gathered through a National Hydraulic Engineering Practices Questionnaire that was distributed to the highway departments of all 50 states and Puerto Rico on October 26, 2009. All recipients of the questionnaire responded within a three month time period providing a snap shot of hydraulic practices of all state highway agencies across the country including Puerto Rico as of January 2010.

The report is divided into major chapters of Organization and Management Structure, Documentation, Policy, Roadway Drainage Policies, Hydrology, Roadway Drainage Design, Culverts, Bridges, Floodplain Management, Environmental Hydraulics, Training, Research, and Software Design Aids with subsections presented within each category where appropriate. Each question in the questionnaire is stated in the corresponding section with a graphic depiction of the collective responses. The graphic depictions show the national perspective. Regional depictions of the responses are included in the Appendix and are referenced in each corresponding chapter text.

The report allows interested parties to view and compare organizational structures, hydraulic policies, hydraulic and environmental engineering practices, software design aids, training practices, and research efforts of individual states or any national trends. While the results display a wide variation in the responses to some questions and nearly complete agreement in others the report is intended only as a reference to current state practices and no attempt is made to recommend or admonish the practices of any state or group of states.

The report has been distributed to FHWA Headquarters, FHWA Division Offices, state highway agencies, and Puerto Rico Department of Transportation and Public Works. The Resource Center Hydraulics Technical Service Team greatly appreciates the cooperation of all participants in their complete and timely response to the National Hydraulic Engineering Practices Questionnaire.

Table of Contents

1.0 Introduction

A snap shot of the hydraulic practices of departments of transportation of the 50 U. S. States and Puerto Rico have been compiled and are presented in this report in groupings by chapters of related hydraulic topics. The snap shot of hydraulic practices was developed from responses received to a National State of Practices Questionnaire distributed to each of the 50 states and Puerto Rico on October 26, 2009. References to “states” made throughout the report means the 50 states plus Puerto Rico. All parties receiving the questionnaire responded within three months and the effective time stamp for the snap shot of hydraulic practices is considered January 2010.

The National Hydraulic Engineering Practices Questionnaire and subsequent report were developed and distributed by the FHWA Resource Center Hydraulics Technical Service Team. The team members participating in the distribution of the questionnaire and preparation of this report are: Larry Arneson, Senior Hydraulic Engineer, Lakewood, CO; Dan Ghere, Senior Hydraulic Engineer, Matteson, IL; Cynthia Nurmi, Hydraulic Engineer, Atlanta, GA; Eric Brown, Hydraulic Engineer, Baltimore, MD; and Veronica Ghelardi, Hydraulic Engineer, Lakewood, CO. The questionnaire and report preparation were both completed with the involvement of and coordination with the FHWA National Hydraulics Team which includes members from FHWA Headquarters hydraulic staff, Turner Fairbank Highway Research Center Hydraulics Laboratory Manager, and the hydraulic staff of FHWA Federal Lands Highways.

Each of the following sections presents a specific topical area of highway hydraulics covered in the questionnaire. Each questionnaire question is repeated in the respective chapter and the collective responses are presented in a graphic format that best fits the subject of the question. Many graphics depict a collective national perspective of all responses while others are presented in a regional grouping to provide a more comparative view of regional practices. The graphics presented in the text of each section represent the national perspective and all graphics of regional practices are located in the Appendix. The regional groupings of the states are Northeast, Mid Atlantic, Southeast, Upper Midwest, Lower Midwest, North Central, West Coast, Southwest, and Puerto Rico.

This report provides states with an opportunity to view practices of others, to evaluate the need for updating or revising manuals and procedures of the state, and, in many cases, to instill confidence in their established hydraulic practices.

We caution that various unique practices and differences in technical terminology among the states and regions of the country may have resulted in differences in interpretation of some of the questions by respondents. Readers should be aware of this possibility in their review of the graphics presented.

FHWA is aware of the considerable time and effort required to complete the questionnaire and we greatly appreciate the cooperation of all involved.

2.0 Organization and Management Structure

2.1 Point of Contact and Management Structure

The point of contact information and the organizational management structure are presented together in this section to facilitate a regional comparison of management structures among the various highway agencies.

Questions A.1, B1a, and B1b.

The first two topical areas of Organization and Management Structure are presented in Section 2.0. Question A identified each responding organization by establishing the point of contact of each respondent and their respective state and region of the country. The number of hydraulic staff positions and the agency's sections delegated with hydraulic design responsibilities were identified in Questions B1a and B1b.

The regional breakdown by geographical areas is as follows:
Northeast – Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont.
MidAtlantic – Delaware, Maryland, New Jersey, New York, Pennsylvania, Virginia, and West Virginia.
Southeast – Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.
Upper Midwest – Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
Lower Midwest – Arkansas, Louisiana, Oklahoma, and Texas.
North Central – Colorado, Kansas, Montana, North Dakota, Nebraska, South Dakota, And Wyoming.
West Coast – Alaska, California, Hawaii, Idaho, Oregon, and Washington.
Southwest – Arizona, New Mexico, Nevada, and Utah.
Puerto Rico – Puerto Rico.

The organizational management structure covered in Questions B1a and B1b are the typical hydraulic sections found in highway agencies for performing hydraulic design responsibilities. These include central office sections of Bridge Hydraulic Section, Roadway Hydraulic Section, Combined Hydraulic Section, Design Section (with collateral duties), and district or region office sections of Hydraulic Section, Design Section, and Maintenance Section.

Question A:

A. Point of Contact Information

Name	
Organization Name	
Position	
E-mail Address	
Telephone Number	
Fax Number	

Which state do you represent?

o	Alabama	o	Illinois	o	Montana	o	Puerto Rico
o	Alaska	o	Indiana	o	Nebraska	o	Rhode Island
o	Arizona	o	Iowa	o	Nevada	o	South Carolina
o	Arkansas	o	Kansas	o	New Hampshire	o	South Dakota
o	California	o	Kentucky	o	New Jersey	o	Tennessee
o	Colorado	o	Louisiana	o	New Mexico	o	Texas
o	Connecticut	o	Maine	o	New York	o	Utah
o	Delaware	o	Maryland	o	North Carolina	o	Vermont
o	District of Columbia	o	Massachusetts	o	North Dakota	o	Virginia
o	Florida	o	Michigan	o	Ohio	o	Washington
o	Georgia	o	Minnesota	o	Oklahoma	o	West Virginia
o	Hawaii	o	Mississippi	o	Oregon	o	Wisconsin
o	Idaho	o	Missouri	o	Pennsylvania	o	Wyoming

Which region of the country do you represent?

o	Northeast (CT, MA, ME, NH, RI, VT)
o	MidAtlantic (DC, DE, MD, NJ, NY, PA, VA, WV)
o	Southeast (AL, FL, GA, KY, MS, NC, SC, TN)
o	Upper Midwest (IL, IN, IA, MI, MN, MO, OH, WI)
o	Lower Midwest (AR, LA, OK, TX)
o	North Central (CO, KS, MT, ND, NE, SD, WY)
o	West Coast (AK, CA, HI, ID, OR, WA)
o	Southwest (AZ, NM, NV, UT)
o	Puerto Rico (PR)

Additional Comments:

Question B.1

B. Organizational/Management Structure

1. Staff

   a. Number of Staff Positions

   (Collateral means the person does hydraulic engineering frequently but not as a full time responsibility.)

Central Office					District Office			
Bridge Hydraulic Section	Roadway Hydraulic Section	Combined Hydraulic Section	Design Section (collateral)	Other	Hydraulic Section	Design Section	Maintenance Section (collateral)	Other

   b. Hydraulic Design Responsibility

   (check all that apply)

	Central Office					District Office			
	Bridge Hydraulic Section	Roadway Hydraulic Section	Combined Hydraulic Section	Design Section (collateral)	Other	Hydraulic Section	Design Section	Maintenance Section (collateral)	Other
Policy	☐	☐	☐	☐	☐	☐	☐	☐	☐
Technical Manual	☐	☐	☐	☐	☐	☐	☐	☐	☐
Provide In-House Training	☐	☐	☐	☐	☐	☐	☐	☐	☐
Bridge Hydraulics	☐	☐	☐	☐	☐	☐	☐	☐	☐
Culvert Hydraulics	☐	☐	☐	☐	☐	☐	☐	☐	☐
Roadway Drainage	☐	☐	☐	☐	☐	☐	☐	☐	☐
Design Review	☐	☐	☐	☐	☐	☐	☐	☐	☐
Erosion and Sediment Control Protection	☐	☐	☐	☐	☐	☐	☐	☐	☐
Storm Water Management	☐	☐	☐	☐	☐	☐	☐	☐	☐

Response:

The responses to Question A are depicted in Figure 2.1.1 which includes a bar chart of the total number of hydraulic staff positions in each of the 50 responding states and Puerto Rico. The designated geographical region of each of these agencies is also identified. Below the bar chart is a tabular format that lists the number of hydraulic staff positions in the various sections of each highway department. A regional presentation of this same graphic detail is presented in the Appendix as Figures A-2.1.1 through A-2.1.9, which show the hydraulic staff positions in each region.

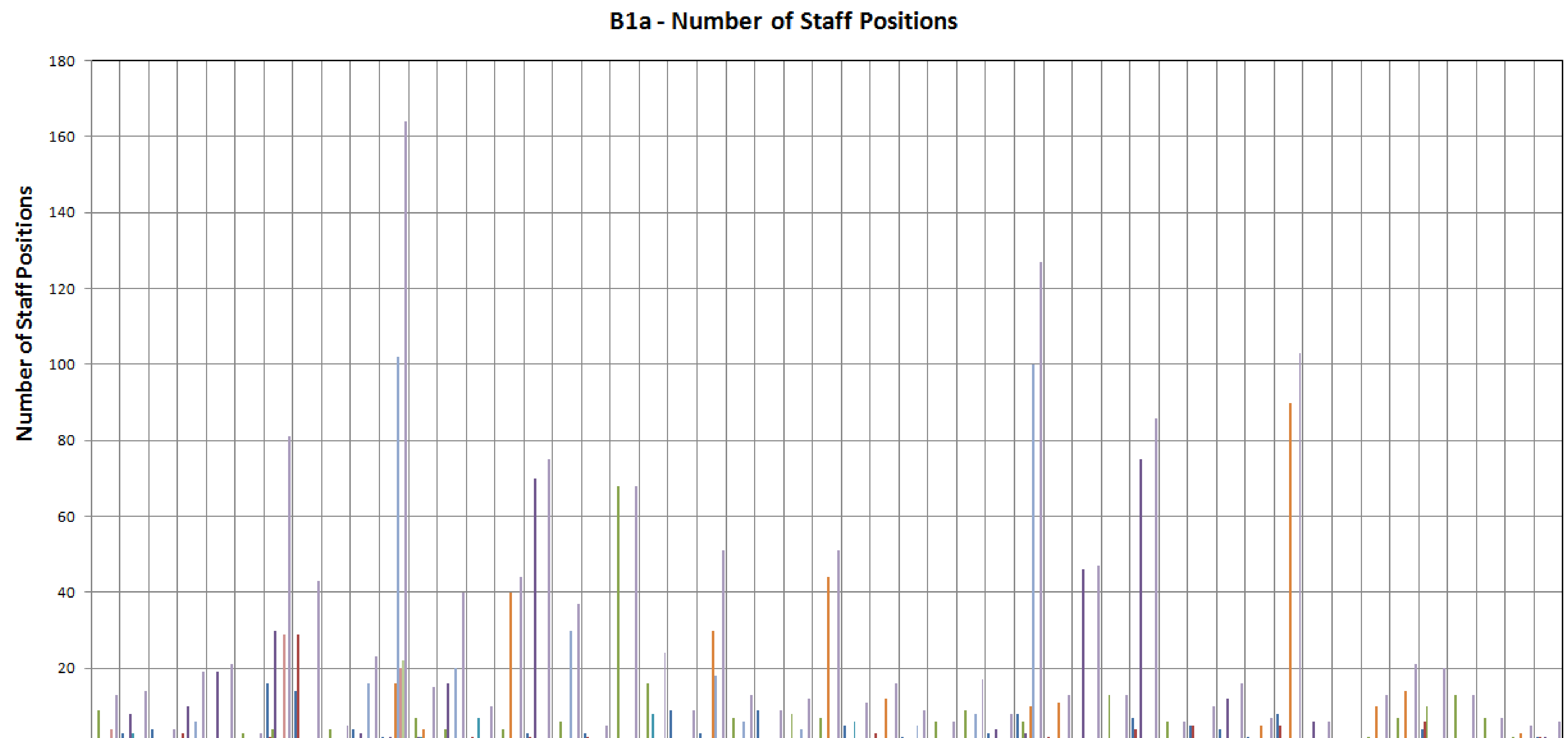
The results, shown in Figure 2.1.2, indicate a wide range of organizational structure of hydraulic responsibilities such that twenty-five (25) responding agencies have a combined hydraulic section in the central office, twenty-six (26) have a bridge hydraulic section, seventeen (17) have a roadway hydraulic section, and twenty-six (26) also have hydraulic responsibilities conducted in their district or regional offices in either a hydraulic section or maintenance section. A regional presentation is shown in Figures B – 2.1 through B – 2.1.9, which shows the hydraulic section responsibilities within each region.

Specific State Comments to Clarify Responses:

- Alaska - Policy and Technical Manuals are done by the District Office Hydraulic Section as a regional specific role or a subordinate to statewide role. For consultant work, the Alaska Highway Drainage Manual would apply.
- Arizona - The department just recently created the Bridge Hydraulics unit (about four years old). All the existing policies and manuals were created prior. In the near future effort will be made to separate the manuals and policy books.
- Connecticut - Hydraulics and Drainage Section: 9 Engineers 1 Secretary / 4 Maintenance Districts: 4 District Drainage Engineers.
- Delaware - Currently, DelDOT does not have a dedicated Hydraulic Section. Designers in each department are responsible for performing all necessary hydrological, hydraulic and scour calculations as required to successfully complete design. Road design and district maintenance offices defer to our Bridge design section for culverts over 20 sf.
- Illinois - IDOT has decentralized over last 4-5 years, w\increased approval authority given to the District hydraulic units. Routine bridge projects are initiated and approved at the District level. All culvert projects are handled at District level, as always, and all roadway drainage designs are handled by District staff, as always. Certain bridge projects and pumping stations remain central office responsibilities. Roadway drainage design typically involves District design staff assisting or displacing hydraulic unit staff. District hydraulic engineers double as bridge engineers in 4 of 9 districts. Consultant % keeps rising- once several districts never used consultants. Now, all do to some extent. Consultants are hired by project\study, as var-var and also in program mode, where they occupy a cubicle\office adjacent to IDOT staff. Becoming prevalent in both District and central office.
- Iowa - Almost all drainage design work is done by the Bridge Office.

- Kentucky - My staff only includes 6 full time people that do hydraulics and hydrology. The district offices have "highway" designers that do and review some drainage. The district designers are not under my supervision.
- Maryland - Both offices under Deputy Administrator of Planning, Engineering, Real Estate and Environment. Roadway Hydraulics Division also performs maintenance/Construction of Stormwater Management facilities. This maintenance function is not performed by the District maintenance forces.
- Missouri - Central Office Bridge - 1 structural hydraulics engineer; 4 bridge location and layout designers (mix of stream and grade crossings); and approximately 6 others with varying titles who perform hydraulics frequently but not full time responsibility. District Office - no titled positions dedicated solely to hydraulics. Designer staff with titles of "senior, intermediate, and highway designer" number about 140 spread over 10 districts. Design tasks vary widely among staff. Mike Harms oversees consultant projects.
- Montana - The MDT Hydraulics Section is centrally located. The staff includes 10 Hydraulic Design Engineers, an Operations Engineer, the Hydraulic Engineer and one CADD detailer. We are a stand-alone functional unit within the Highways Bureau. We are responsible for all Bridge opening waterway design, Culvert design, permanent erosion control, storm drain design, Bridge scour reviews, scour mitigation projects and POA development for in-place structures, and we obtain Floodplain Permits. We assist Maintenance with drainage related issues. We also assist our consultant Design Bureau in review of Hydraulic related designs for consultant projects and review all system impact submittals from developers.
- Nevada - The Hydraulics Section works closely with our Environmental Services Division, and we share duties for environmental and stormwater quality permitting requirements.
- New York - Main Office Hydraulics (in Office of Structures) does hydraulic/hydrologic analysis for bridge replacements is; also analysis and design for scour countermeasures, stream restoration projects, and coordinates with Environmental office on COE Nationwide Permit Regional Conditions. We assist Regional and Main Office Design as requested i.e. energy dissipators for culverts. The Design Office has primary responsibility for culvert design, roadway drainage and stormwater management. Regional Hydraulic Engineers do bridge scour evaluations hydraulics as part of their design duties; also culvert hydraulics. Regional Hydraulic Engineers usually report to Regional Bridge Management Engineers.
- Pennsylvania - Our preferred option is for PennDOT to do H&H design and obtain the permit. Our second preference is for PennDOT to do preliminary H&H work to establish waterway opening acceptable to regulatory agency (PADEP).
- South Carolina - SCDOT is centralized with 4 Production Groups and a Support Group that deals with H & H issues. Each Production Group has 4 employees which do both Road and Bridge Hydraulics. The Support Group has 8 employees responsible for Policy, Manual updates, Bridge Scour Program, MS4 Program, Encroachment Permits (H & H), and Drainage Complaints. Training is normally either done on the job or through NHI Courses.

- South Dakota - Roadway Designers are responsible for the design of small culverts (basins less than 1000 acres) and storm drainage systems. Also general erosion and sediment control features.
- Tennessee - The Hydraulics Section in the Structures Division is responsible for Hydraulic Design of structures with a 50 year flood of 500 cfs or greater, bridge scour calculations, bridge deck drainage, obtaining USCG permits, USACE and TVA reservoir fill offset plans, and FEMA NFIP coordination. The Roadway Design Division handles all other drainage and erosion control.
- Wisconsin - We have a Storm Water Management position in our Bureau of Environment but this position is currently vacant.

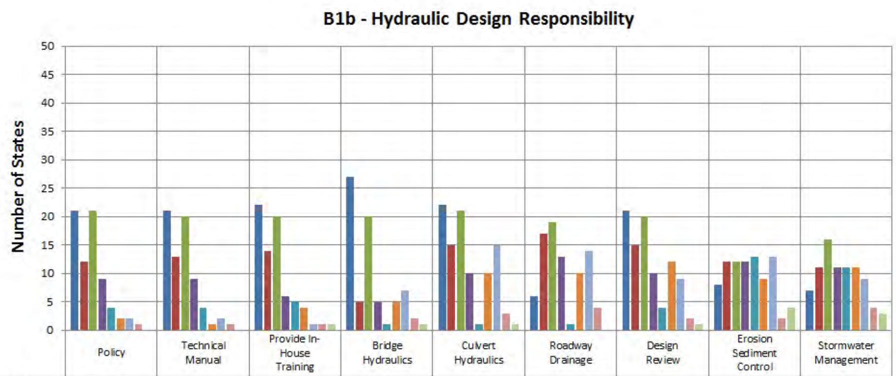


	CT	ME	MA	NH	RI	VT	DE	MD	NJ	NY	PA	VA	WV
Region	Northeast						MidAtlantic						
Central Office Bridge Hydraulic Section		3	4		0		16	14		4	2		
Central Office Roadway Hydraulic Section			0	3	1		2	29					
Central Office Combined Hydraulic Section	9		0		1	3	4		4			7	4
Central Office Design Section (collateral)		8	0	10	19		30			3	2	2	16
Central Office Other		3	0									2	
District Office Hydraulic Section			0								16	4	
District Office Design Section (collateral)			0	6						16	102		20
District Office Maintenance Section (collateral)	4		0				29		1		20		
District Office Other			0								22		
Total	13	14	4	19	21	3	81	43	5	23	164	15	40

	AL	FL	GA	KY	MS	NC	SC	TN	IL	IN	IA	MI	MN	MO	OH	WI
Region	Southeast								Upper Midwest							
Central Office Bridge Hydraulic Section	1		3		3			9	3		9			5	1	2
Central Office Roadway Hydraulic Section	2		2		2										3	1
Central Office Combined Hydraulic Section		4		6		68	16			7		8	7			
Central Office Design Section (collateral)			70	1												
Central Office Other	7						8							6		1
District Office Hydraulic Section		40			0	0			30				44		12	
District Office Design Section (collateral)				30		0			18	6		4				5
District Office Maintenance Section (collateral)						0										
District Office Other																
Total	10	44	75	37	5	68	24	9	51	13	9	12	51	11	16	9

	AR	LA	OK	TX	CO	KS	MT	NE	ND	SD	WY	AK	CA	HI	ID	OR	WA	AZ	NV	NM	UT	PR
Region	Lower Midwest				North Central							West Coast						Southwest				PR
Central Office Bridge Hydraulic Section			3	8	0	1		7		5	4	2	8			1		4				2
Central Office Roadway Hydraulic Section			1		2	0		4		5			5		1			6				2
Central Office Combined Hydraulic Section	6	9	0	6	0	0	13		6	0						2	7	10	13	7	2	
Central Office Design Section (collateral)			4	3	0	46		75		0	12			6								2
Central Office Other				0	0	0				0												
District Office Hydraulic Section			0	10	11	0	0			0		5	90			10	14				3	
District Office Design Section (collateral)		8	0	100	0	0	0			0												
District Office Maintenance Section (collateral)			0	0	0	0	0			0							0					
District Office Other				0	0	0				0												
Total	6	17	8	127	13	47	13	86	6	10	16	7	103	6	1	13	21	20	13	7	5	6

Figure 2.1.1 Number of hydraulic staff total and in each section, organized by state and region.



	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	21	21	22	27	22	6	21	8	7
Central Office Roadway Hydraulic Section	12	13	14	5	15	17	15	12	11
Central Office Combined Hydraulic Section	21	20	20	20	21	19	20	12	16
Central Office Design Section (collateral)	9	9	6	5	10	13	10	12	11
Central Office Other	4	4	5	1	1	1	4	13	11
District Office Hydraulic Section	2	1	4	5	10	10	12	9	11
District Office Design Section (collateral)	2	2	1	7	15	14	9	13	9
District Office Maintenance Section (collateral)	1	1	1	2	3	4	2	2	4
District Office Other	0	0	1	1	1	0	1	4	3

Figure 2.1.2 – Number of states with hydraulic design responsibilities in the indicated sections.

2.2 Consultant Work

The organizational structure and staffing levels of highway departments are often supplemented by consultants performing design responsibilities on hydraulic projects. Identifying the percent of hydraulic work performed by consultants and identifying which states are also incorporating design build projects into their highway program is necessary to provide a clear overview of organizational structure and staffing levels. This section contains three questions regarding the amount of design work annually performed by consultants and the use of design build contracts.

Question B.2.a

2. Consultant Work
   a. What percentage of your annual budget, in terms of hydraulic engineering projects, is designed by consultants?

0-25%	26-50%	51-75%	76-100%
○	○	○	○

Response:

A summary of the responses is shown in the Table 2.2.1 below. A map (Figure 2.2.1) shows each state's response showing the percentage annual budget of projects designed by consultants.

Table 2.2.1 Percent of Annual Budget Designed by Consultants

Percent Annual Budget	*Number States*
0 to 25%	16
26 to 50%	13
51 to 75%	13
76 to 100%	9

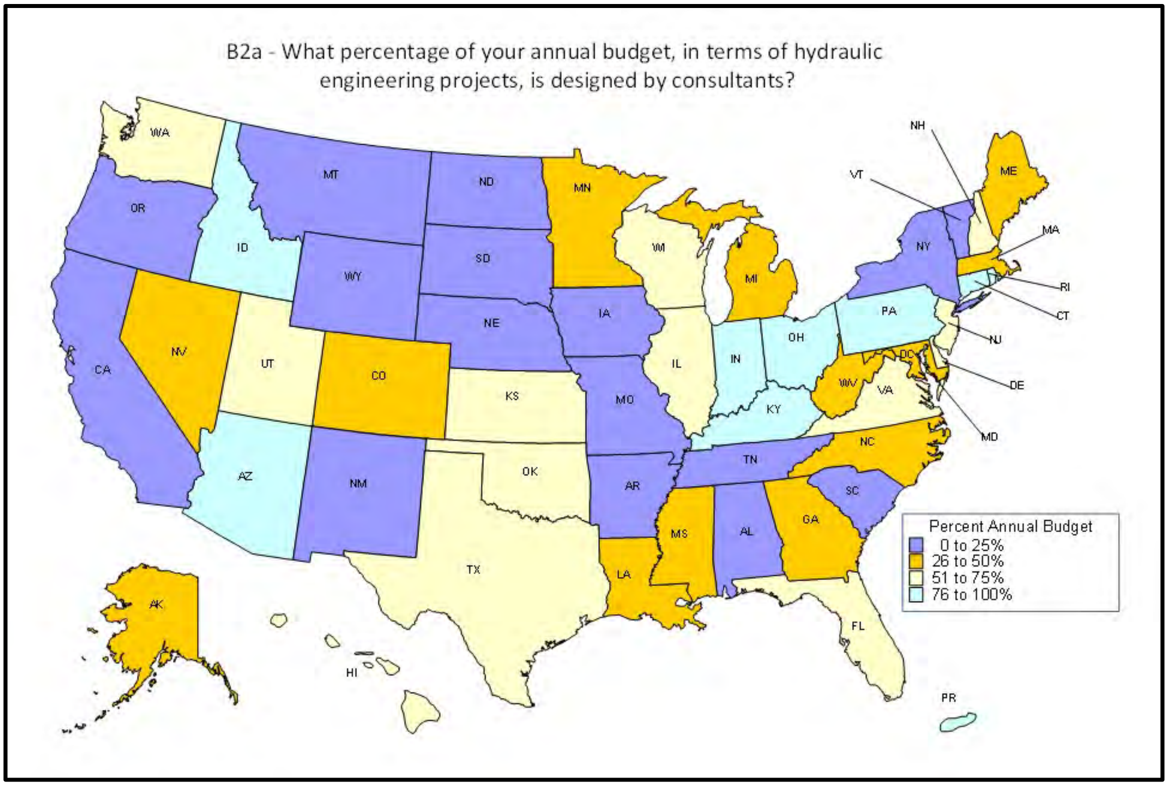


Figure 2.2.1 National perspective of percent of annual budget for hydraulic projects which are designed by consultants.

Questions B.2.b and B.2.c

b. Has your organization had any design build projects?

Yes	No
○	○

c. Have you developed hydraulic design criteria for these projects?

Yes	No
○	○

Additional Comments:

Response:

The responses to Question B.2.b indicate that 36 states have initiated design build projects and 14 states and Puerto Rico have not yet initiated any design build projects. The responses to Question B.2.c. are shown as a national map in Figure 2.2.2, that provides a combined response to both questions.

Specific State Comments to Clarify Responses:

- California - Currently in process of developing a template for design-build contracts that will include requirements for hydraulic elements of the project.
- Florida - Design/build and PPP projects are becoming more frequent.
- New Hampshire - We have only had one design-build project.
- North Dakota - We will be doing one design/build project next year for a box culvert replacement.
- Pennsylvania - Design build team must still obtain the permit. Our least preferred option, usually used in emergencies, is to provide rough waterway opening (usually same as existing) that is acceptable to PADEP. Design build team must complete H&H design and obtain permit.
- West Virginia - Consultant work has decreased significantly in the last 10 years. The Hydraulic & Drainage Unit was formed 7 years ago and has gradually increased its scope.

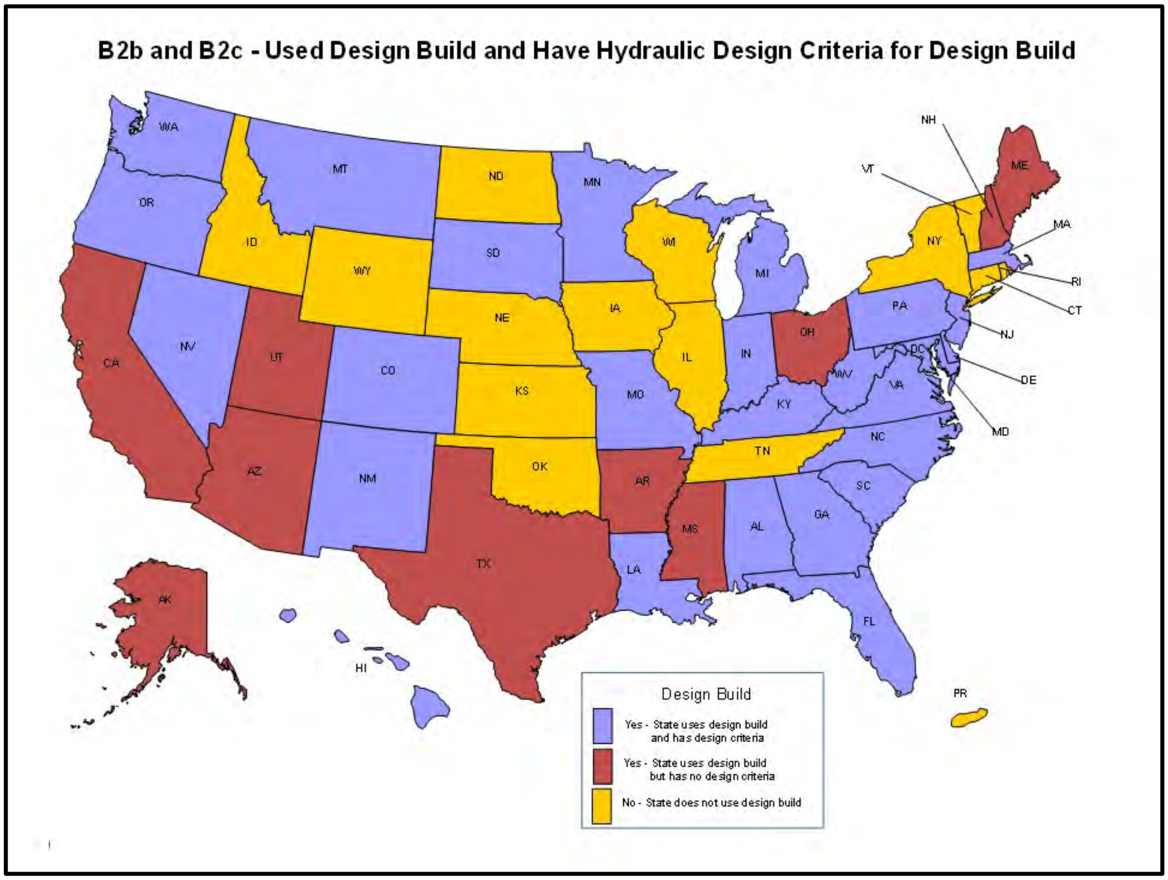


Figure 2.2.2 Combined response about states' use of design build and development of hydraulic design criteria for design build consultants.

3.0 Documentation

This chapter includes the questions and responses that fall under the category of documentation. This documentation includes questions related to hydraulic reports and hydraulic data provided on bridge and roadway design plans.

3.1 Reports

This section includes three questions related to the format of hydraulic reports and the retention of reports for future documentation. Utilizing a template format in preparation of hydraulics reports is an efficient and effective means of maintaining consistency in hydraulic designs. The question does not distinguish between templates used for hydraulic data collection and templates used for final report preparation.

Question C.1.a

C. Documentation
   1. Reports
      a. Do you use a template/form to complete hydraulic reports?

Yes	No
○	○

If the template/form is online, please provide the link to the template/form.

Response:

The responses to Question C.1.a indicate that 30 states use a template form for Hydraulic Reports and 20 states and Puerto Rico do not. These results are shown in a national perspective in Figure 3.1.1.

Twelve (12) states provided a web link for their hydraulic report template form as follows:

- Delaware:
  http://deldot.gov/information/pubs_forms/manuals/bridge_design/index.shtml
- Kansas:
  http://kart.ksdot.org/
- Minnesota:
  http://www.dot.state.mn.us/stateaid/ProjDeliv/Plans/HydraulicFloodAnalysis.doc/

http://www.dot.state.mn.us/stateaid/ProjDeliv/Plans/RiskAssessmentforEncroachmentDesign.doc

- Missouri:
  http://epg.modot.mo.gov/index.php?title=Category:101_Standard_Forms
- Nevada:
  http://www.nevadadot.com/reports%5Fpubs/Drainage%5FManual/
  http://www.nevadadot.com/reports%5Fpubs/Drainage%5FManual/
- North Carolina:
  http://www.ncdot.org/doh/preconstruct/highway/hydro/gl0399web/appendices.html
- Oregon:
  ftp://ftp.odot.state.or.us/techserv/GeoEnvironmental/Hydraulics/Hydraulics%20Manual/Chapter_04/CHAPTER_04.pdf
- Pennsylvania:
  http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/H&HHomepage?OpenFrameset
  QA checklist that is used to ensure all the required data as outlined in DM-2 Chapter 10 is included in the H&H Report.
- Tennessee:
  http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/structures/hydraulic.htm
- Utah:
  http://www.udot.utah.gov/main/uconowner.gf?n=200403161014303
- Vermont:
  http://vdotforms.vdot.virginia.gov/
- West Virginia:
  http://www.wvdot.com/engineering/TOC_engineering.htm / scroll down to 2007 Drainage Manual, section 3.5.3 starting on page 3-5.

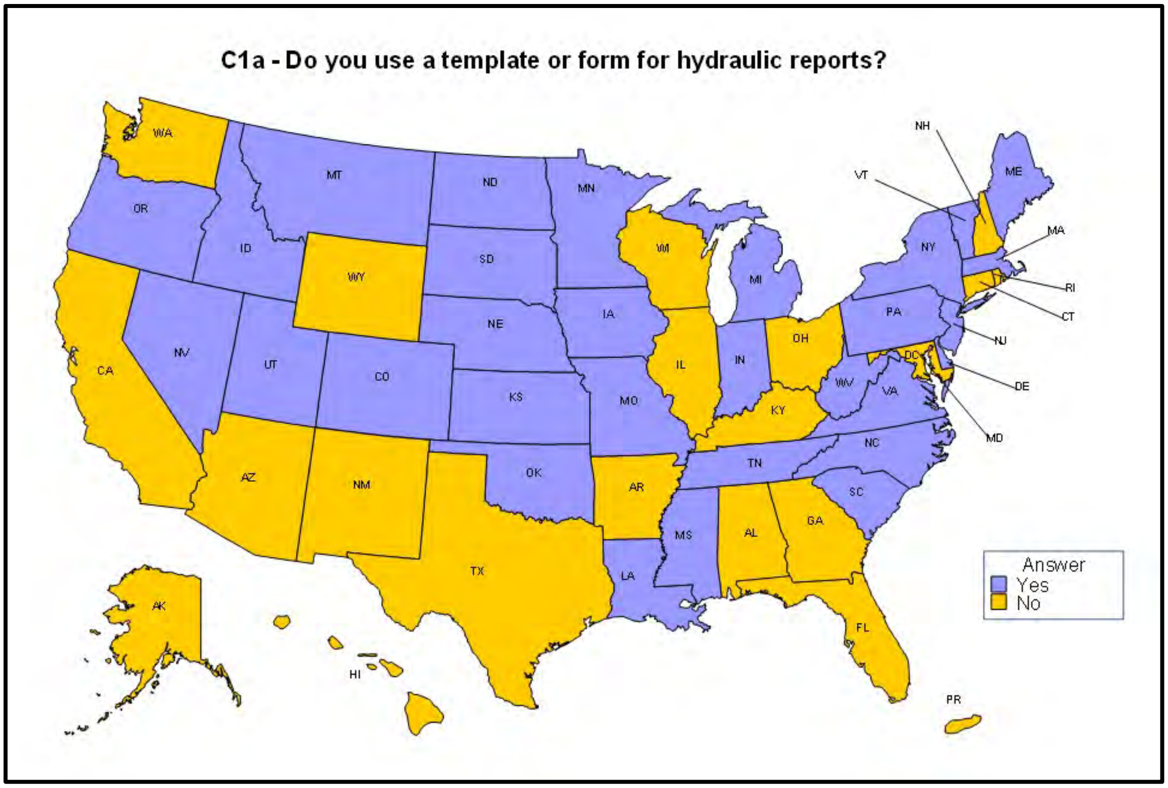


Figure 3.1.1 States that use and those that do not use a template or form for hydraulic reports.

<u>Question C.1.b</u>

b. How long are hydraulic reports kept?

Permanently		Number of Years	
Yes	No		
○	○		

Response:

The response to Question C.1.b shown in Figure 3.1.2 indicates that 42 states keep hydraulic reports permanently and 9 states keep them for various periods from 2 years to 50 years.

Specific State Comments to Clarify Responses:

- Missouri – Varies
- New Mexico – As long as archives allow
- South Dakota – 25+ years
- Wisconsin – Permanent to 25 years

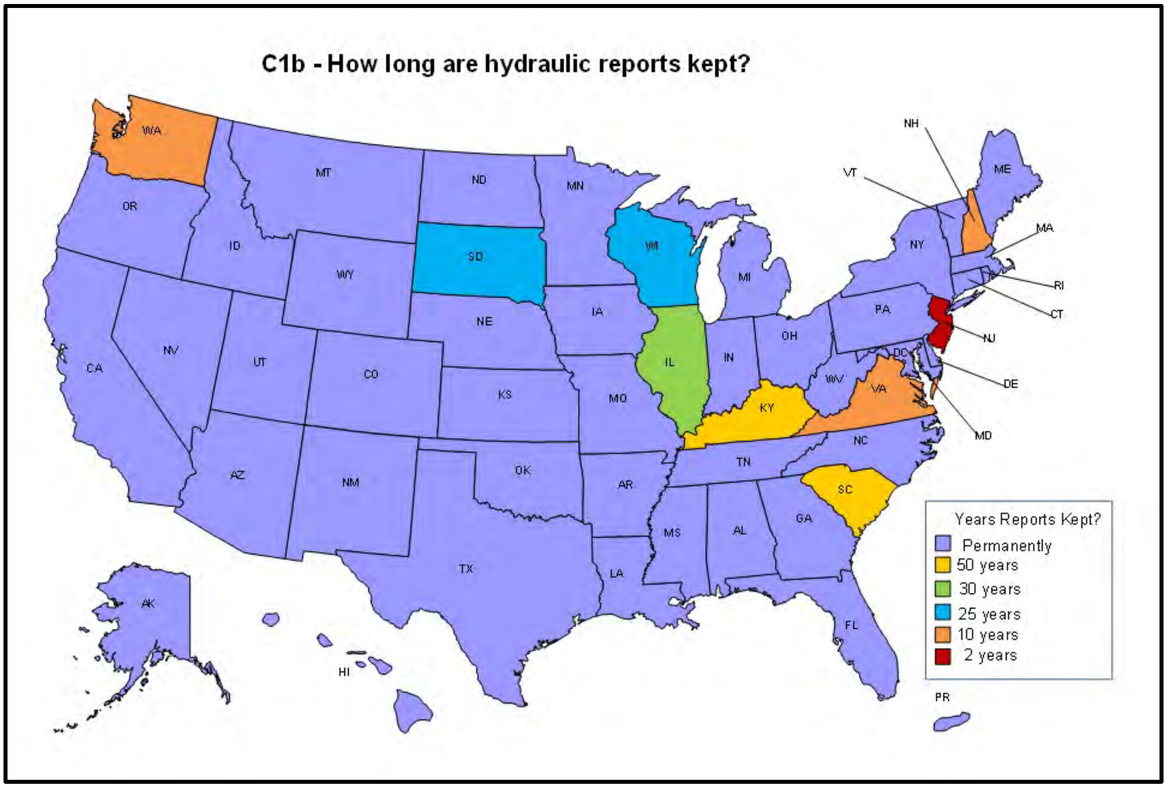


Figure 3.1.2 National map showing the number of years the responding transportation agencies maintain their records of hydraulic reports.

Question C.1.c

c. Are these reports available to designers and consultants for future projects?

Yes	No
○	○

Response:

All respondents indicated that the hydraulic reports kept in storage are available for designers and consultants on future projects. No graphic depiction of the responses is provided.

3.2 Plans

Question C.2.a

2. Plans
   a. What information is routinely included on plans or in reports?

	Design Plans		Hydraulic Reports	
	Bridge	Roadway	Bridge	Roadway
Design Discharge	☐	☐	☐	☐
Drainage Area	☐	☐	☐	☐
Water Surface Elevation	☐	☐	☐	☐
-- Design Flow Elevation	☐	☐	☐	☐
-- 100-Year Flow Elevation	☐	☐	☐	☐
-- 500-Year Flow Elevation	☐	☐	☐	☐
-- Other	☐	☐	☐	☐
Backwater	☐	☐	☐	☐
Computed Scour	☐	☐	☐	☐
Scour Elevations	☐	☐	☐	☐
Foundation Type and Depth	☐	☐	☐	☐
Original Channel Cross-section	☐	☐	☐	☐
Original Channel Profile	☐	☐	☐	☐
Culvert	☐	☐	☐	☐
-- Culvert Size	☐	☐	☐	☐
-- Culvert Length	☐	☐	☐	☐
-- Culvert Location	☐	☐	☐	☐
-- Alternative Pipe Size	☐	☐	☐	☐
Erosion Control	☐	☐	☐	☐
Other	☐	☐	☐	☐

Response:

This question asked what types of hydraulic information are routinely included on plans or in reports. This question makes a distinction between roadway plans and bridge plans and between roadway hydraulic reports and bridge hydraulic reports requiring the responses to be presented in four separate figures. The responses are shown in bar charts in Figures 3.2.1, 3.2.2, 3.2.3, and 3.2.4 and indicate the number of agencies responding affirmatively to hydraulic data items in the list.

Specific State Comments to Clarify Responses:

- Alaska - Roadway design plans include water surface elevations when designs include fish passage designs, storm sewers, other critical design considerations, such as floodplain regulations.
- Arizona – Bridge Design Plans include overtopping water surface elevation.
- Connecticut – Roadway Design Plans include design frequency and temporary hydraulic facility data.
- Delaware – Bridge Design Plans include 25 and 50 year water surface elevations.
- Hawaii – Roadway Design Plans include 25 year Hydraulic Gradeline.
- Illinois – Bridge Design Plans include waterway opening. Roadway Design Plans include outlet protection details.
- Louisiana – Bridge Design Plans include highwater elevation.
- Maine – Bridge Design Plans include 50 year water surface elevation.
- Maryland – Bridge Design Plans include 2 and 10 year water surface elevations. Roadway Design Plans include stormwater management facilities and dams.
- Minnesota – Roadway Design Plans include additional data for ponds and large culverts.
- Montana – Bridge Design Plans include velocity and overtopping water surface elevation.
- New Hampshire – Bridge Design Plans include 10, 25, and 50 year water surface elevations.
- North Caroline – Reports include Water Classification, Jurisdictional status, Historical HW data, FEMA data, rating curve pre & post.
- Oregon – Bridge Design Plans include overtopping water surface elevation.
- Pennsylvania – Bridge Design Plans include temporary conditions for lower flows. Roadway Design Plans include baffle configuration for culverts.
- West Virginia – Bridge Design Plans include overtopping highwater elevation. Roadway Design Plans include ditch linings.
- Vermont - Roadway projects are typically structure less than 6'.

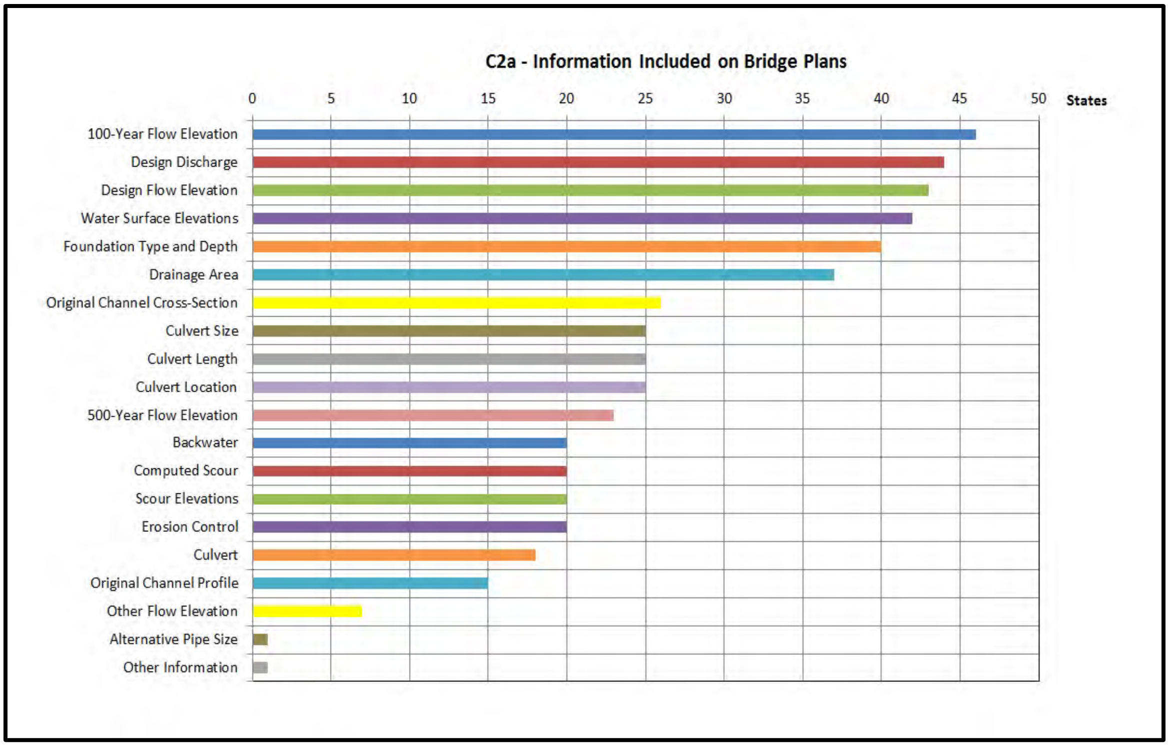


Figure 3.2.1 Bar chart of number of states indicating hydraulic data items recorded on bridge plans.

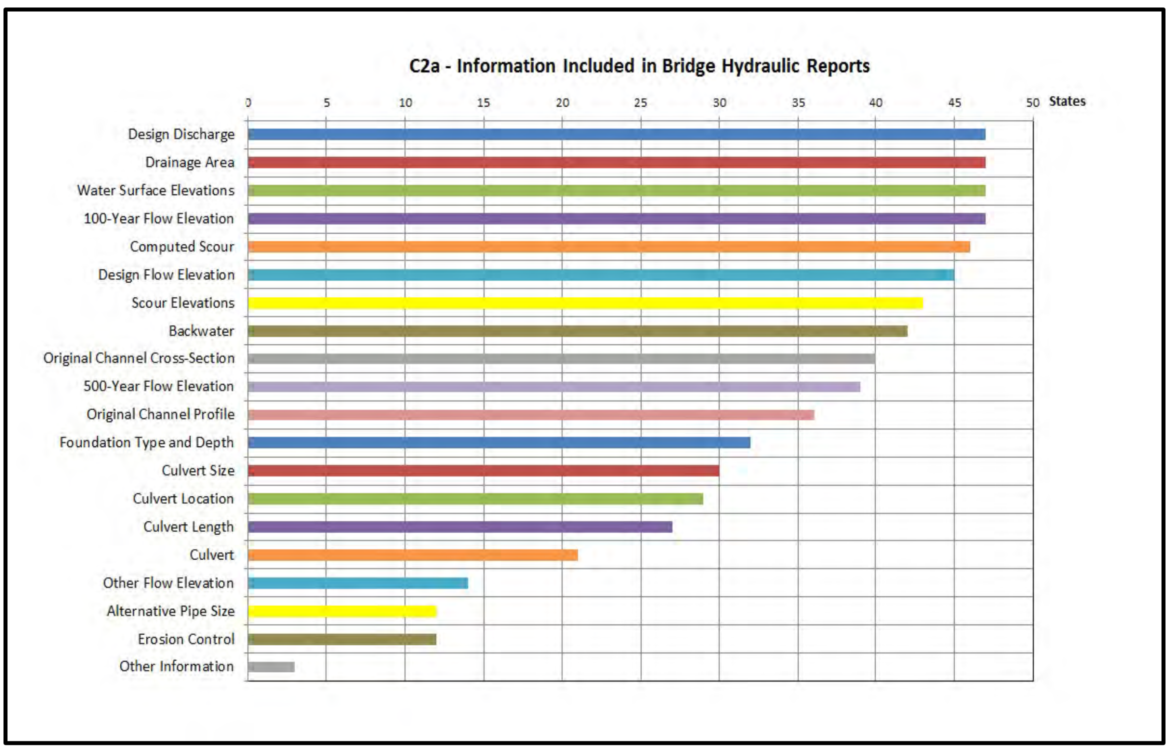


Figure 3.2.2 Bar chart of number of states indicating respective hydraulic data items included in bridge hydraulic reports.

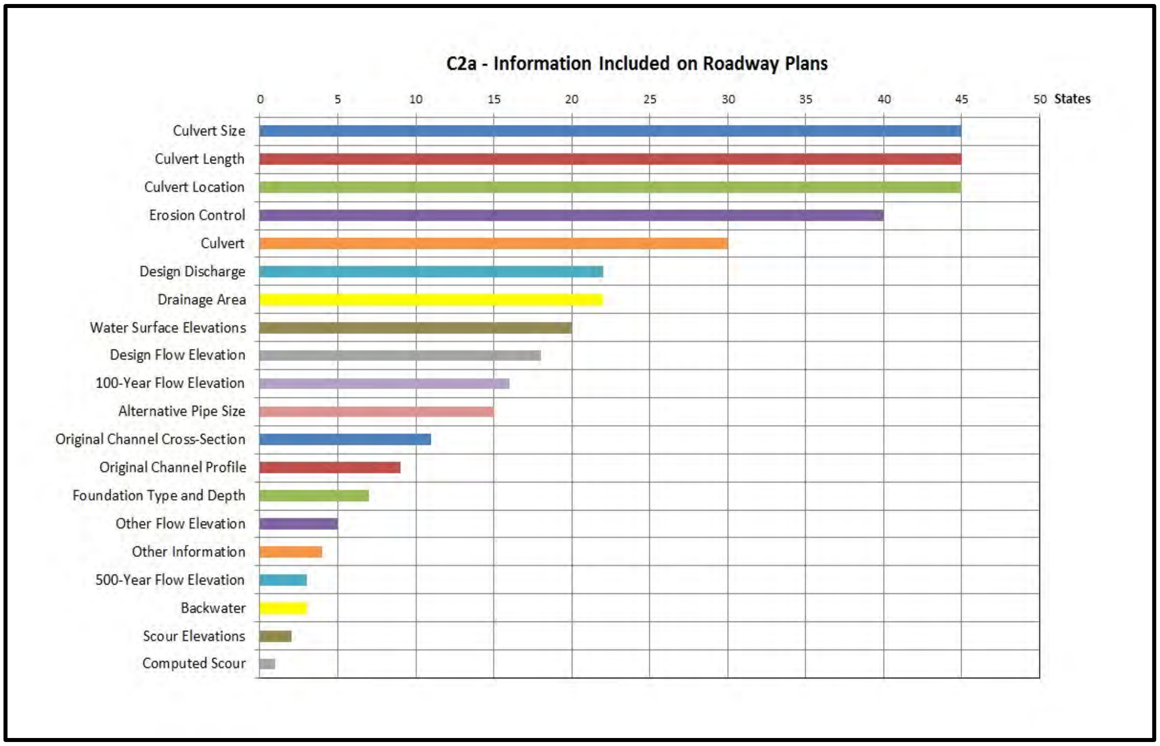


Figure 3.2.3 Bar chart of number of states indicating respective hydraulic items recorded on roadway plans.

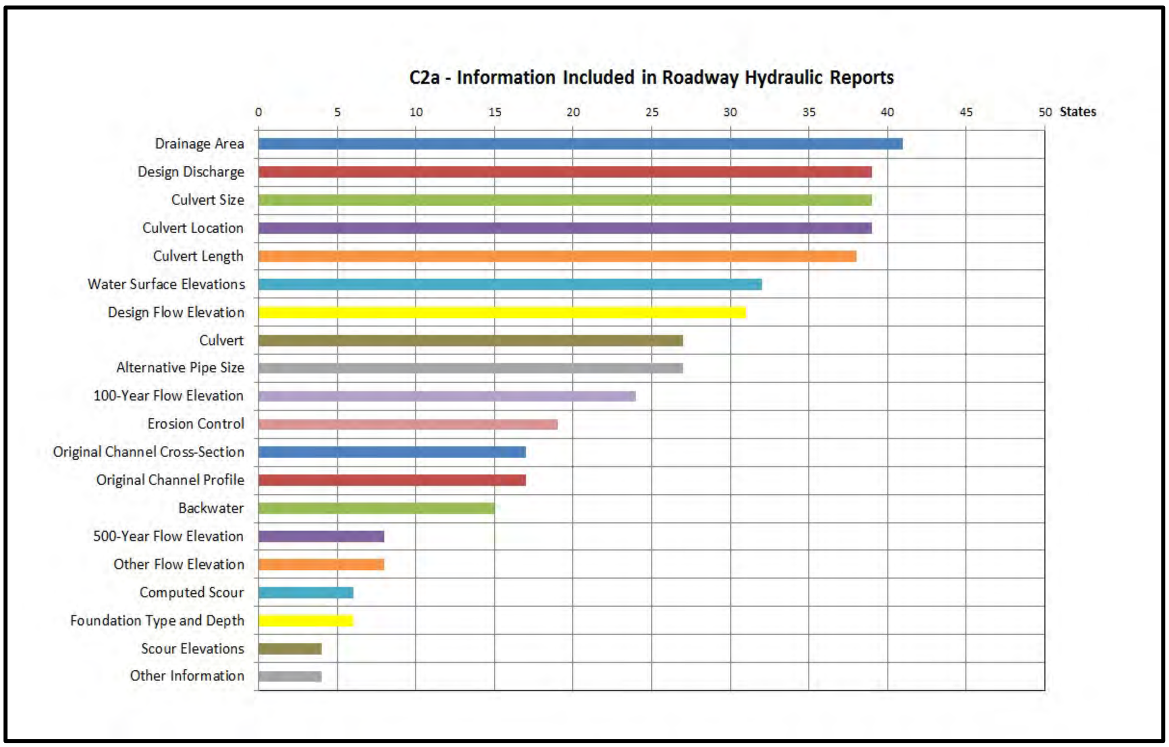


Figure 3.2.4 Bar chart of number of states indicating respective hydraulic items recorded in roadway hydraulic reports.

<u>**Question C.2.b**</u>

b. Is as-built information recorded and archived?

Yes	No
○	○

Response:

The responses indicate that 43 states and Puerto Rico record and archive as-built plan information and 7 states do not. The results are shown in the national map of Figure 3.2.5.

Specific State Comments to Clarify Responses:

- Illinois - Hydraulic Reports for bridges, culverts and pumping stations are kept for 30 years. Roadway plans are also kept for a lengthy period of time. IDOT is in the process of archiving plans, reports, etc. electronically, but paper copies of the above are still required and stored.
- Nevada - NDOT is in the early stages of archiving into a digital format (pdfs).
- New Jersey - We do not have enough space to store drainage reports permanently.

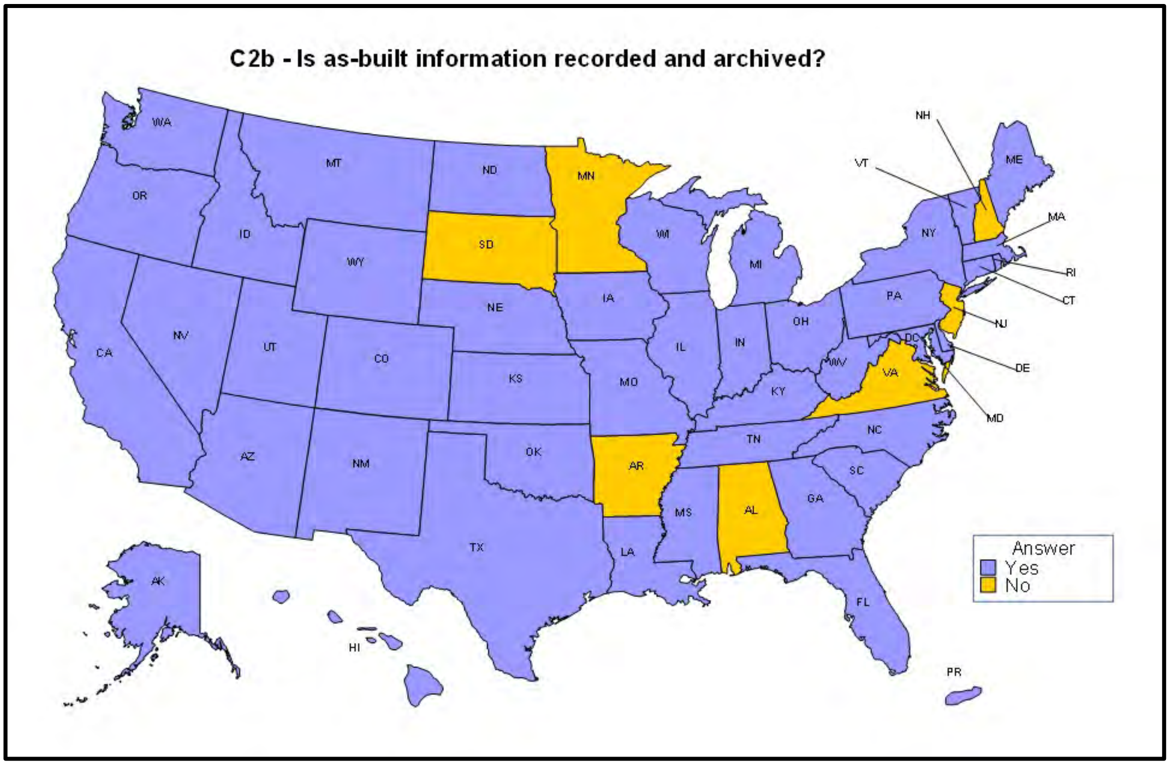


Figure 3.2.5. National perspective of states that record and archive as-built plan information.

Question C.2.c

c. Do local agency plans and reports also include this information?

Yes	No
○	○

Additional Comments:

Response:

The responses to Question C.2.c. were evenly divided between the states with 25 states indicating that local agency plans and reports include the same hydraulic data as was indicated for state plans and reports and 25 states and Puerto Rico stating that local agency plans and reports do not include the hydraulic data. A national breakdown of the yes and no responses are shown in Figure 3.2.6.

Specific State Comments to Clarify Responses:

- Alaska - Outline for hydraulic reports in chapter 4 of Alaska Highway Drainage Manual.
- Arizona - Don't know the specific requirements of local agencies, but the designs are conducted by the same consultants who do our work and would turn out to have the same level of effort. Local governments' major projects that we review have the same level of design as our projects.
- California - Reports/documentation is advised, not required, so not likely that local agencies always have this retained or developed. Even in the DOT, documentation for every project is not generated.
- Indiana - For local agency plans I can only address the federal aid projects since they are the only ones requiring a state review.
- Missouri - Federally funded local agency bridge replacement projects typically include information similar to that of state bridge plans.
- Montana - Unsure of local agency requirements. Any consultant performing work for the MDT is required to provide all Hydraulic reports and data as if we were doing the work internally.
- New Hampshire - Not sure how to respond to question 2c regarding information from "local agency".
- New Mexico - A preliminary report is prepared prior to 30% plan inspection. A final report is prepared to 60% plan inspection. A bridge sheet is prepared to present the waterway data and scour depth at various flood frequency.

- New York - Local agencies: hydraulic data reports and plans - some agencies include specified items, some don't. Varies widely.
- Oklahoma - The as-built plans are stored at the central office and at the related Division Office.
- Puerto Rico – Do not know if local agency includes the same information.
- South Dakota - Local Agency plans and reports are not consistent in format or content. It is unknown where some local agency design information is stored and for how long.
- Tennessee - All this information is required for bridges and has been since the early 1990s but is not always available for locally designed and built structures.
- West Virginia - For major sites where WVDOH reviews them, we retain the information.

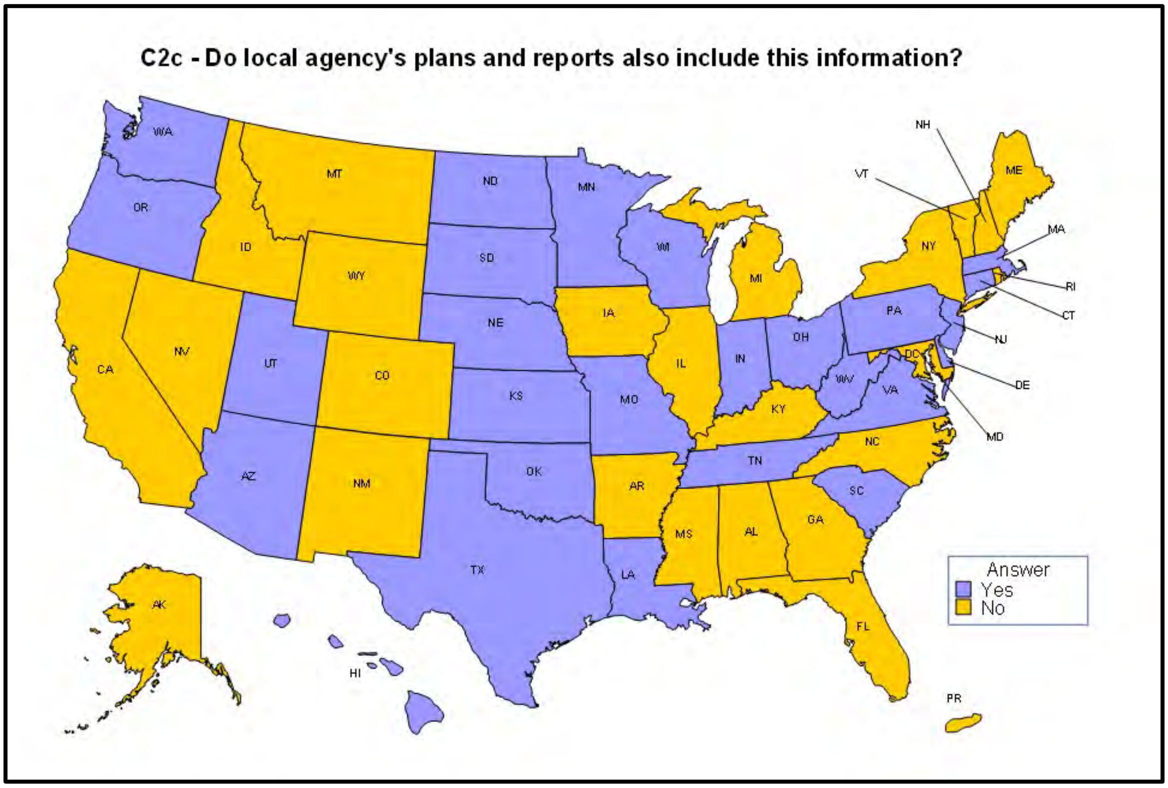


Figure 3.2.6. Map indicating whether local agency plans and reports include the same hydraulic data as is found on state plans and reports.

4.0 Policy

The policy section of the questionnaire includes 15 questions that range from the type of hydraulic manuals and who was responsible for content to specific policies on design frequencies, roadway drainage criteria, and pipe selection. The objective in including the policy questions was to determine which states have documented their design policies in their manuals to ensure consistency in design application and to see if there is a significant range in policy values that may affect level of service to highway users or create issues with driver expectations.

4.1 Manuals

This section contains four questions on the content of roadway and bridge hydraulic manuals. The first question lists various hydraulic topics and asks the transportation agency to identify whether the respective topics are located in the agency's Roadway Design Manual, Bridge Design Manual, Combined Drainage Manual, or other manual. The next three questions identify whether the primary developers of the manuals were in-house staff, consultants, or others and what publication sources were used for the technical guidance.

<u>Question D.1.a</u>

D. Policy
   1. Manual(s)
      a. Content
         (check all that apply)

	Roadway Design Manual	Bridge Hydraulics Manual	Combined Drainage Manual	Other Manual
Hydrology	☐	☐	☐	☐
Bridge Hydraulics	☐	☐	☐	☐
Scour Evaluations	☐	☐	☐	☐
Stream Stability	☐	☐	☐	☐
Countermeasures	☐	☐	☐	☐
Culvert Hydraulics	☐	☐	☐	☐
Roadway Drainage	☐	☐	☐	☐
Coastal Hydraulics	☐	☐	☐	☐
Software Applications	☐	☐	☐	☐
Erosion and Sediment Control	☐	☐	☐	☐
Storm Water Management	☐	☐	☐	☐

Response:

The responses to this question are presented in Figure 4.1.1 in a bar chart format that shows the number of states that have placed the respective hydraulic topics into the four manual choices presented.

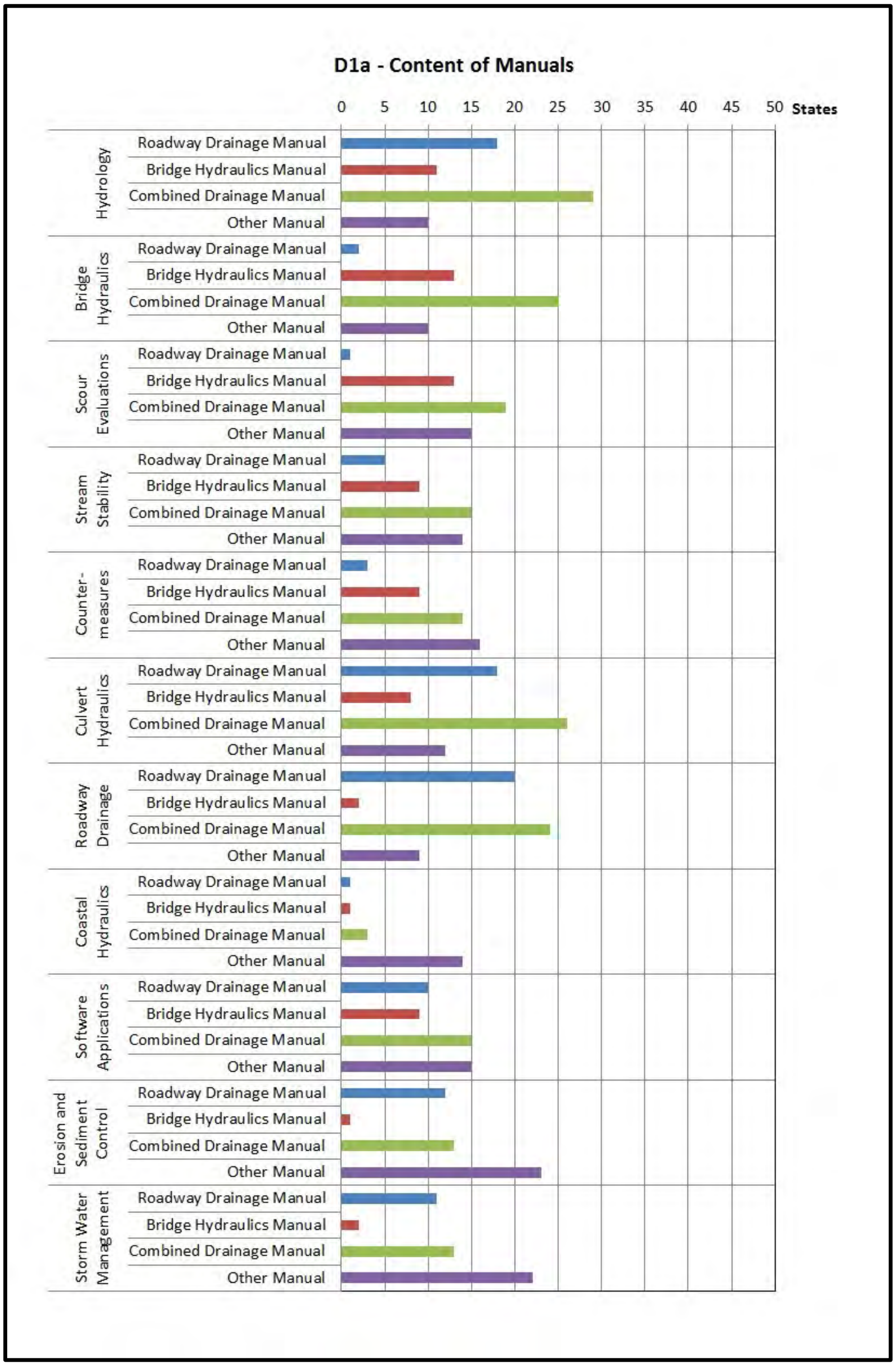


Figure 4.1.1 Number of states that include the designated hydraulic content in specific manual types.

Questions D.1.b and c

b. Roadway Drainage Design Guidance

	In-house Staff	Consultants	Others
Developed By	☐	☐	☐
Updated By	☐	☐	☐

Date Last Updated		

Reviewed by FHWA Division Office?

Yes	No
○	○

c. Bridge Hydraulics Design Guidance

	In-house Staff	Consultants	Others
Developed By	☐	☐	☐
Updated By	☐	☐	☐

Date Last Updated		

Reviewed by FHWA Division Office?

Yes	No
○	○

Response:

The responses to both questions are combined in a bar chart format in Figure 4.1.2.

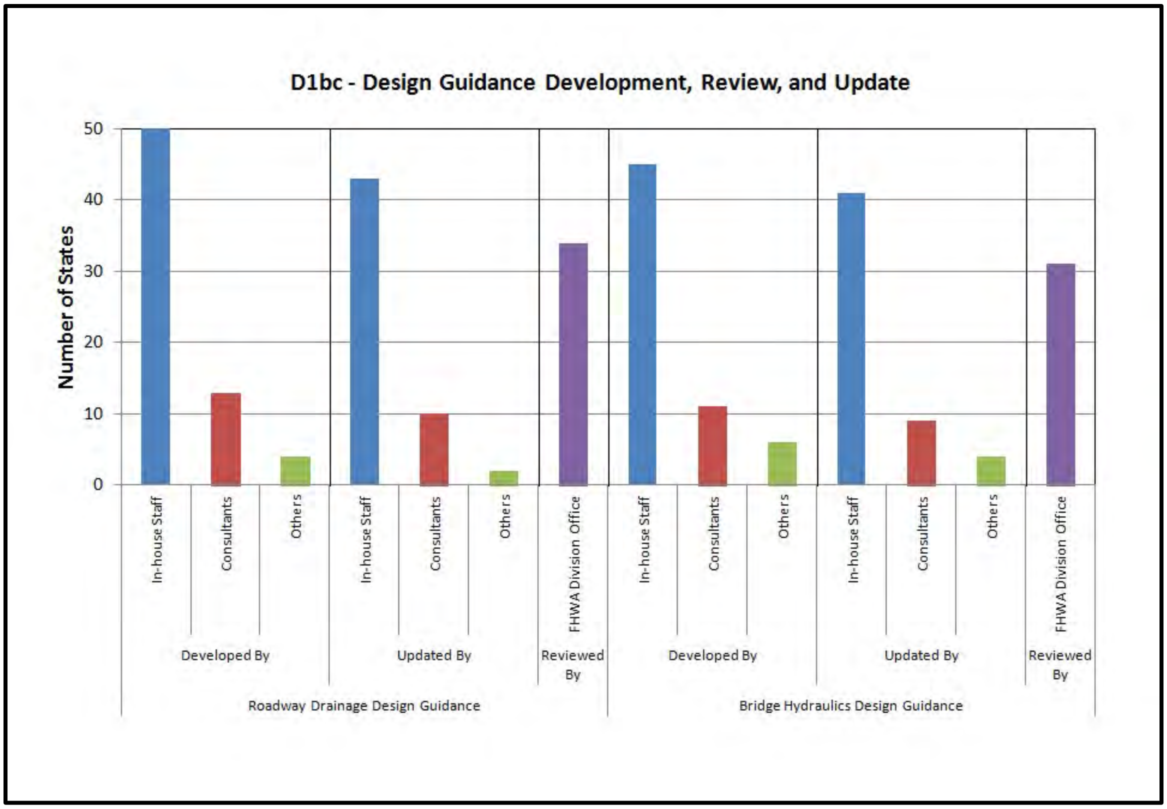


Figure 4.1.2 Bar chart showing number of states with either in-house staff, consultants, or other party responsible for design guidance development. Also shown is the number of states that have design guidance reviewed by the FHWA Division Office.

Question D.1.d

d. Sources of Information

	AASHTO Drainage Manual and/or Hydraulic Design Guidelines	FHWA Publications	Research Reports	Other
Source(s) of Information to Develop State Manuals	☐	☐	☐	☐
Recommended Source(s) of Information in Addition to State Manual	☐	☐	☐	☐

Response:

The responses indicate that most states have used material from a combination of the AASHTO Drainage Manual, the AASHTO Hydraulic Design Guidelines, FHWA publications, and research reports for their drainage manuals. Those manuals are also recommended by most states for additional information on subjects not covered in the state manual.

The responses are shown in Figure 4.1.3 in a bar chart format displaying the number of states responding to each of the choices provided and in a national perspective in Table 4.1.1 identifying the response of each state and Puerto Rico.

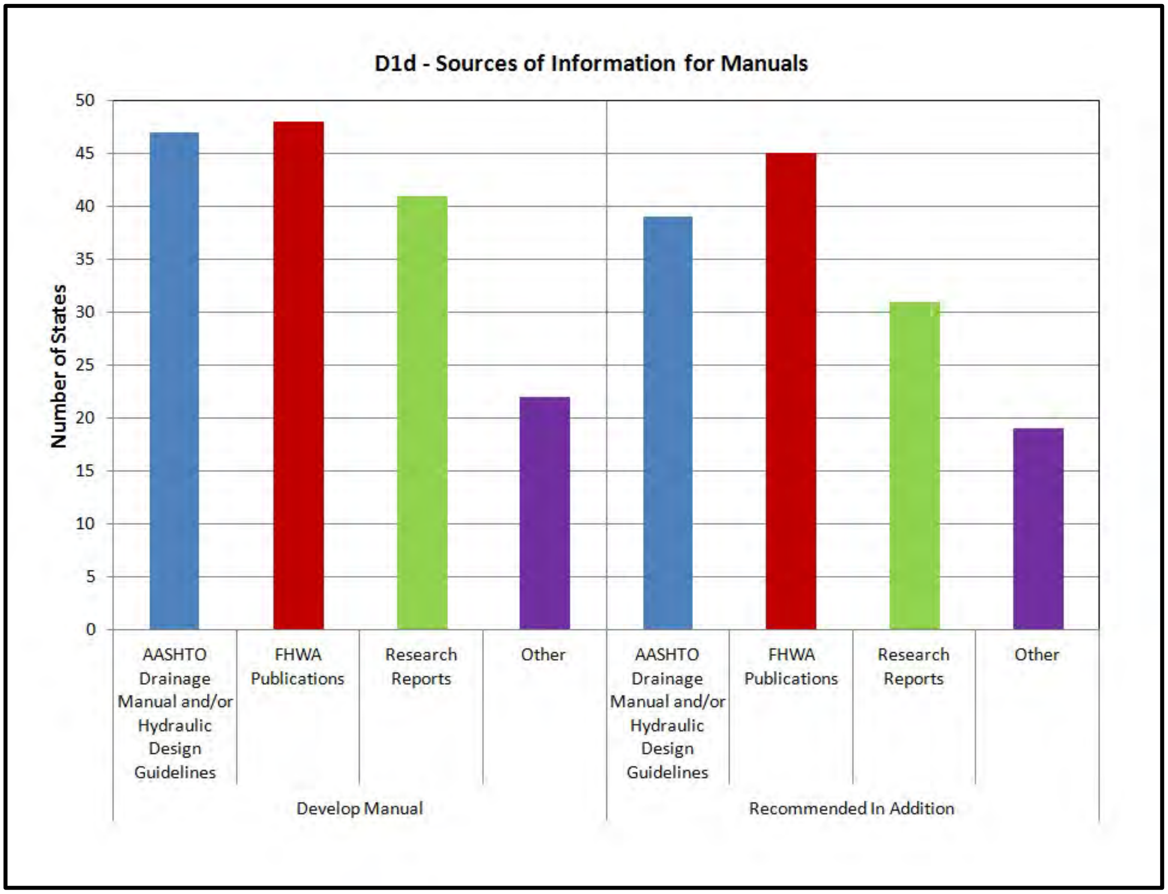


Figure 4.1.3 Chart of number of states that used the respective national engineering publications as sources of information for their drainage manuals or as recommended references.

Table 4.1.1 Individual state's responses regarding source material for the state manuals and recommended additional resources.

D1d – Sources of Information								
	Used in Development of State Manuals				Recommended as Additional Resource			
State	AASHTO Drainage Manual and/or Hydraulic Design Guidelines	FHWA Publications	Research Reports	Other	AASHTO Drainage Manual and/or Hydraulic Design Guidelines	FHWA Publications	Research Reports	Other
AL								
AK	X	X	X	X	X	X	X	X
AZ	X	X	X					
AR	X	X	X		X	X		
CA	X	X	X	X		X	X	X
CO	X	X	X		X	X	X	
CT	X	X	X		X	X	X	
DE	X	X		X	X	X	X	X
FL		X	X			X		
GA	X	X	X	X		X	X	
HI	X	X			X	X		
ID	X	X			X	X		
IL	X	X	X	X	X	X	X	X
IN	X	X	X	X	X	X	X	X
IA						X	X	
KS	X	X	X	X	X	X	X	X
KY	X	X	X			X		
LA	X	X	X	X	X	X		
ME	X	X	X	X				
MD	X	X	X	X	X	X	X	X
MA	X	X	X		X	X	X	
MI	X	X				X	X	
MN	X	X				X	X	X
MS								
MO	X	X	X	X	X	X	X	X
MT	X	X			X	X		
NE	X	X	X		X	X	X	
NV	X	X	X	X	X	X	X	X
NH	X	X	X	X	X	X	X	X
NJ	X	X	X	X	X	X	X	X
NM	X	X	X		X	X		
NY	X	X			X	X		
NC	X	X	X		X	X		X
ND	X	X	X		X	X		
OH	X	X	X					
OK	X	X	X	X	X	X		
OR	X	X	X		X	X	X	
PA	X	X	X		X	X	X	
PR	X	X	X	X	X	X	X	X
RI	X	X	X		X	X	X	X
SC	X	X	X	X	X	X	X	
SD	X	X	X		X	X	X	X
TN	X	X	X		X	X	X	
TX	X	X	X		X	X	X	
UT	X	X	X	X	X	X	X	X
VT	X	X	X					
VA	X	X	X		X	X	X	
WA	X	X	X	X	X	X	X	
WV	X	X	X	X	X	X	X	X
WI	X	X	X	X	X	X		
WY	X	X	X	X	X	X	X	X

Question D.1.e

e. If posted online, what is the address of your state drainage manual?

Response:

The web site addresses for those states responding are shown below:

- Arizona:
  http://www.azdot.gov/Highways/Roadway_Engineering/Drainage_Design/index.asp / Look under Manuals\Roadway Design Guidelines\Chapter 600
- Arkansas:
  http://www.arkansashighways.com/manuals/manuals.aspx Drainage Manual was developed when Hydraulics Section was initially formed in early 80's and has not been revised. Plan to revise manual, based on AASHTO Model.
- California:
  http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm
- Colorado:
  http://www.coloradodot.info/programs/environmental/water-quality/documents/drainage-design-manual
- Connecticut:
  ConnDOT Drainage Manual:
  http://www.ct.gov/dot/cwp/view.asp?a=1385&Q=260116&dotPNavCtr=|#40139 / / 2004 Connecticut Stormwater Quality Manual:
  http://www.dep.state.ct.us/wtr/stormwater/strmwtrman.htm
- Delaware:
  http://deldot.gov/information/business/drc/index.shtml
- Florida:
  http://www.dot.state.fl.us/rddesign/dr/Manualsandhandbooks.shtm
- Georgia:
  http://www.dot.ga.gov/doingbusiness/PoliciesManuals/roads/Drainage/Drainage%20Manual.pdf
- Hawaii:
  The Hawaii Department of Transportation developed a "Design Criteria for Highway Drainage" document, dated 5/15/06. This document describes the hydrologic, hydraulic, and materials used for highway drainage. Detailed design methodology is referred to the various HEC and other FHWA manuals/guidelines. The document is currently in a process of being updated. It is currently under review by our DOT and local FHWA office. I anticipate the document to be effective in the spring/summer of 2010.
- Illinois:
  http://www.dot.il.gov/bridges/brmanuals.html

- Indiana:
  http://www.in.gov/dot/div/contracts/standards/dm/english/index.html
- Kansas:
  http://kart.ksdot.org Kansas DOT does not have a separate Bridge Hydraulics Manual. The Bridge Design Manual has a section dedicated to bridge hydrology and hydraulics. Design of bridges is based on AADT or recurrence interval, with suggested clearances for drift and debris. FEMA backwater allowances are also considered.
- Kentucky:
  http://transportation.ky.gov/design/drainage/drainage.html
- Louisiana:
  http://www.dotd.louisiana.gov/highways/project_devel/design/standardforms.asp
- Maryland:
  http://www.mdt.mt.gov/publications/manuals.shtml
- Michigan:
  http://www.michigan.gov/stormwatermgt/0,1607,7-205--93193--,00.html
- Minnesota:
  http://www.dot.state.mn.us/bridge/hydraulics/drainagemanual/
- Missouri:
  http://epg.modot.org / / All manuals are integrated into "Engineering Policy Guide" (EPG) Primary sections related to drainage are 748, 749, 750, and part of 127, 640, 751, and others.
  http://epg.modot.org / / All manuals are integrated into "Engineering Policy Guide" (EPG) Primary sections related to drainage are 748, 749, 750, and part of 127, 640, 751, and others.
  http://epg.modot.org/ / EPG Sections 748, 749, 750, also part of 127, 640, 751 and others primarily pertain to drainage design.
- Nebraska:
  www.nebraskatransportation.org/roadway-design/manual.htm
- Nevada:
  http://www.nevadadot.com/reports%5Fpubs/Drainage%5FManual/
- New Hampshire:
  http://www.nh.gov/dot/org/projectdevelopment/highwaydesign/designmanual/index.htm / There are other manuals that are not posted online yet.
- New Jersey:
  http://www.state.nj.us/transportation/eng/documents/drainage/drainage.shtm
- New York:
  Bridge Manual:
  https://www.nysdot.gov/divisions/engineering/structures/manuals/bridge-manual-usc / / Highway Design Manual:
  https://www.nysdot.gov/portal/page/portal/divisions/engineering/design/dqab/hdm
- North Carolina:
  http://www.ncdot.org/doh/preconstruct/highway/hydro/gl0399web/default.html
- Ohio:
  http://www.dot.state.oh.us/Divisions/HighwayOps/Structures/Hydraulic/LandD/Pages/LDManual,Volume2.aspx

- Oregon:
  http://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/hyd_manual_info.shtml
- Pennsylvania:
  http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/H&HHomepage?OpenFrameset / / Design Manual 2 Chapter 10 is Publication # 13M / Design Manual 4 Chapter 7 is Publication # 15M / PennDOT Drainage Manual is Publication # 584 - updating is in progress
- Rhode Island:
  http://www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/t4guide/desman.htm
- South Carolina:
  http://www.scdot.org/doing/hydrology_requirements.shtml
- Tennessee:
  http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/structures/hydraulc.htm / /
  http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DrainManChap%201-10.htm
- Texas:
  http://onlinemanuals.txdot.gov/txdotmanuals/hyd/index.htm /
  http://onlinemanuals.txdot.gov/txdotmanuals/geo/index.htm /
  http://onlinemanuals.txdot.gov/txdotmanuals/env/index.htm
- Utah:
  http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:826,
- Virginia:
  http://www.virginiadot.org/business/locdes/hydra-drainage-manual.asp
- Washington:
  www.wsdot.wa.gov/publications/manuals/fulltext/M23-03/HydraulicsManual.pdf /
  www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/HighwayRunoff.pdf
- West Virginia:
  http://www.wvdot.com/engineering/TOC_engineering.htm
- Wisconsin:
  FDM Chapters 10 - Erosion Control and Storm Water Quality and Chapter 13 Drainage http://roadwaystandards.dot.wi.gov/standards/fdm/ / / Bridge Manual - http://on.dot.wi.gov/dtid_bos/extranet/structures/bridge-manual/index.htm

4.2 Hydrology Policies

This section consists of one multi-part question concerning the design frequency for the various roadway classifications of Interstate, Major Arterials, Minor Arterials, and Local Roads. Each of these roadway classifications is further broken down into categories of Bridge, Bridge Foundation Scour Design, Culvert, Storm Drain, Pavement Drainage, and Depressed Sections. A final category of Temporary Structure inquiries into the frequency used to design temporary stream crossings during construction and also any design frequency specified for contractors' haul roads.

Question D.2.a

2. Hydrology
   a. What Peak Discharge Return Period do you use to design the following:
      (check all that apply or most nearly applies)

Interstates

	< 10 year	10-year	25-year	50-year	100-year	500-year	Overtopping
Bridge	☐	☐	☐	☐	☐	☐	☐
Bridge Foundation Scour Design	☐	☐	☐	☐	☐	☐	☐
Culvert	☐	☐	☐	☐	☐	☐	☐
Storm Drain	☐	☐	☐	☐	☐	☐	☐
Pavement Drainage	☐	☐	☐	☐	☐	☐	☐
Depressed Sections	☐	☐	☐	☐	☐	☐	☐

Major Arterials

	< 10 year	10-year	25-year	50-year	100-year	500-year	Overtopping
Bridge	☐	☐	☐	☐	☐	☐	☐
Bridge Foundation Scour Design	☐	☐	☐	☐	☐	☐	☐
Culvert	☐	☐	☐	☐	☐	☐	☐
Storm Drain	☐	☐	☐	☐	☐	☐	☐
Pavement Drainage	☐	☐	☐	☐	☐	☐	☐
Depressed Sections	☐	☐	☐	☐	☐	☐	☐

Minor Arterials

	< 10 year	10-year	25-year	50-year	100-year	500-year	Overtopping
Bridge	☐	☐	☐	☐	☐	☐	☐
Bridge Foundation Scour Design	☐	☐	☐	☐	☐	☐	☐
Culvert	☐	☐	☐	☐	☐	☐	☐
Storm Drain	☐	☐	☐	☐	☐	☐	☐
Pavement Drainage	☐	☐	☐	☐	☐	☐	☐
Depressed Sections	☐	☐	☐	☐	☐	☐	☐

Local Roads

	< 10 year	10-year	25-year	50-year	100-year	500-year	Overtopping
Bridge	☐	☐	☐	☐	☐	☐	☐
Bridge Foundation Scour Design	☐	☐	☐	☐	☐	☐	☐
Culvert	☐	☐	☐	☐	☐	☐	☐
Storm Drain	☐	☐	☐	☐	☐	☐	☐
Pavement Drainage	☐	☐	☐	☐	☐	☐	☐
Depressed Sections	☐	☐	☐	☐	☐	☐	☐
Driveway (Entrance) Culverts	☐	☐	☐	☐	☐	☐	☐

Temporary Structures

	< 10 year	10-year	25-year	50-year	100-year	500-year	Overtopping
Stream Crossing	☐	☐	☐	☐	☐	☐	☐
Access Road (Construction Only)	☐	☐	☐	☐	☐	☐	☐

Response:

The responses are broken down by roadway classification and displayed in Figures 4.2.1 through 4.2.5 in a bar chart format which summarizes the total number of states for each frequency and type roadway. Tables 4.2.1 through 4.2.5 provide the design frequency information for each state.

Interstates:

Many states have shown several different frequencies as the design frequency for Interstate bridges. This may be interpreted as indicating that the lowest frequency shown is the design frequency used to establish initial bridge opening size, low beam elevation, and roadway profile grade. The other frequencies are used to ensure compliance with regulatory permit rules and as check floods for scour analysis. Twelve (12) states and Puerto Rico have shown a minimum design frequency for Interstates as the 100 year frequency storm event and thirty-one (31) states have shown their minimum design frequency for Interstate bridges as the 50 year storm event. Six (6) states have shown a design frequency less than the 50 year storm event for design of Interstate bridges.

Most states show a range of frequencies used for scour analysis with four (4) states starting with their bridge design frequency of the 50 year storm event and thirty three states (33) starting with the 100 year storm event. Nineteen (19) states indicated that they evaluate the 100 year scour and also analyze scour for a check flood of either the overtopping or 500 year frequency whichever is smaller. Six (6) states and Puerto Rico reported using only the 100 year frequency to calculate scour for bridges designed on the Interstate system.

The design storm frequency used for culvert design on Interstate systems is the same as that used for bridge design in thirty-three (33) states and Puerto Rico. Thirteen (13) states allow a lower design frequency for culverts than bridges on the Interstate system and two (2) states use higher design frequency for culverts than bridges.

Thirty-one (31) states use a 10 year frequency design for storm drain design on the interstate system, six (6) states and Puerto Rico use a 25 year design frequency, and eleven (11) states use a 50 year design frequency. Where multiple frequencies are shown, it is interpreted to indicate that a higher frequency is used at sag locations.

On Interstate systems the design frequency used for pavement drainage analysis is a 10-year frequency storm event in thirty-one (31) states, a 25-year storm event in five (5) states and Puerto Rico, and a 50-year storm event in nine (9) states with an additional five (5) states not responding to that question.

Three (3) states use a 10 year design storm frequency for the design of drainage facilities on depressed sections of interstate highways. Five (5) states use a twenty-five (25) year design storm frequency and thirty-two states and Puerto Rico use a 50-year design frequency. Two states use a 100 year design frequency for the design of pavement drainage facilities in depressed sections of interstate highways.

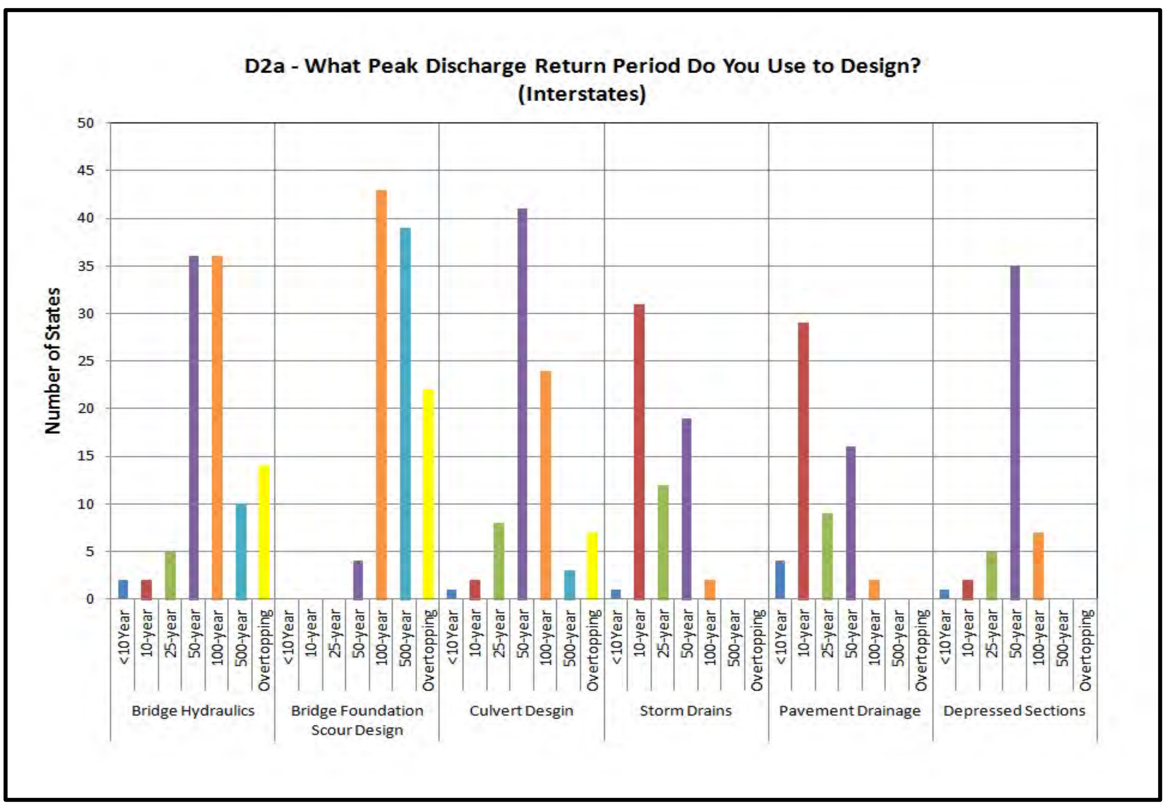


Figure 4.2.1 Number of states using the specified peak discharge return period for each of the structure types listed for interstate projects.

Table 4.2.1 Peak Discharge Return Periods for Interstate structures by state.

D2a – Peak Discharge Return Period																																										
	Interstates																																									
	Bridge							Foundation Scour							Culvert							Storm Drain							Pavement Drainage							Depressed Sections						
State	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping
AL				■								■	■	■				■					■		■					■		■							■			
AK	■			■	■	■	■				■	■	■	■	■			■	■				■	■	■					■									■			
AZ				■									■					■					■							■									■			
AR				■									■					■							■							■										
CA				■	■							■				■			■					■							■								■			
CO				■	■	■	■				■	■	■	■				■	■	■	■	■	■						■	■						■				■		
CT			■	■	■							■	■				■	■	■				■							■									■			
DE				■								■	■	■				■					■							■									■			
FL				■								■	■	■				■					■						■											■		
GA				■	■							■	■	■				■	■				■		■					■		■					■		■			
HI				■	■							■	■					■	■					■							■								■			
ID				■	■								■					■					■	■						■	■											
IL				■	■	■	■					■	■	■				■	■	■	■		■		■					■		■							■	■		
IN					■							■	■						■				■		■					■									■			
IA					■							■	■	■				■	■				■							■												
KS					■		■				■	■	■	■				■	■		■				■														■			
KY				■								■					■						■															■				
LA				■	■							■	■	■				■	■				■							■												
ME				■	■		■				■	■						■	■						■							■										
MD					■							■	■						■				■	■	■					■												
MA				■								■						■					■							■									■			
MI					■		■					■	■	■				■			■		■							■									■			
MN				■	■	■	■					■	■	■				■	■				■		■					■		■								■		
MS				■	■							■	■						■																							
MO			■	■	■	■	■					■	■					■	■		■		■	■	■					■	■	■					■		■			
MT				■	■	■	■					■	■	■				■	■	■	■				■	■						■	■						■	■		
NE					■		■						■					■							■							■							■			
NV				■	■	■	■					■	■	■				■	■					■		■					■		■					■		■		
NH				■	■												■	■					■							■												
NJ					■								■				■							■							■							■				
NM				■								■						■							■							■							■			
NY				■	■							■	■					■					■							■									■			
NC			■	■	■							■	■	■			■	■	■				■						■									■	■			
ND				■								■	■					■							■							■							■			
OH				■								■	■	■				■					■							■									■			
OK																		■					■							■									■			
OR				■	■							■	■	■				■	■				■							■	■	■						■	■			
PA				■									■	■				■							■							■							■			
PR					■							■							■					■							■								■			
RI	■	■	■		■	■	■					■	■																													
SC				■	■							■	■					■					■							■									■			
SD				■	■							■	■				■	■																								
TN					■							■	■					■					■		■					■		■							■			
TX				■								■		■				■							■							■							■			
UT					■	■						■						■					■							■									■			
VT					■							■							■				■							■									■			
VA		■	■	■								■	■	■		■	■	■	■				■	■					■	■									■	■		
WA					■		■					■	■	■			■		■					■						■									■			
WV				■	■	■	■					■	■					■			■		■							■									■			
WI					■							■		■				■						■							■								■			
WY				■								■	■					■							■							■							■			

Major Arterials:

The bar chart presentation below indicates that many states have a range of design frequencies for Major Arterials that is broken down by additional criteria such as traffic volume.

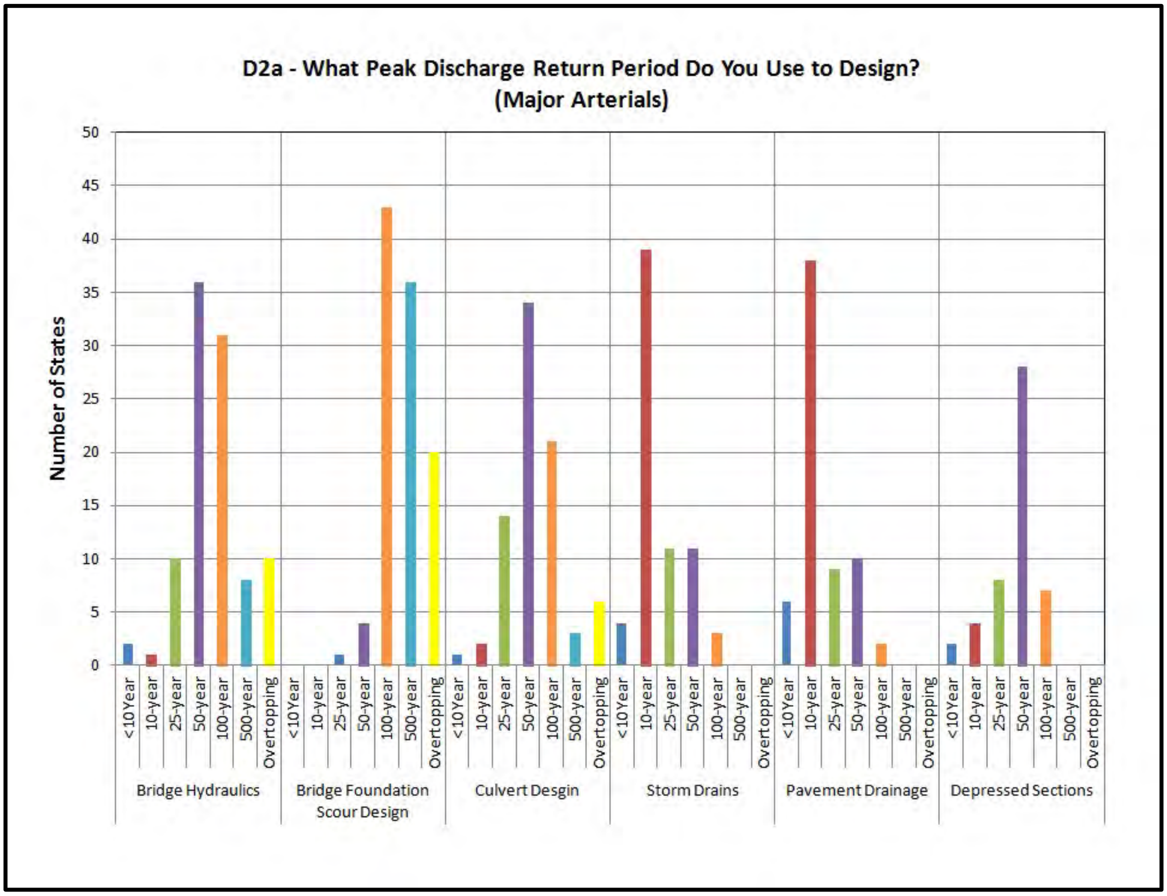


Figure 4.2.2 Number of states using the specified peak discharge return period for the design of various structure types on highways classified as Major Arterials.

Table 4.2.2 Peak Discharge Return Periods for Major Arterial structures by state.

D2a – Peak Discharge Return Period																																										
	Major Arterials																																									
	Bridge							Foundation Scour							Culvert							Storm Drain							Pavement Drainage							Depressed Sections						
State	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping
AL			■	■								■	■	■			■	■					■		■					■		■							■			
AK	■			■	■	■	■				■	■	■	■	■			■	■				■	■	■					■									■			
AZ				■									■					■					■							■									■			
AR				■									■					■					■							■												
CA				■	■							■				■			■				■	■						■	■								■			
CO			■	■	■	■	■			■	■	■	■	■			■	■	■	■	■	■	■						■	■						■				■		
CT			■	■	■							■	■				■	■	■				■							■								■				
DE				■								■	■	■				■					■							■									■			
FL				■								■	■					■				■							■								■					
GA				■								■	■	■				■	■				■		■					■		■					■		■			
HI				■	■							■	■					■	■					■							■							■				
ID				■	■								■				■	■					■	■						■	■											
IL				■	■	■	■					■	■	■				■	■	■	■		■		■					■		■							■	■		
IN					■							■	■						■				■		■					■									■			
IA				■	■							■	■	■				■	■				■							■												
KS				■	■		■				■	■		■			■				■																					
KY				■								■					■						■															■				
LA				■	■							■	■	■				■	■				■							■												
ME				■	■						■	■						■	■				■							■												
MD					■							■	■						■				■	■						■										■		
MA				■								■						■					■							■									■			
MI					■		■					■	■	■				■			■		■							■									■			
MN				■	■	■	■					■	■	■				■	■				■		■					■		■								■		
MS				■	■							■	■						■																							
MO			■	■	■	■	■					■	■					■	■		■		■	■	■					■	■	■					■		■			
MT				■	■	■	■					■	■	■				■	■	■	■		■	■	■	■				■	■	■	■						■	■		
NE					■								■					■					■		■					■		■							■			
NV			■		■	■	■					■	■	■			■		■					■		■					■		■					■		■		
NH				■														■					■							■												
NJ					■								■				■						■							■								■				
NM				■								■						■				■							■							■						
NY				■	■							■	■					■					■							■									■			
NC				■								■						■					■						■										■			
ND				■								■	■				■						■							■	■							■				
OH			■									■	■	■			■						■						■										■			
OK																		■					■							■									■			
OR				■	■							■	■	■				■	■				■							■	■	■						■	■			
PA				■									■	■				■							■							■							■			
PR					■							■							■					■							■								■			
RI	■	■	■		■	■						■																														
SC				■	■							■	■					■					■							■									■			
SD			■									■	■				■						■							■												
TN					■							■	■					■					■		■					■		■							■			
TX			■	■								■		■			■						■							■									■			
UT				■								■				■							■							■								■				
VT				■								■						■					■							■							■					
VA				■								■	■	■				■						■						■									■			
WA					■							■	■	■			■		■					■						■									■			
WV				■	■		■					■	■					■					■							■									■			
WI					■							■		■				■					■							■									■			
WY			■		■							■	■				■		■			■				■			■										■	■		

Minor Arterials:

The responses to question D.2.a for Minor Arterials are shown in Figure 4.2.3. A breakout of the design discharge return frequency question for Minor Arterials is provided in Table 4.2.3. The responses again indicate that many states have a further break down by traffic volume within the Minor Arterials classification.

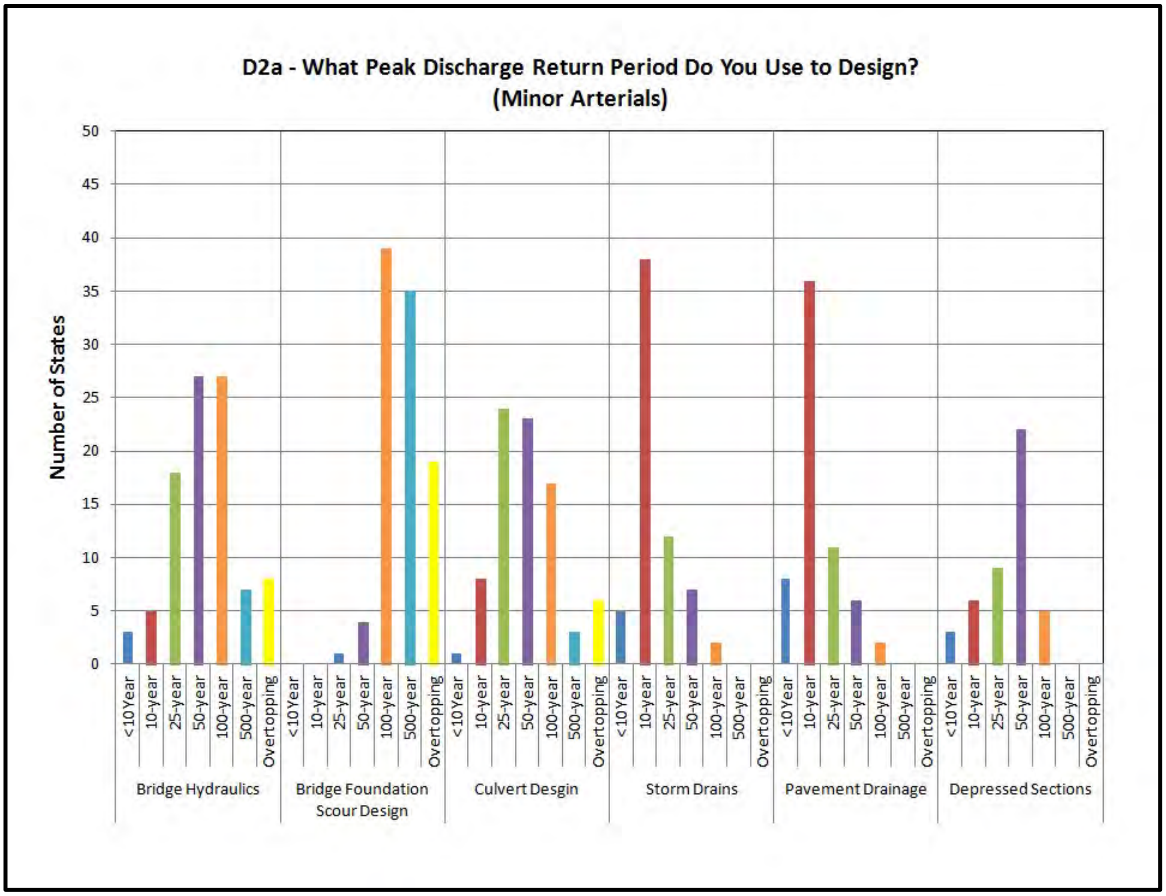


Figure 4.2.3. Number of states using specified peak discharge return period for design of various structure types on highways classified as Minor Arterials.

Table 4.2.3 Peak Discharge Return Periods for Minor Arterial structures by state.

D2a – Peak Discharge Return Period																																										
	Minor Arterials																																									
	Bridge							Foundation Scour							Culvert							Storm Drain							Pavement Drainage							Depressed Sections						
State	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping
AL			■	■								■	■	■			■	■					■		■					■		■							■			
AK	■			■	■	■	■				■	■	■	■	■	■		■	■				■	■						■									■			
AZ			■										■				■						■							■								■				
AR				■									■					■					■							■												
CA				■	■							■				■			■				■	■						■	■								■			
CO			■	■	■	■	■			■	■	■	■	■			■	■	■	■	■	■	■						■	■						■				■		
CT			■	■	■							■	■				■	■	■				■							■								■				
DE				■								■	■	■				■						■							■								■			
FL			■									■	■				■					■							■							■						
GA	■	■	■	■								■	■	■		■	■	■	■				■		■					■		■					■		■			
HI				■	■							■	■					■	■					■							■							■				
ID				■	■								■				■	■					■	■						■	■											
IL				■	■	■	■					■	■	■				■	■	■	■		■		■					■		■							■			
IN					■							■	■						■				■		■					■									■			
IA				■	■							■	■	■				■	■			■							■													
KS																																										
KY				■								■					■						■															■				
LA																																										
ME				■	■						■	■						■	■				■							■												
MD				■								■	■					■						■						■	■											
MA		■										■				■							■							■									■			
MI					■		■					■	■	■				■			■		■							■									■			
MN				■	■	■	■					■	■	■			■	■	■				■		■					■		■								■		
MS				■	■							■	■						■																							
MO			■	■	■	■	■					■	■			■	■	■			■	■	■	■					■	■	■											
MT			■	■	■	■	■					■	■	■			■	■	■	■	■		■	■	■	■				■	■	■	■						■	■		
NE					■								■								■		■	■						■	■								■			
NV			■		■	■	■					■	■	■			■		■				■			■				■			■				■			■		
NH				■													■						■							■												
NJ					■								■				■						■							■								■				
NM				■								■						■					■							■							■					
NY				■	■							■	■					■					■							■								■				
NC				■								■						■					■						■										■			
ND				■								■	■				■						■							■								■				
OH		■										■	■	■		■							■						■										■			
OK																	■						■							■									■			
OR			■		■							■	■	■			■						■							■	■						■	■				
PA			■										■	■			■							■							■							■				
PR					■							■							■					■							■								■			
RI	■	■	■		■																																					
SC			■		■							■	■					■					■							■									■			
SD			■									■	■				■						■							■												
TN		■			■							■	■	■				■					■		■					■		■							■			
TX			■	■								■		■		■							■							■									■			
UT				■							■					■							■							■							■					
VT				■								■						■					■							■							■					
VA			■									■	■	■			■						■						■										■			
WA					■							■	■	■			■		■					■						■									■			
WV			■		■							■	■				■						■							■									■			
WI					■							■		■			■						■							■									■			
WY			■									■	■				■		■			■							■							■				■		

Local Roadways:

The last of the design frequency questions asked what peak discharge return period was used for Local Roadway projects as shown below. The responses shown in Figure 4.2.4 indicate that the full range of design frequencies is used for the various local road classifications and structure types. Table 4.2.4 contains a breakdown of responses from each state regarding design frequency for local roadways.

Specific State Comments to Clarify Responses:

- Alaska - Culverts: 10 yr flood when fish passage; 100 yr flood when floodplain; 50 yr sole area access route - local roads
- Pennsylvania - Minor arterials and Local Roads Storm Drains: Per DM-2. Chapter 10.2.C.2. Storm Frequency. A 10-year storm frequency shall be used for city streets and for all highways with longitudinal drains, side drains, and slope pipes. For the storm frequency of culvert cross drains and any type of drainage facility in an underpass or depressed section of highway, refer to Section 10.6.E and Table 10.6.1. Additional criteria for the design frequency are indicated in Section 10.3.C. 3. When a pipe is part of a storm sewer system and crosses the roadway, it shall be designed as a storm sewer with the same design storm as the remainder of the drainage system. 4. Greater design frequencies may be justified on individual projects.

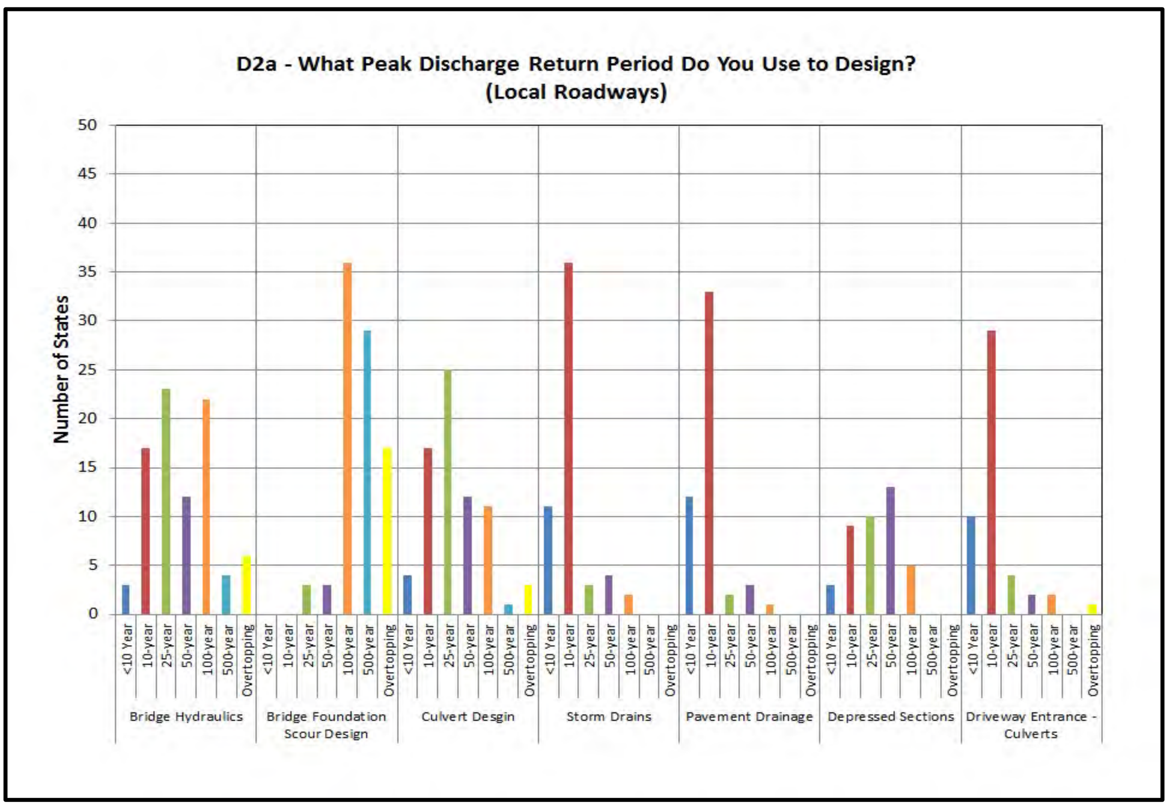


Figure 4.2.4 Number of states using the specified design frequency for various local roadways projects.

Table 4.2.4 Peak Discharge Return Periods for Local Roadway structures by state.

D2a – Peak Discharge Return Period																																																	
	Local Roadways																																																
	Bridge							Foundation Scour							Culvert							Storm Drain							Pavement Drainage							Depressed Sections							Driveway Entrance Culverts						
State	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping
AL			X	X								X	X	X			X	X					X		X					X		X							X						X	X			
AK	X			X	X	X	X				X	X	X	X	X	X		X	X				X	X						X									X				X		X	X	X	X	X
AZ			X										X				X						X							X								X							X				
AR				X									X					X					X							X																X			
CA				X	X							X				X			X				X	X						X	X								X							X	X		
CO			X	X	X	X	X			X	X	X	X	X			X	X	X	X	X	X	X						X	X						X				X					X	X	X	X	X
CT			X	X	X							X	X				X	X	X				X							X								X							X	X	X		
DE				X								X	X	X				X						X							X								X							X			
FL			X									X	X				X					X							X							X									X				
GA	X	X	X	X								X	X	X		X	X	X	X				X		X					X		X					X		X				X	X	X	X			
HI				X	X							X	X					X	X					X							X							X								X	X		
ID				X	X								X				X	X					X	X						X	X															X	X		
IL				X	X	X	X					X	X	X				X	X	X	X		X		X					X		X							X							X	X	X	X
IN					X							X	X						X				X		X					X									X								X		
IA				X	X							X	X	X				X	X			X							X																X	X		
KS																																																	
KY				X								X					X						X															X							X			
LA																																																	
ME				X	X						X	X						X	X				X							X																X	X		
MD				X								X	X					X						X						X	X															X			
MA		X										X				X							X							X									X					X					
MI					X		X					X	X	X				X			X		X							X									X								X		X
MN				X	X	X	X					X	X	X			X	X	X				X		X					X		X								X						X	X	X	X
MS				X	X							X	X						X																										X	X		
MO			X	X	X	X	X					X	X			X	X	X			X	X	X	X					X	X	X														X	X	X	X	X
MT			X	X	X	X	X					X	X	X			X	X	X	X	X		X	X	X	X				X	X	X	X						X	X					X	X	X	X	X
NE					X								X								X		X	X						X	X								X								X		
NV			X		X	X	X					X	X	X			X		X				X			X				X			X				X			X					X		X	X	X
NH				X													X						X							X																X			
NJ					X								X				X						X							X								X									X		
NM				X								X						X					X							X							X									X			
NY				X	X							X	X					X					X							X								X								X			
NC				X								X						X					X						X										X							X			
ND				X								X	X				X						X							X								X								X			
OH		X										X	X	X		X							X						X										X					X					
OK																	X						X							X									X										
OR			X		X							X	X	X			X						X							X	X						X	X							X		X		
PA			X										X	X			X							X							X							X							X				
PR					X							X							X					X							X								X								X		
RI	X	X	X		X																																						X	X	X		X		
SC			X		X							X	X					X					X							X									X						X		X		
SD			X									X	X				X						X							X															X				
TN		X			X							X	X	X				X					X		X					X		X							X					X			X		
TX			X	X								X		X		X							X							X									X						X	X			
UT				X							X					X							X							X							X									X			
VT				X								X						X					X							X							X									X			
VA			X									X	X	X			X						X						X										X						X				
WA					X							X	X	X			X		X					X						X									X								X		
WV			X		X							X	X				X						X							X									X						X		X		
WI					X							X		X			X						X							X									X								X		
WY			X									X	X				X		X			X							X							X				X					X				

Temporary Structures:

Question D.2.a closed with a question on the design return period used by states for temporary stream crossings and for access roads for contractor's equipment.

Temporary Structures

	< 10 year	10-year	25-year	50-year	100-year	500-year	Overtopping
Stream Crossing	☐	☐	☐	☐	☐	☐	☐
Access Road (Construction Only)	☐	☐	☐	☐	☐	☐	☐

Responses:

Twenty-eight (28) states reported that they use less than a 10 year design for temporary stream crossings and nineteen (19) states use a risk based design. Twenty-six (26) states reported that they use less than a 10 year design for contractor's access roads and seventeen (17) states reported that they use a risk based design.

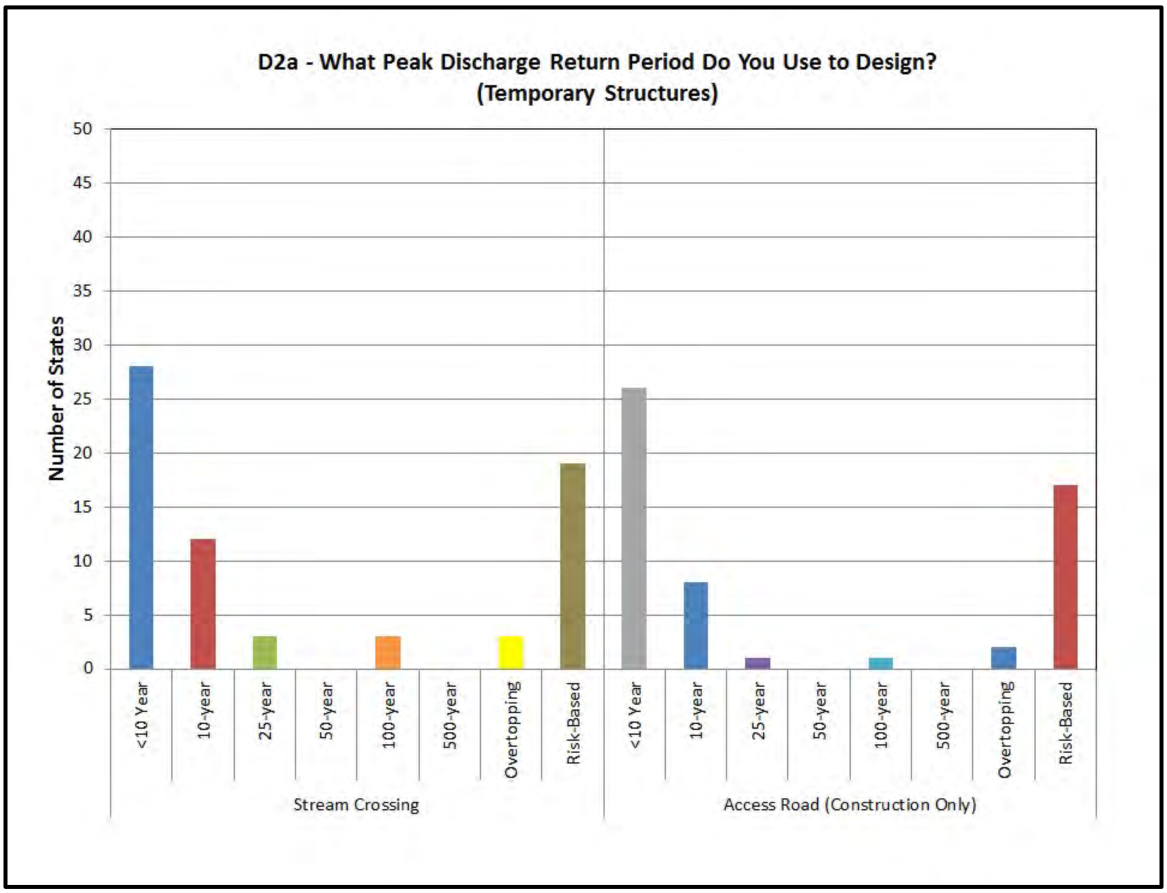


Figure 4.2.5 Number of states using the specified design frequency for stream crossing design and contractor's access road design.

Table 4.2.5 Peak Discharge Return Periods for Temporary Structures.

D2a- Design Flows																
	Temporary Structures															
	Stream Crossing								Access Road (Construction Only)							
State	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	Risk-Based	<10 yr	10 yr	25 yr	50 yr	100 yr	500 yr	Overtopping	Risk-Based
AL	■								■							
AK	■							■	■							■
AZ			■								■					
AR	■								■							
CA								■								■
CO								■		■						
CT								■	■							■
DE								■								■
FL		■							■							
GA	■	■							■	■						
HI	■															■
ID																
IL	■								■							
IN		■								■						
IA		■								■						
KS	■							■	■							■
KY								■								
LA								■								■
ME																
MD	■							■	■							■
MA								■								■
MI		■					■	■		■					■	■
MN								■								■
MS	■															
MO																
MT	■						■	■								
NE	■							■	■							■
NV	■	■			■			■	■	■			■			■
NH	■								■							
NJ		■								■						
NM	■								■							
NY							■	■							■	■
NC		■						■	■							■
ND																
OH	■															
OK	■							■	■							■
OR								■								■
PA	■								■							
PR	■								■							
RI			■													
SC	■								■							
SD	■	■							■							
TN	■								■							
TX	■								■							
UT	■	■							■	■						
VT		■														
VA	■								■							
WA	■								■							
WV	■	■			■				■							
WI	■								■							
WY	■		■		■											

4.3 Design Considerations

This question concerns the states' policies for consideration of future development, climate change, and sea level change in their hydrologic and hydraulic designs.

Question D.3

3. Do Hydrologic and Hydraulic Designs Consider:

	Yes	No
Future Development	○	○
Climate Change	○	○
Sea Level Change	○	○

Response:

The responses show that a total of thirty-three (33) states consider future development in design however only two (2) states, Massachusetts and Puerto Rico, consider climate change in design. Seven (7) east coast states consider sea level change during project design. A national perspective for all three parts of this question is provided in Figure 4.3.1.

Specific State Comments to Clarify Responses:

- Alaska - Research underway to evaluate climate change/vulnerability effects. Low lying projects near sea may consider sea level rise. Use HEC 22 for high water criteria. Also consider artesian conditions. 36 inch minimum when icing is a problem.
- Pennsylvania - Question 3 Future Development: Yes, in some cases. From DM-2 Chap 10.6 When the known events are smaller than the design event, considerable care is required because the estimate of the design peak flow is an extrapolation from the observed historical data. If the watershed is or has undergone development, construction of flood control structures, reforestation, or other changes since the observed historical events, or if future changes are anticipated, care must be taken to ensure that these factors are appropriately accounted for in the hydrologic study. Climate Change & Sea Level Change - no requirements to date.

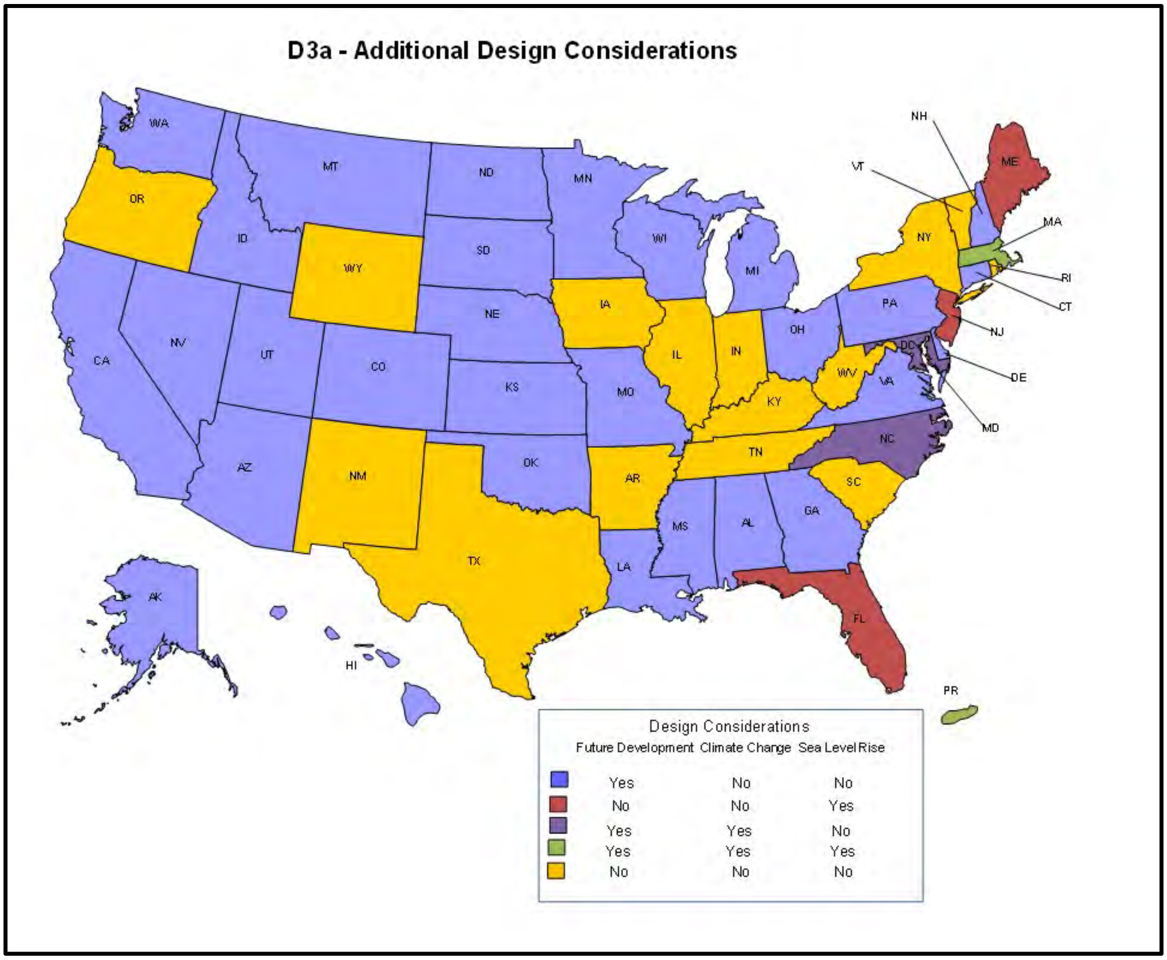


Figure 4.3.1 States that consider future development, climate change, or sea level rise in hydrologic design.

4.4 Roadway Drainage Policies

This section of the questionnaire addresses the roadway drainage policies of each agency. Policies covered include use of cooperative projects with local agencies, allowable design velocities, and freeboard at inlets and access holes.

<u>Question D.4.a</u>

4. Roadway Drainage
   a. Are cooperative storm drain projects with local agencies allowed?
      (Mutually beneficial projects paid for in a format cooperative manner by all parties.)

Yes	No
○	○

What is the basis for the cost sharing for cooperative storm drain projects?

	Yes	No
Ratio of Drainage Areas	○	○
Ratio of Discharges	○	○
Additional Costs	○	○

Other basis for cost sharing of cooperative storm drain projects?

Response:

The response is shown in Figure 4.4.1 as a bar chart indicating the number of states that responded to each choice in the question and in Figure 4.4.2 as a national map showing the individual response of each state.

Specific State Comments to Clarify Responses:

- Alaska – Case-by-Case Basis
- Arizona - Local Authority pays all costs over and above what we'd do for our normal design criteria.
- Delaware - Cost sharing is project and funding source specific. As we move toward a watershed approach there may be opportunities for additional cost sharing, possibly even cost reductions, through joint permitting & land acquisitions.
- Florida - Cost sharing varies. Sometimes we build the infrastructure and then give away maintenance permanently.

- Missouri - Cost share would be negotiated between entities.
- Montana - Secondary and Urban projects are allocated to the local area and prioritized by local officials based on needs. Participation ratios should be determined by proration of discharge however more liberal methods such as "add-on costs" may be used where warranted.
- Nebraska - Work done in state ROW.
- Nevada - Additional right-of-way needs verses additional drainage facilities. Timing of facilities can also be a factor where the Department will front the money to construct a needed facility, then be reimbursed as the local agency funds become available.
- New Hampshire - Normally determined on a case by case basis.
- New York - For Federal funding: cost is shared by the ration of discharges. State funds for additional costs.
- South Dakota - The cost share is dependent upon several condition.
- Utah - Agreements are set by the regions and districts maintenance and operation engineers.
- West Virginia - Based on the portion of the project that will benefit the highway compared to the portion of the project that will benefit the local property owners. Some specific costs are negotiated on a case by case basis.
- Wisconsin - Cost sharing is handled at the Regions and all three methods are used.

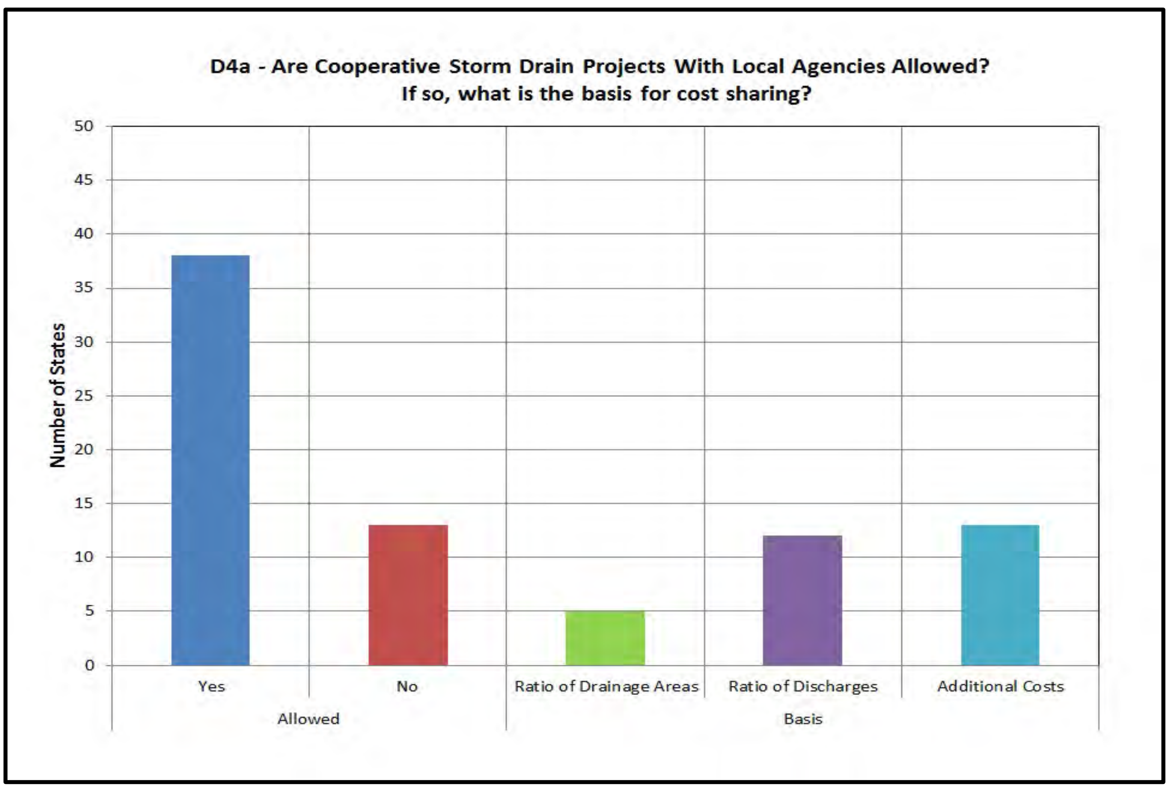


Figure 4.4.1 Number of states that allow cooperative storm drain projects and the cost sharing basis allowed.

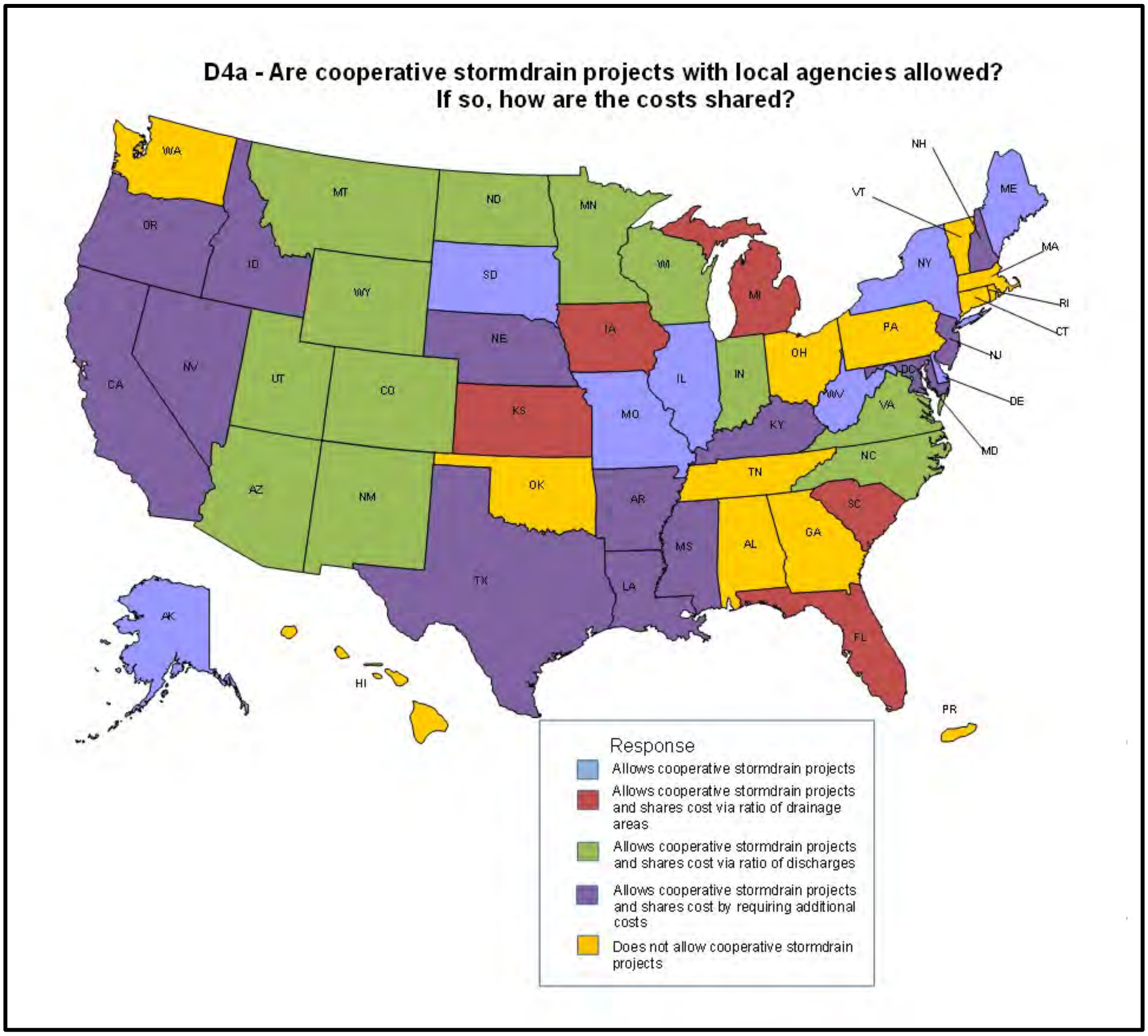


Figure 4.4.2 States that allow cooperative storm drain projects and the basis for the cost sharing.

Questions D.4.b and D.4.c

These two related questions address the states' policies on minimum and maximum allowable velocities in storm drains.

b. Do you specify a minimum allowable velocity in storm drains?

Yes	No
○	○

What is the minimum allowable velocity in storm drains?

Yes	No
○	○

What is the maximum allowable velocity in storm drains?

Response:

The states' responses are shown in a bar chart format in Figure 4.4.3 and in a national perspective in Figures 4.4.4 and 4.4.5 which provide the specific minimum and maximum velocities sited by each state.

Specific State Comments to Clarify Responses:

- Alaska – Minimum allowable velocity - Use HEC 22.
- Arizona – Minimum allowable velocity - 3 ft/s for self-cleaning.
- Colorado – Maximum allowable velocity - The velocity of flow shall not be greater than 22 ft/s at major storm (1000-year).
- Florida - Minimum allowable velocity - 2.5 fps in the north / 2.0 fps in the south.
- Massachusetts - Minimum allowable velocity - 3 FPS with pipe flowing 1/3 full
- Missouri - Minimum allowable velocity - 3 fps EPG 751.4.2.5
- Pennsylvania – Maximum allowable velocity - velocities greater than 17.5 feet per second require special provisions be used. Design Manual 4 Chapter 7 page A.7.5. We specify a minimum allowable slope of 0.35 % in Design Manual 2 Chapter 10 page 10-32.
- Washington - Minimum allowable velocity - 3 fps (calculated under full flow conditions)
- Wisconsin - Minimum full flow velocity shall be 2.5 fps, and preferably 3 fps.

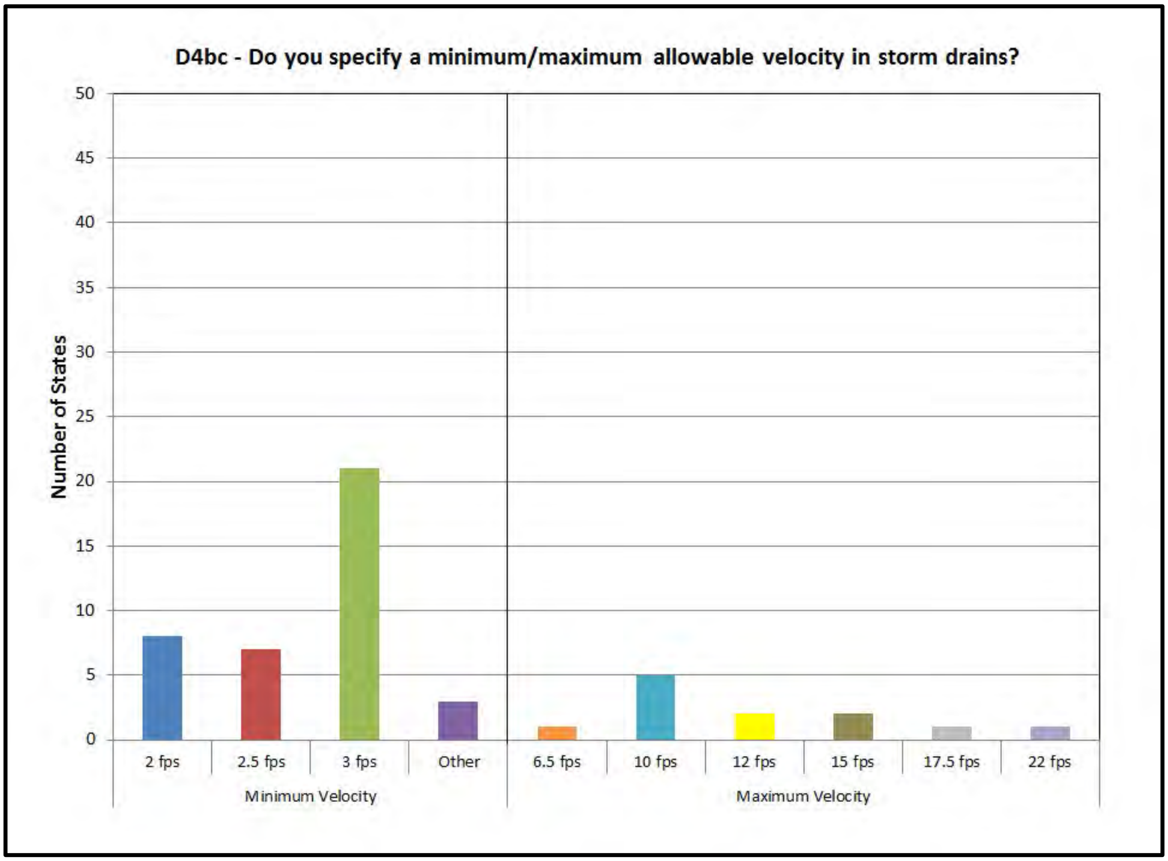


Figure 4.4.3 Number of states indicating minimum and maximum velocities allowed in storm drain design.

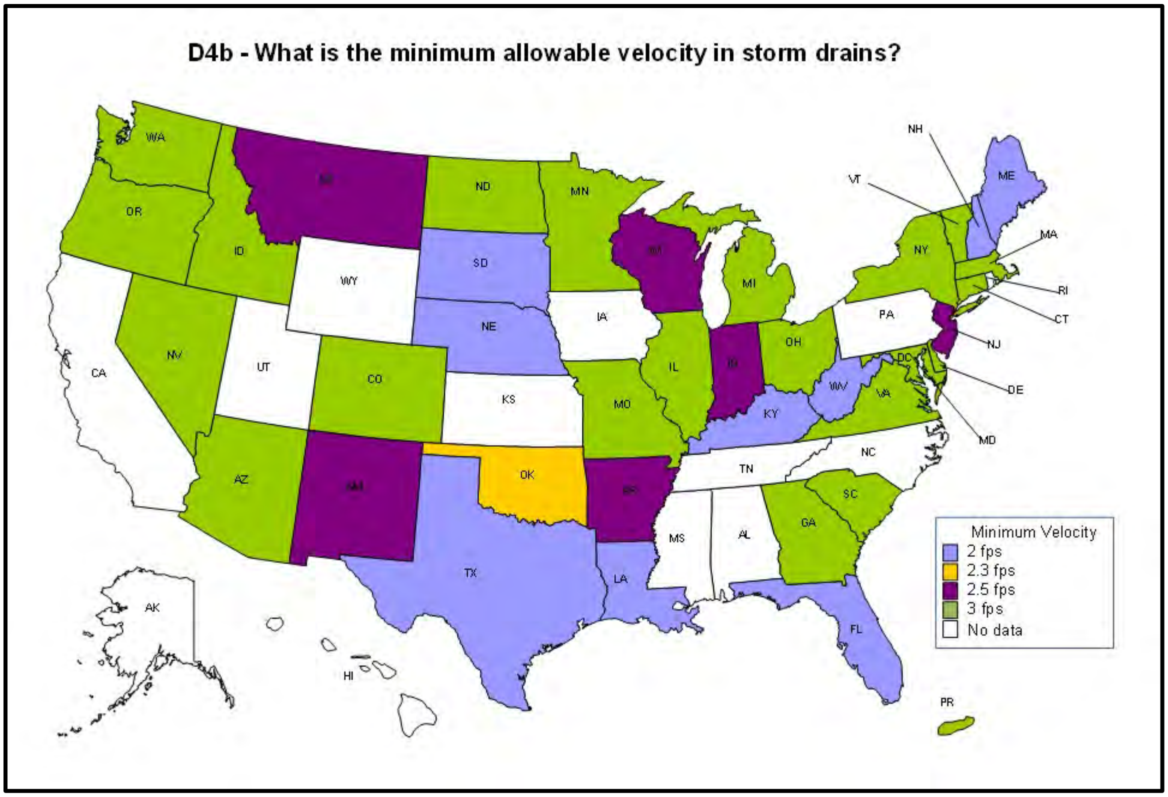


Figure.4.4.4 Minimum velocity allowed in storm drain design.

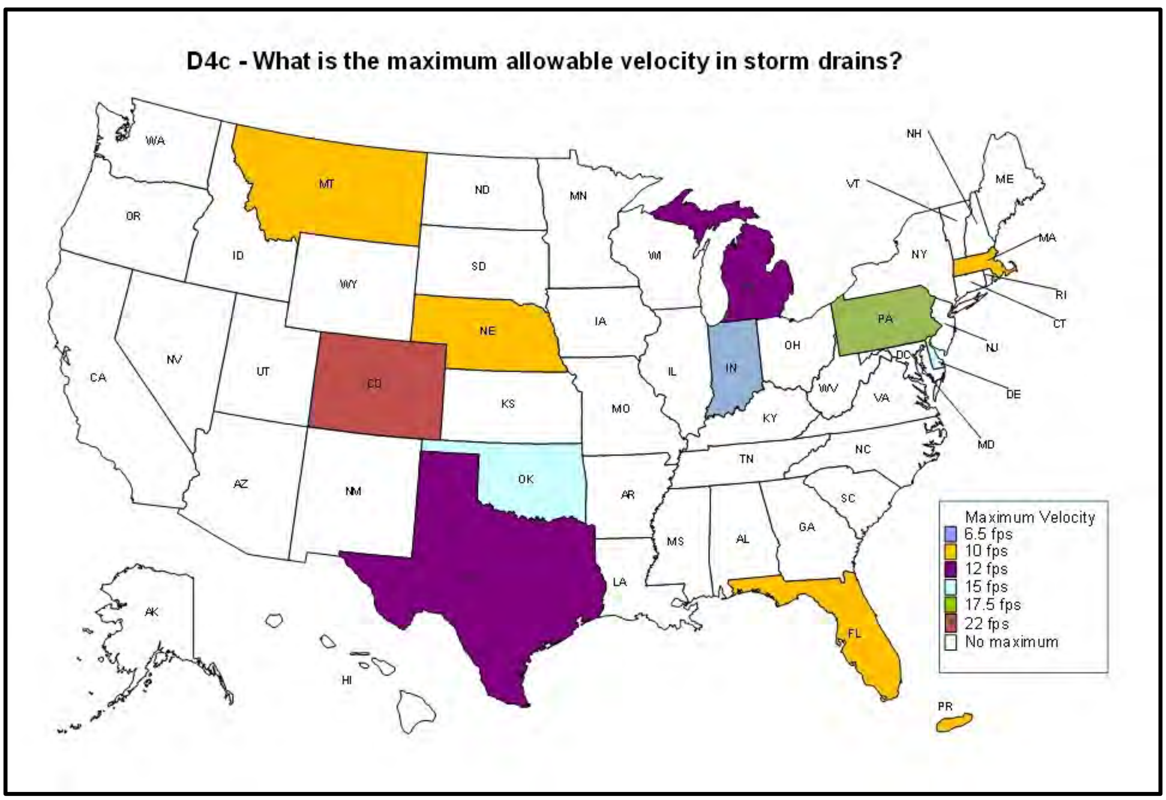


Figure 4.4.5 Maximum velocity allowed in storm drain design.

Question D.4.d

d. Do you have requirements to prevent surcharge in inlets, access holes, and junctions?

Yes	No
○	○

What are the requirements to prevent surcharge?

Response:

Thirty three (33) states and Puerto Rico indicated that they have a policy limiting surcharge in storm drain systems and sixteen (16) states indicated they do not have such policies. The response of individual states can be seen in the national perspective presented in Figure 4.4.6. Also, specific state responses are provided below:

Requirements to prevent surcharge:

- Arizona - Hydraulic gradeline must be no higher than the crown of pipe. This means pipes must flow just full at most; also meaning pipes will not flow in pressure flow.
- California - Establish max. allowable height of hydraulic grade line at 0.75 ft. below intake lip of inlets.
- Colorado - Interception rates on inlets.
- Connecticut - Head water in structures is limited to 1' below the top of grate. / Storm drains are designed for "just-full" condition.
- Delaware - Hydraulic Grade Line (HGL) 1 ft below top elevation of all manhole covers or / top of any inlet.
- Georgia - Design with computer software such as StormCAD to accurately compute the EGL and HGL.
- Idaho - 2.0 ft freeboard for all manholes/inlets.
- Illinois - HGL plot is checked to verify.
- Indiana - Gravity flow for the 10-year storm event.
- Kansas - Detailed in the Drainage Manual.
- Kentucky - 100 year storm can't surcharge out of the ground
- Massachusetts - Design HGL 2 ft below manhole rim cover and drain inlet elevations / Also See Section 8.4.4.5 of the 2006 MassDOT PDDG
- Michigan - Surcharging only allowed if caused by high tailwater condition.
- Minnesota - HGL computed, pipe sizes adjusted if HGL elevation above ground at structures.

- Missouri - Calculated water surface elevation (HGL). Calculated hydraulic grade line is to be at least 1 foot below intake at drop inlets and at least 2 feet below the top of manhole covers. EPG 750.4.4.7
- Montana - Hydraulic Grade lines are evaluated to insure potential surcharge would not cause damage. Typically no special modifications to Manhole covers or inlets are used.
- Nebraska - >75 ft. below intake
- Nevada - If pressure flow is unavoidable, the HGL shall remain at least one foot below ground surface.
- New Jersey - The Hydraulic Grade Line must be at least 1 foot below the grate or rim of the structure.
- New Mexico - Limit hydraulic grade line to 1 foot below top of grate elevation.
- New York - Design storm: HGL designed to be below the crown of the pipe to maintain open channel flow.
- North Carolina - Limit headwater depth of open end culverts and freeboard below grate or manholes in storm drain systems.
- North Dakota - Our general design guidance is to design for 8/10 part full. However, surcharging is sometimes permitted at some locations.
- Ohio - For roadways w/ > 2000 ADT: 1. HGL shall not exceed 12" below edge of pavement for sections w/o curb. 2. HGL shall not exceed the elevation of a curb opening inlet or grate elevation of a pavement catch basin.
- Oklahoma - Based on the hydraulic grade line. Use larger size of structure if needed.
- Oregon - tp://ftp.odot.state.or.us/techserv/Geo-Environmental/Hydraulics/Hydraulics%20Manual/Chapter_13/Chapter_13_appendix_G/CHAPTER_13_Appendix_G.pdf
- Pennsylvania - DM-2 Chap 10 Page 36 requires that preliminary methods to compute the hydraulic grade line of a pipe system shall adhere to the guidelines indicated in HEC-22, Section 7.5. The HGL shall be established to evaluate overall system performance and ensure that at the design discharge, the storm drain system does not inundate or adversely affect inlets, access, holes, or other appurtenances.
- Puerto Rico - Water surface elevation must be kept below the top of inlet grate or curb opening inlet lip, and at least 0.60 meters below the top of manhole covers.
- South Carolina - d less than or equal to 0.94 D
- South Dakota - Hydraulic gradeline is computed when needed.
- Tennessee - Calculation of energy grade line and hydraulic gradeline is used to determine capacity of system.
- Washington - Size pipe capacities for non-pressure flow.
- West Virginia - The storm drain shall be design such that the hydraulic grade line does not exceed any point above which there would be unacceptable flooding of the traveled way or adjoining property. This includes tops of manholes, junctions, and inlets. (WVDOH Drainage Manual, 5.2.8)

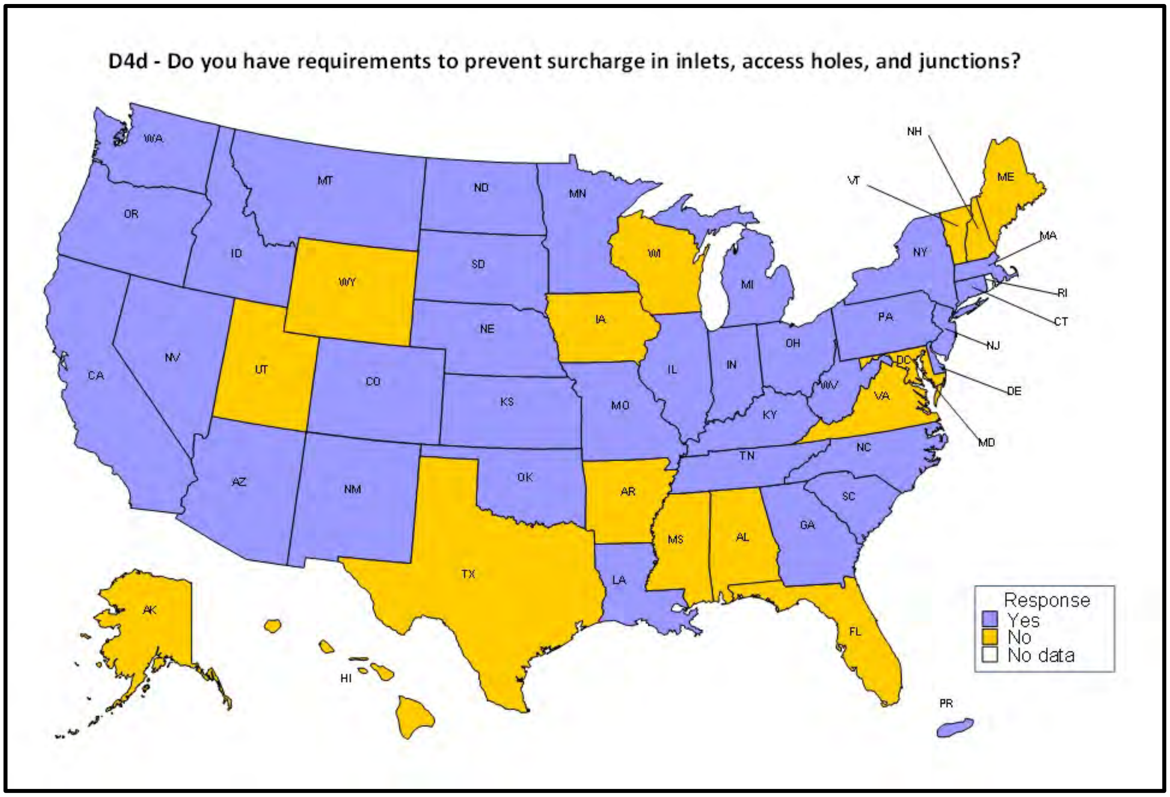


Figure 4.4.6 States that have and those that do not have a policy to prevent surcharge in inlet and access hole structures.

4.5 Policies on Pipe Selection

This section addresses states' policies for both storm drains and cross road culverts. The questions cover consideration of life-cycle costs, material selection, minimum sizes, and alternative pipe selection methodologies.

Question D.5.a

This question identified which states have current pipe selection policies for culverts and storm drains and which have policies under development.

5. Pipe Selection
   a. Do you have pipe selection policies?

	Yes	No	Under Development
Culverts	☐	☐	☐
Storm Drains	☐	☐	☐

Response:

The response indicates that forty-five (45) states have both culvert and pipe selection policies and four (4) states have culvert policies under development and three (3) states have storm drain policies under development. No graphic is provided for this response.

Specific State Comments to Clarify Responses:

- Arizona - We have a pipe selection guideline procedural manual, which takes into account soil properties, fill height loading, trench or non-trench conditions, properties of various pipe shapes (arch, elliptical, circular, structural plate).
- Colorado - CDOT is currently developing Pipe Material Selection Procedures.
- Delaware - http://deldot.gov/information/pubs_forms/manuals/dgm/pdf/1-20_revised_pipe_materials.pdf
- Georgia - Pipe material selection based partly on application, resistivity, and pH.
- Montana - MDT has published Culvert Service Life guidelines which take into account soil side and water corrosivity when determining gage and coating requirements. We currently employ a 75 year service life for new or replacement culverts. We also have published Pipe Material Selection guidelines that aid in selection of materials for specific applications.
- Nevada - NOT's Draft Culvert Selection Process is available upon request. Hopefully will be on our website soon.
- New Hampshire - Generally discussed with construction and design staff.
- Oklahoma - We are working on improving pipe selection procedure.
- Pennsylvania - See Design Manual 2 Chapter 10 Table 10.3.5.
  South Dakota - Not normally on a site by site basis. Pipe selection routinely allows CMP under entrances and intersection roads to state highways. HDPE is routinely allowed in approaches up to 36" in diameter.
- Tennessee - http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DrainManChap%201-10.htm

<u>Question D.5.b</u>

b. Do you consider life-cycle costs in pipe selection?

	Yes	No
Culverts	☐	☐
Storm Drains	☐	☐

Response:

Thirty-one (31) states and Puerto Rico reported that they consider life-cycle costs in pipe selection for both culvert and storm drain design. Figure 4.5.1 and 4.5.2 provide a national map that identifies the practices of individual states respectively in the categories of culvert and storm drain design.

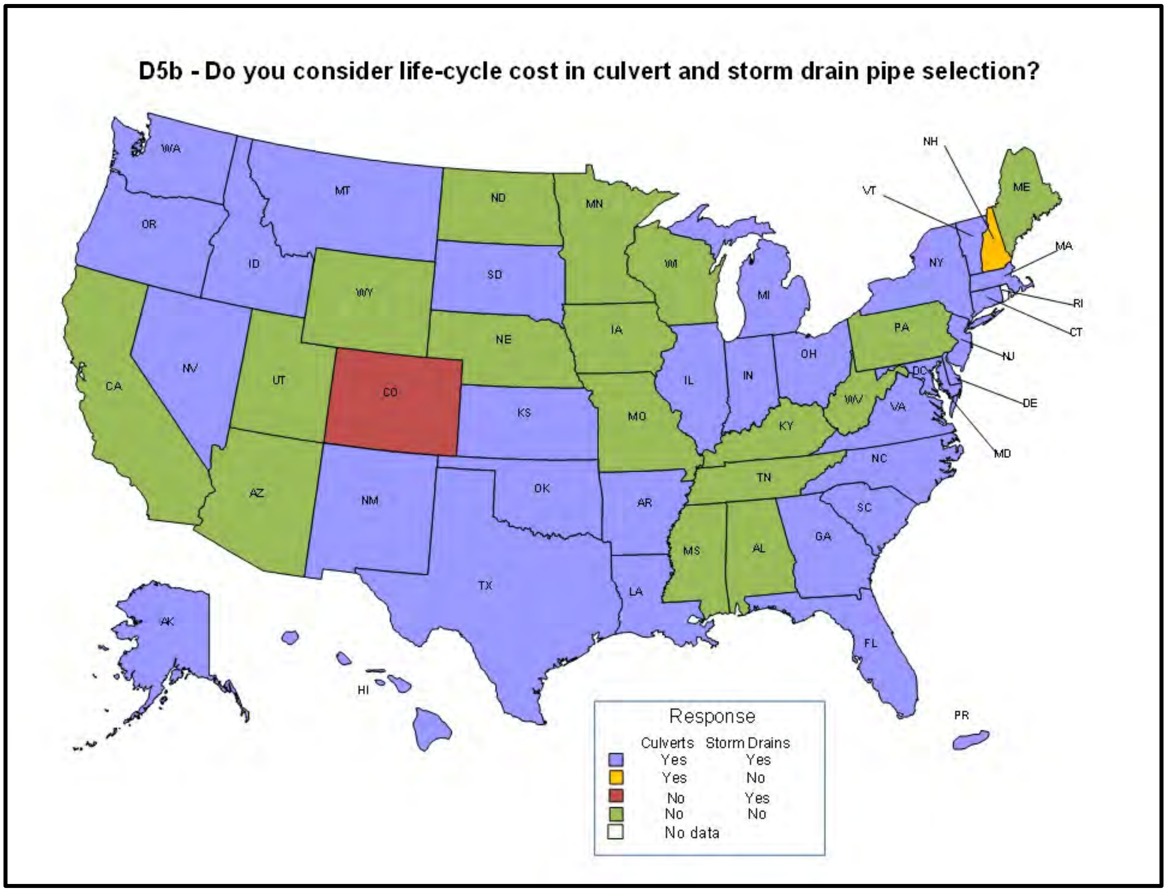


Figure 4.5.1 States that consider life-cycle costs in design in culvert and storm drain pipe selection.

Question D.5.c

c. What pipe materials do you allow?

	Interstates or Major Arterials				Minor Arterials or Local Road Culverts				Storm Drains			
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
Steel/Aluminum	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Concrete	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
HDPE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
PVC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Other	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Response:

Figure 4.5.2 provides a breakdown of each category by number of states allowing their use. Table 4.5.1 provides information on what material each state allows for the design of culverts. Table 4.5.2 provides information on what material each state allows for the design of storm drains.

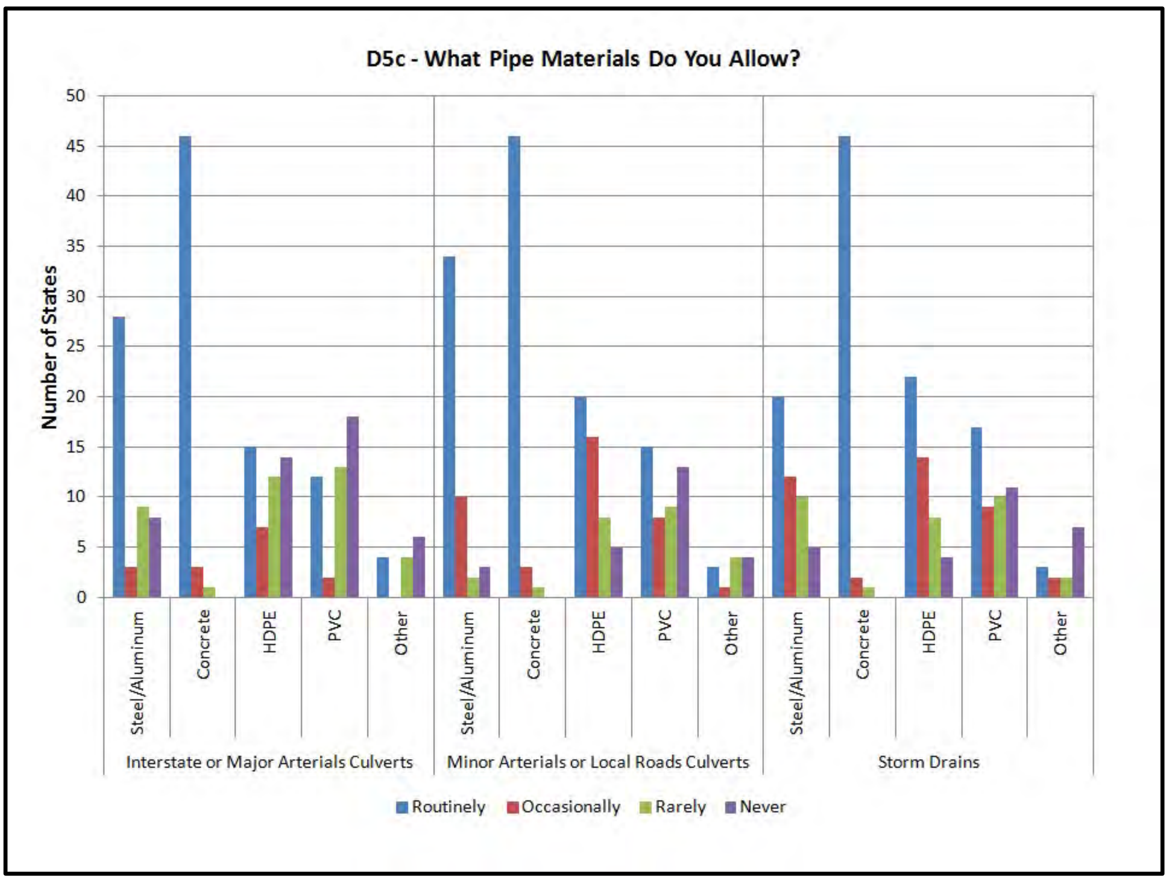


Figure 4.5.2 Number of states that allow the use of the pipe materials specified.

Table 4.5.1 Pipe material allowed in each state for culvert design.

D5c – What pipe materials do you allow?

Culverts

Interstates or Major Arterials

State	Steel\ Aluminum				Concrete				HDPE				PVC				Other			
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL				■	■							■				■				
AK	■					■			■						■				■	
AZ	■					■				■						■				■
AR				■	■							■				■				
CA	■				■				■				■							
CO	■				■							■				■				
CT	■				■					■					■					
DE			■		■						■									
FL	■				■				■				■							
GA	■				■				■				■							
HI		■			■				■							■				
ID	■				■				■				■						■	
IL				■	■							■				■				
IN	■				■						■				■					
IA			■		■						■					■				
KS			■		■						■				■					
KY	■				■				■				■							
LA		■			■						■				■					
ME	■				■						■				■					
MD	■				■							■			■					
MA			■		■					■						■				
MI	■				■					■										
MN			■		■						■				■					
MS				■	■				■				■				■			
MO				■	■							■				■				
MT	■				■															
NE	■				■				■				■							
NV				■	■							■				■				■
NH		■			■				■						■					
NJ			■		■							■				■				
NM	■				■						■					■				■
NY			■		■					■					■					
NC	■				■						■				■					■
ND	■				■							■				■				
OH	■				■				■				■				■			
OK					■							■								
OR	■				■				■				■				■			
PA	■				■							■				■	■			
PR				■	■						■				■					■
RI																				
SC						■				■				■						
SD			■		■							■				■				
TN				■	■							■				■				
TX	■				■							■				■				■
UT	■				■				■				■						■	
VT	■						■				■					■				
VA	■				■				■				■							
WA	■				■				■				■							
WV	■				■					■				■						
WI			■		■						■				■				■	
WY	■				■															

Minor Arterials or Local Roadways

State	Steel\ Aluminum				Concrete				HDPE				PVC				Other			
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL				■	■							■				■				
AK	■					■			■						■				■	
AZ	■					■				■						■				
AR		■			■						■				■					
CA	■				■				■				■							
CO	■				■						■					■				
CT	■				■					■					■					
DE		■			■					■										
FL	■				■				■				■							
GA	■				■				■				■							
HI		■			■				■							■				
ID	■				■				■				■						■	
IL	■				■					■				■						
IN	■				■					■				■						
IA		■			■					■						■				
KS		■			■						■				■					
KY	■				■				■				■							
LA		■			■						■			■						
ME	■				■				■				■							
MD	■				■					■				■						
MA	■				■					■						■				
MI	■				■					■										
MN	■				■					■				■						
MS				■	■							■				■				■
MO	■				■				■				■							
MT	■				■						■				■					
NE	■				■				■				■							
NV	■				■				■							■			■	
NH		■			■				■						■					
NJ			■		■					■					■					
NM	■				■						■					■				■
NY			■		■					■					■					
NC	■				■					■				■						■
ND	■				■							■				■				
OH	■				■				■				■				■			
OK		■			■						■									
OR	■				■				■				■				■			
PA	■				■				■				■				■			
PR				■	■						■				■					■
RI																				
SC						■				■				■						
SD		■			■							■				■				
TN		■			■							■				■				
TX	■				■					■				■				■		
UT	■				■				■				■						■	
VT	■						■			■						■				
VA	■				■				■				■							
WA	■				■				■				■							
WV	■				■				■				■							
WI	■				■				■											
WY	■				■															

Table 4.5.2 Pipe material allowed for storm drain design.

D5c – What pipe materials do you allow?																				
Storm Drains																				
	All Roadways																			
	Steel\ Aluminum				Concrete				HDPE				PVC				Other			
State	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL	X					X				X					X					
AK	X				X				X						X				X	
AZ			X		X						X					X				X
AR		X			X						X				X					
CA	X				X				X				X							
CO				X	X							X				X				X
CT		X			X					X					X					
DE		X			X					X										
FL	X				X				X				X							
GA	X				X				X				X							
HI		X			X				X							X				
ID					X				X				X						X	
IL		X			X					X				X						
IN			X		X				X				X							
IA			X		X						X					X				
KS		X			X						X				X					
KY	X				X				X				X							
LA		X			X						X		X							
ME	X								X				X							
MD	X				X					X				X						
MA		X			X					X						X				
MI	X				X						X				X					
MN			X		X					X				X						
MS				X	X							X				X				X
MO		X			X					X				X						
MT				X	X									X						
NE					X				X				X							
NV				X	X				X							X				X
NH		X			X				X						X					
NJ			X		X					X					X					
NM	X				X					X						X				X
NY			X		X				X							X				
NC	X				X					X				X						X
ND	X				X					X				X						
OH	X				X				X				X				X			
OK		X			X						X									
OR	X				X				X				X				X			
PA	X				X				X				X				X			
PR			X		X				X				X							X
RI																				
SC						X				X				X						
SD			X		X							X				X				
TN				X	X							X			X					
TX	X				X					X				X				X		
UT	X				X				X				X					X		
VT		X					X		X							X				
VA	X				X				X				X							
WA	X				X				X				X							
WV	X				X				X				X							
WI			X		X						X				X					
WY			X		X															

Question D.5.d

d. What is the allowable minimum pipe size?

	<12 in	12 in	18 in	24 in	Other
Interstate or Major Arterial Culvert	☐	☐	☐	☐	☐
Minor Arterial or Local Road Culvert	☐	☐	☐	☐	☐
Storm Drains	☐	☐	☐	☐	☐

Additional Comments:

Response:

Figure 4.5.3 provides a bar chart showing the number of states requiring each of the minimum pipe sizes listed. Figures 4.5.4 and 4.5.5 show the responses of individual states for minimum size for cross drainage culverts on Interstates and minor arterials respectively. Figure 4.5.6 shows the individual responses for minimum size for storm drain design.

Specific State Comments to Clarify Responses:

- New Jersey - Our minimum pipe size is 15 inches, and 18 inches at low points and downstream of low points.
- North Dakota - minimum storm drain size is 15"
- Pennsylvania - Note: the question is allowed not used.□ Response would be different to use see DM 2, Ch 10 page 10-38; Question 5 e: See DM 2, Ch 10 Table 10.3.5 on page 10-37.
- South Dakota - We allow 18" minimum pipe size in approaches.

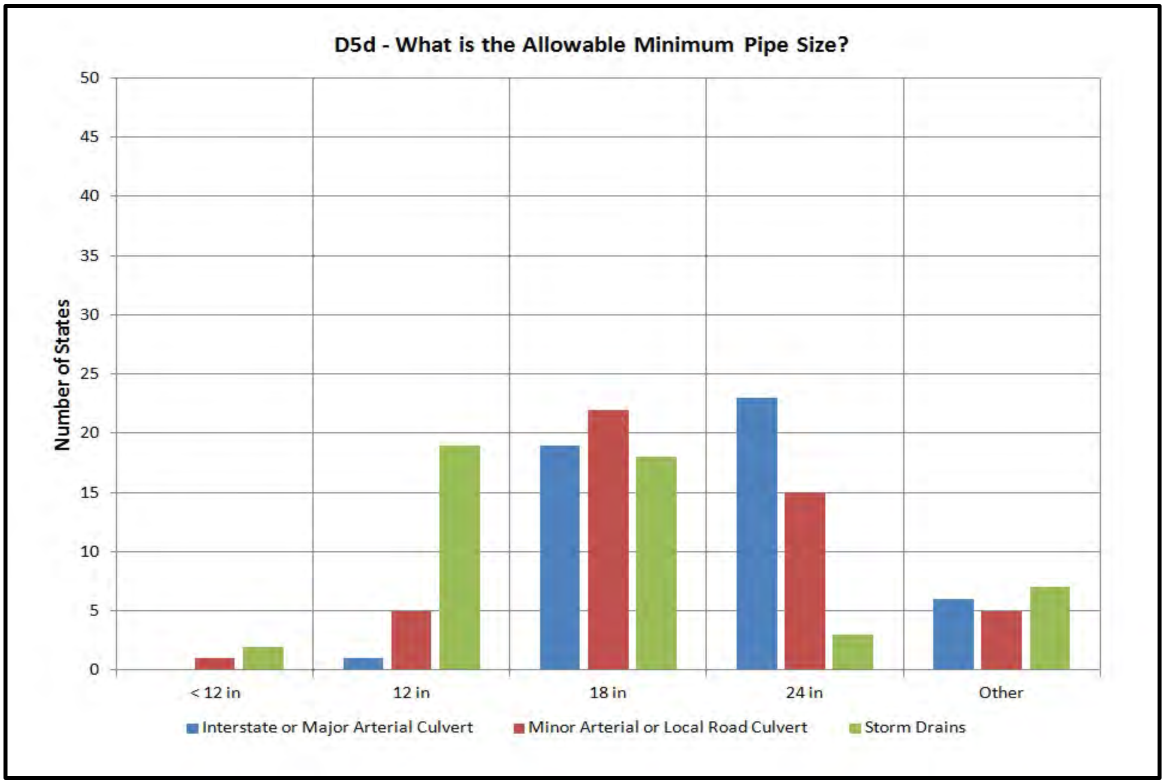


Figure 4.5.3 Minimum pipe sizes specified by states.

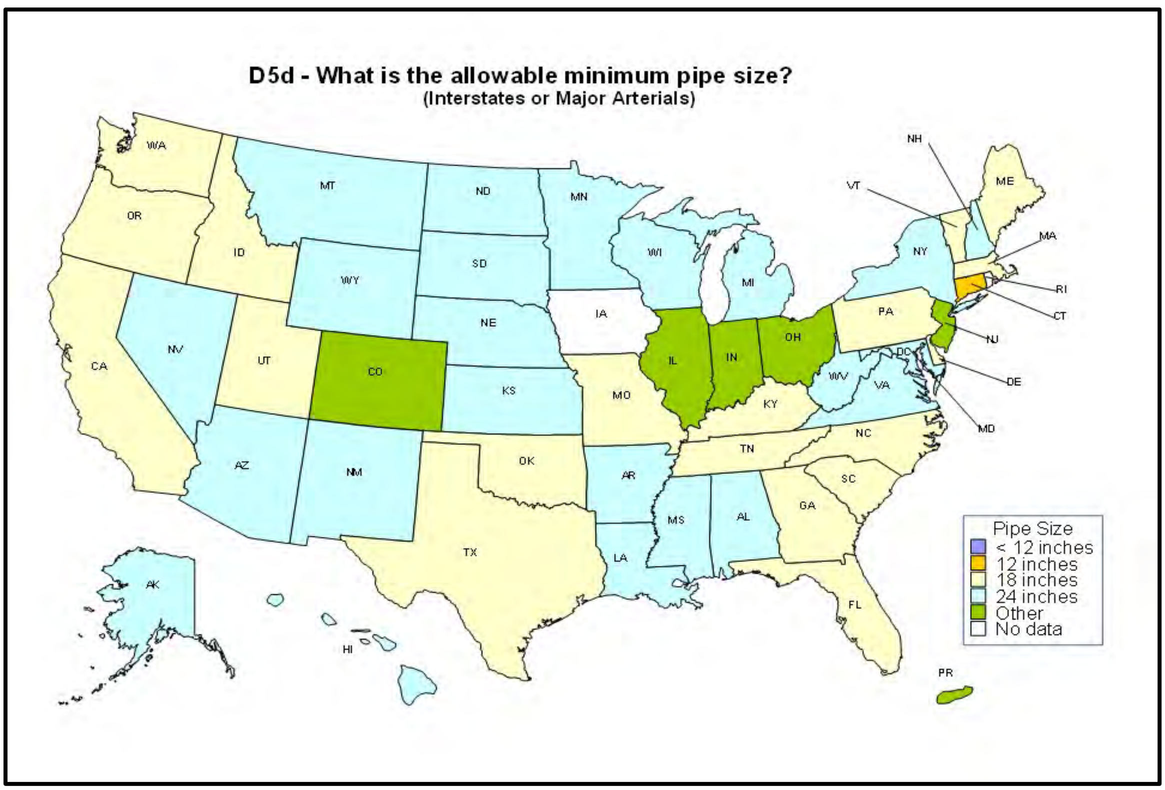


Figure 4.5.4 Minimum pipe size allowed on Interstates and major arterials.

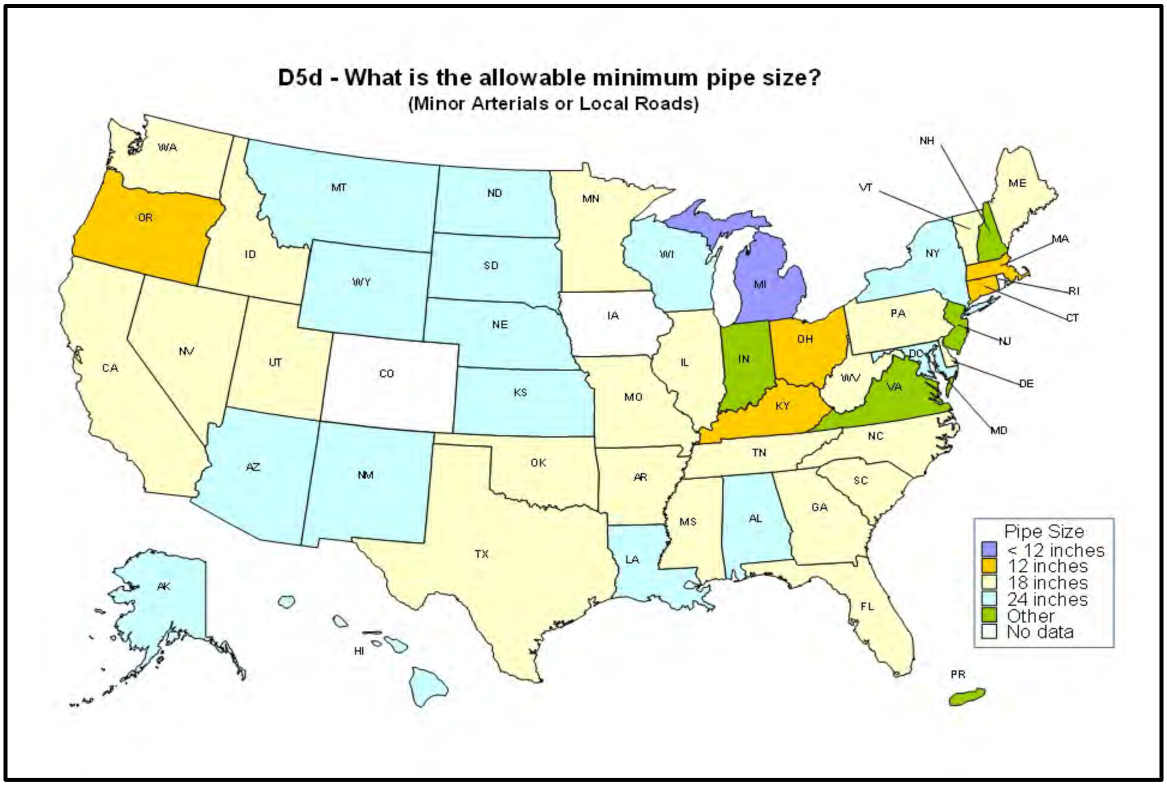


Figure 4.5.5 Minimum pipe size allowed on minor arterials and local roads.

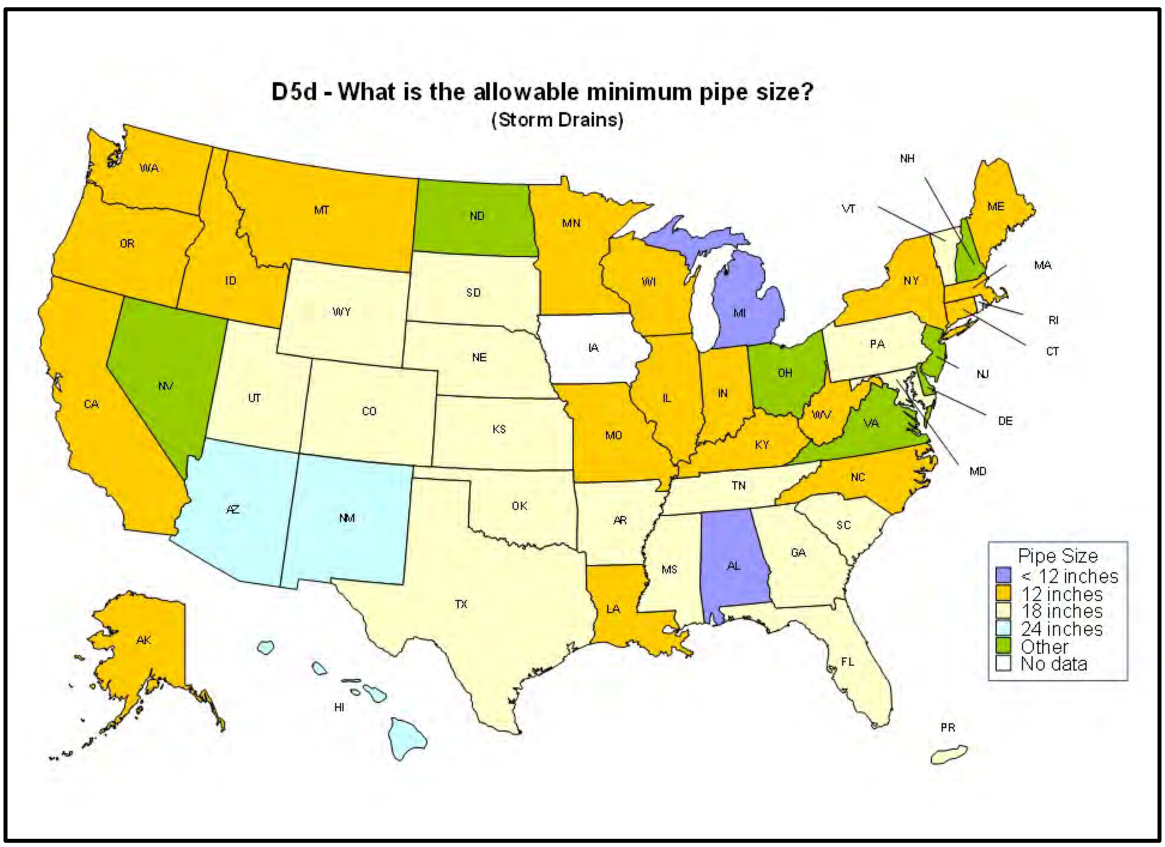


Figure 4.5.6 Minimum pipe size allowed for storm drain design.

Question D.5.e

- Do you have an alternative pipe selection methodology?

Yes	No
○	○

Additional Comments:

Response:

Thirty-five (35) states reported that they have an alternative pipe selection methodology fifteen (15) states reported they do not and one (1) state did not respond. The actual response of each state is indicated in the national map in Figure 4.5.7.

Specific State Comments to Clarify Responses:

- Hawaii - Pipe material alternative criteria is specified in our "Design Criteria for Highway Drainage".
- Maryland - Alternate pipe selection methodology used for small culverts only.
- Missouri - On every project designed with concrete pipe (Higher ADT routes), the contractor may propose substitution with hydraulically equivalent aluminum-coated steel, polymer coated steel, or PVC pipe.
- South Carolina - SCDOT Instructional Bulletin on Design and Implementation of Alternate Pipe can be found at the following site: http://www.scdot.org/doing/pdfs/instbulletins/ib09-4.pdf
- Washington – High velocities in pipes may limit some pipe alternatives in favor of more abrasion resistant pipe materials.
- West Virginia - DD-503, Alternate Pipe Material Selection / http://www.wvdot.com/engineering/TOC_engineering.htm / Design Directives
- Wyoming - Alternatives are considered and used in first cost analysis. Selection may be based on corrosion, cost, scour potential, etc. Sometimes alternatives are put in the plans. Contractor may use value engineering to substitute upon WYDOT approval.

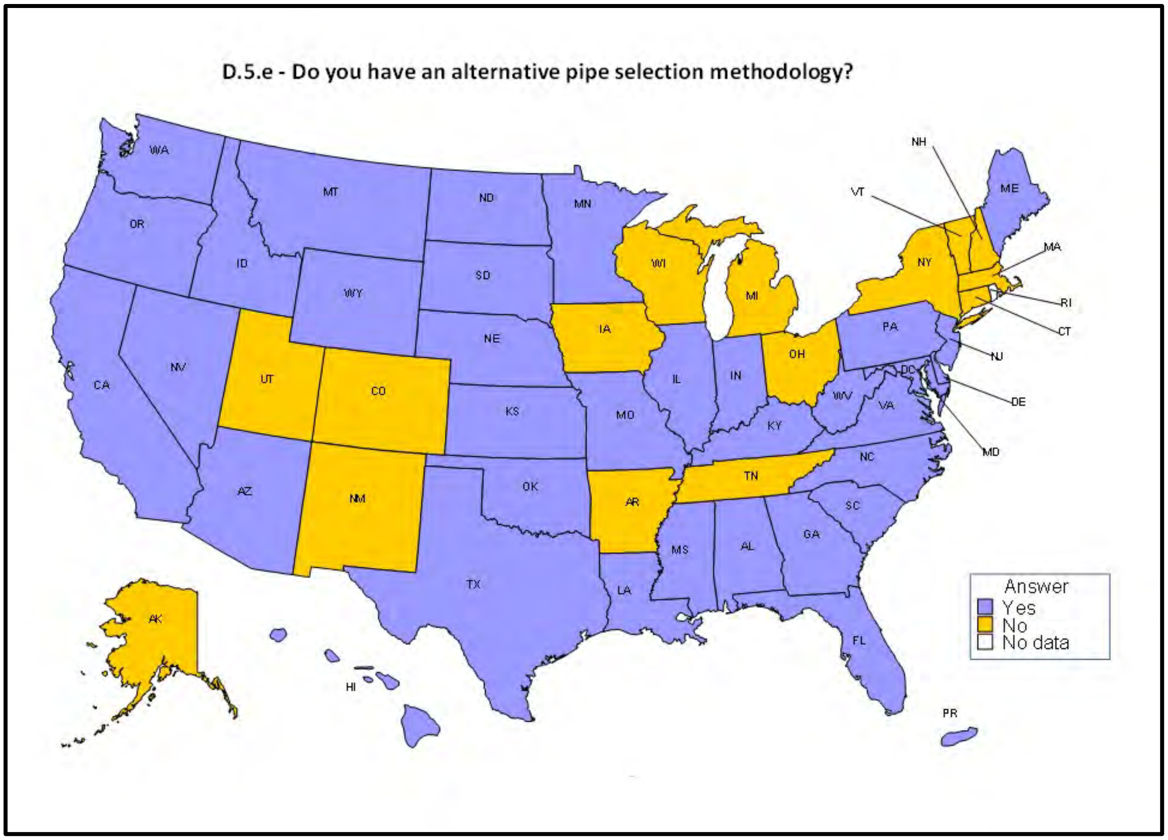


Figure 4.5.7 States' responses to whether they have an alternative pipe selection methodology.

5.0 Hydrology

This chapter contains two sections on hydrology practices that deal with methodologies used and data sources.

5.1 Methodology used

This section presents a two part question addressing what methodologies transportation agencies use in the design of various drainage structures and what watershed limitations are applied to the use of the Rational Equation.

<u>Question E.1</u>

E. Hydrology
  1. Methodology Used
     (check all that apply)

	Bridges	Culverts	Roadway Drainage
Log-Pearson III (Bulletin 17B)	☐	☐	☐
SCS Unit Hydrograph	☐	☐	☐
Snyder's Unit Hydrograph	☐	☐	☐
TR-55	☐	☐	☐
TR-20	☐	☐	☐
USGS Regression Equations	☐	☐	☐
USGS Streamstats	☐	☐	☐
Rational Method	☐	☐	☐

What is maximum drainage area that you use for the Rational Method?

	Bridges		Culverts		Roadway Drainage	
Maximum Drainage Area (acres)						

Other Hydrologic Methodologies Used?

Response:

The results are shown in Figure 5.1.1 in a bar chart format indicating the number of states responding to which methodologies they use for the design of bridges, culverts, and roadway drainage structures. The response to the second part of the question concerning drainage area limitations for use of the Rational Method for bridges, culverts, and roadway drainage are shown in Figures 5.1.2, 5.1.3, and 5.1.4 respectively. A list of other hydrologic methodologies used follows:

Other Hydrologic Methodologies Used:

- Alaska - Flow Duration Analyses (when data is avail), slope area method, low flow statistical analysis/study by USGS.
- Arizona - Our Unit Hydrograph procedure is the Clark Method, which is not represented here. Our Flood Frequency Analysis using gage records is by graphical analysis on Log-Normal, Log Extreme Values and Extreme Values plots, which is not represented here, either.
- California - Basin transfer of gauged data.
- Connecticut - ConnDOT Drainage Manual Chapter 6 Appendix D - Hydrologic Design Report Format.
- Delaware - Recorded Data & Published Reports. http://water.usgs.gov/osw/streamstats/delaware.html / http://deldot.gov/information/business/drc/misc_files/regression_equation_application_procedures.pdf
- Florida - Rational formula limited to Tc<30 minutes.
- Hawaii - WMS software.
- Illinois - HMS, HEC-1. Illinois StreamStats is on-line and heavily used at "rural" crossings\watersheds. Illinois State Water Survey Bulletin 70 data (rainfall depths and time distributions) drives Rational Method and hydrograph models for IDOT.
- Indiana - DNR recommendation letter when a permit is required.
- Iowa - Iowa DOT Runoff Chart for Rural Culverts.
- Kansas - State-wide regression equations and a modified rational method have been developed for Kansas by research project at University of Kansas.
- Maine - Maintenance experience at site.
- Maryland - Thomas Equations.
- Massachusetts - FHWA WMS.
- Michigan - Michigan's DEQ has tweaked the SCS method.
- Minnesota - StreamStats being developed for MN, will use in the future.
- Missouri - FEMA Flood Insurance Study (FIS) determined discharges.
- Montana - USGS Channel geometry, Regional Frequency analysis. We also use WMS and HEC-HMS software modeling tools.
- New Hampshire - New England High and Low Method.
- North Carolina - NCDOT Hydrologic Nomographs (see manual).
- Rhode Island - HEC-RAS.
- South Dakota - USGS Stream Stats is in development. HEC-HMS has been used on a few sites.
- Tennessee - Roadway Designers routinely use Deepak Drainage for culvert design.
- Texas - Other statistical distributions for gauge analysis such as L-moments.
- Virginia - Daniel Anderson.
- Washington - HSPF Continuous Rainfall Simulation. The upper limit for the Rational Formula is set at the lower limit of our USGS Regression Equations, which varies throughout the state's nine regions, but is never more than 422

acres. So, effectively, the WSDOT upper limit for the Rational Formula is 422 acres or less (100 to 200 acres more typically).

- West Virginia - We use TR-55 from 200 acres up to 5 to 10 square miles, greater than that, USGS Regression Equations.
- Wyoming - Urban rainfall runoff model. IDF curve ABC gage analysis. Gumbel may be analyzed but almost never selected.

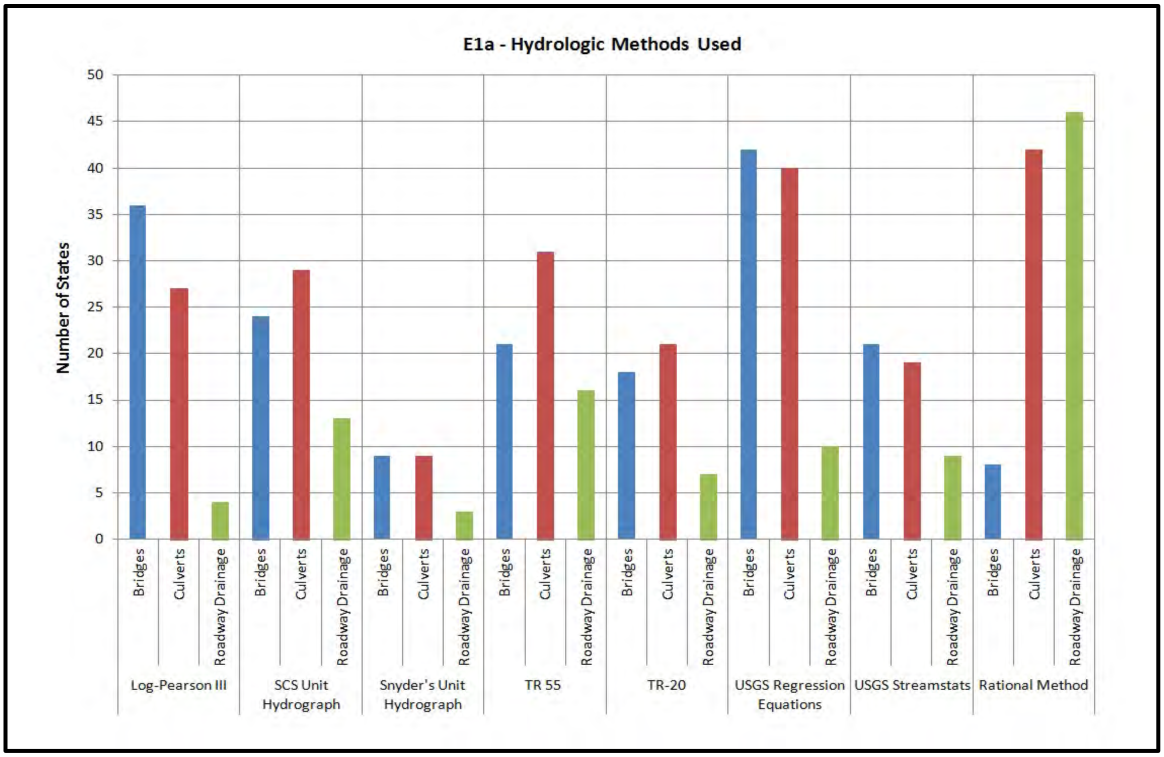


Figure 5.1.1 Number of states using the hydrologic methods identified for the design of bridges, culverts, and roadway drainage structures.

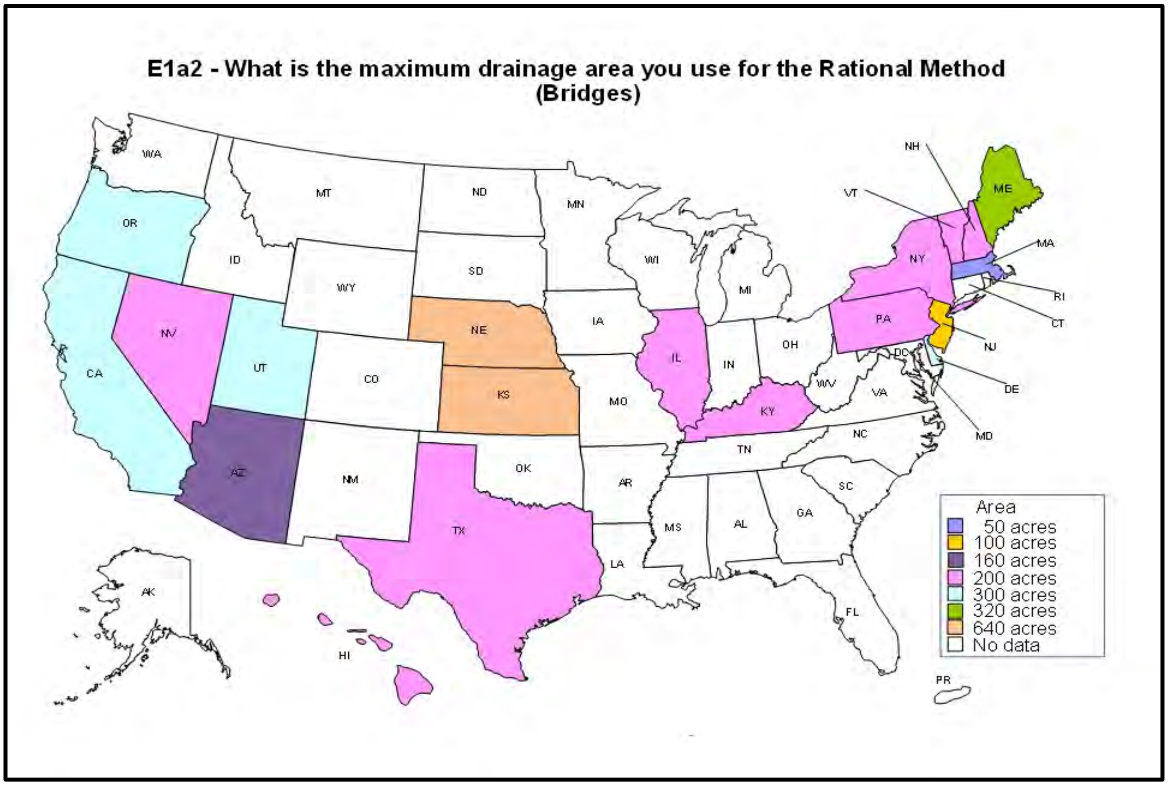


Figure 5.1.2 Drainage area limitation used for Rational Method in bridge design.

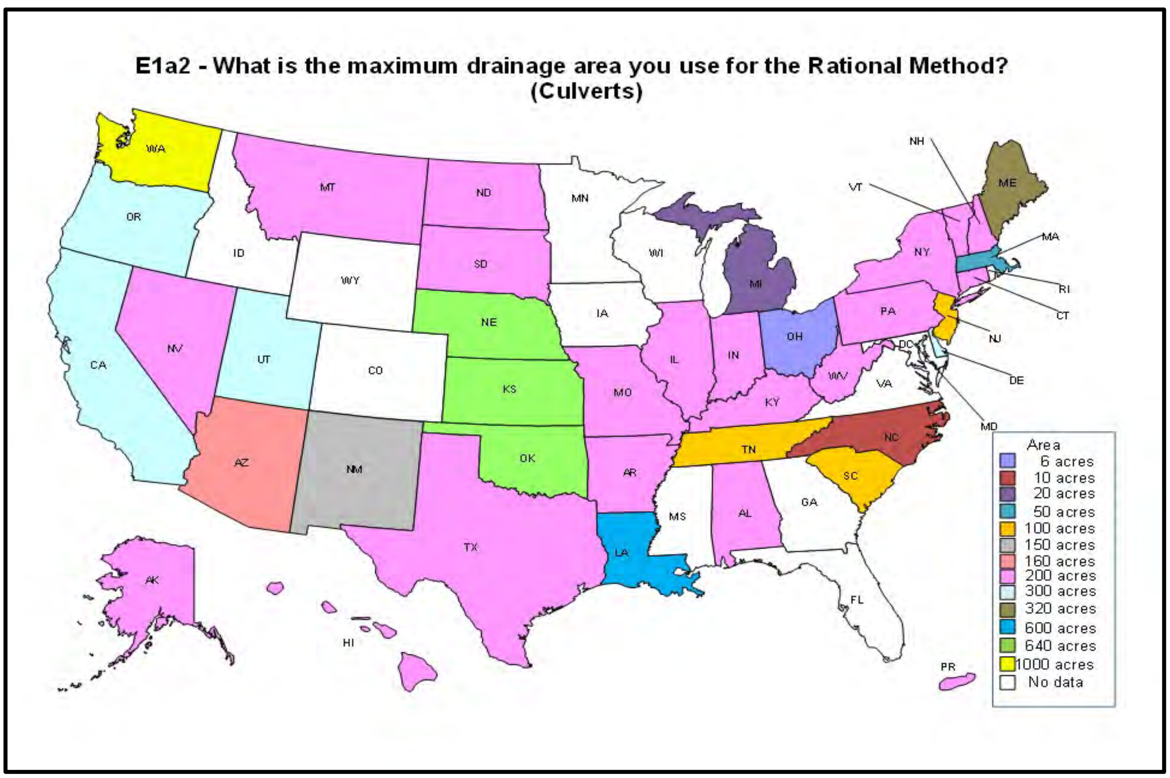


Figure 5.1.3 Drainage area limitation used for Rational Method in culvert design.

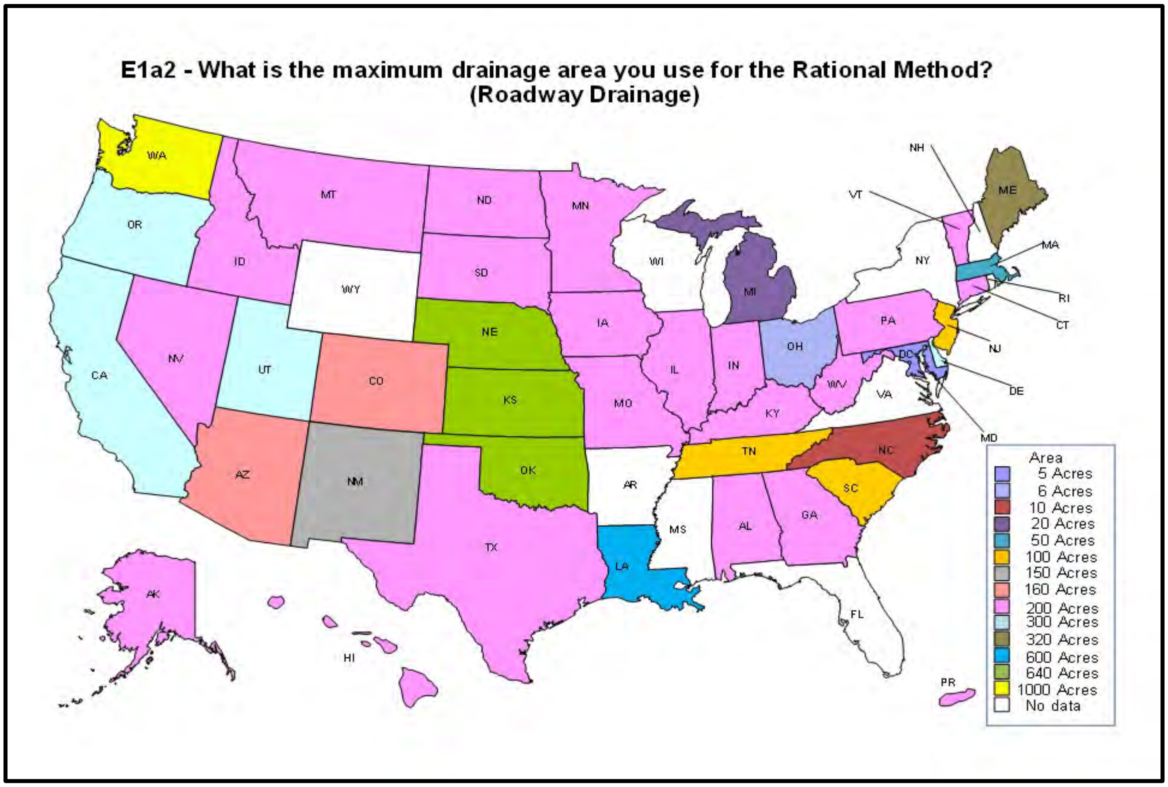


Figure 5.1.4 Drainage area limitation used for Rational Method in roadway drainage design.

5.2 Hydrology Data Sources

This section addresses the data sources used by each state to determine site hydrology.

<u>Question E.2</u>

E.

2. Data Sources
   (check all that apply)

		Traditional (Paper)	Digital (Online)
NOAA 14 Atlas		☐	☐
NOAA2		☐	☐
HYDRO-35		☐	☐
TP-40		☐	☐
USGS Topographic Maps		☐	☐
Land Use		☐	☐
Soil Type		☐	☐
Digital Elevation Data		☐	☐
Other		☐	☐

Additional Comments:

Response:

Figure 5.2.1 provides a bar chart presentation of the number of states using each of the data sources listed. Table 5.2.1 shows how each state responded to the questions on data sources for hydrology. A list of other hydrologic data sources follows.

Other Hydrologic Data Sources:

- Alaska - TP-47 (1963); Digital Land Use, Soil Type, Elevation Data where available.
- California - Ca. Dept. of Water Res.
- Illinois - ISWS Bulletin 70
- Kansas – Others.
- Montana - There is a large amount of data available to us in the way of aerial photo history (including flood photos), USGS technical and open-file reports for flood events. Landowner and Maintenance personnel interviews play a large role in calibrating events. We partner with the USGS with Stream gage data

collection and development of regression equations and updating flood frequency curves for gages.

- Nebraska - Historic Floods / Local studies.
- New Hampshire - UNH & Dartmouth. NHDOT has a Transportation Management Center (TMC) that monitors precipitation at several real time gages, and other basic Meteorology for forecasting purposes and emergency response. Bridge scour is also monitored by the TMC.
- New Jersey - We also use HEC-RAS and HEC-2 as data sources.
- Oklahoma - New 1999 USGS Study. ODOT has a new 1999 USGS study for rainfall depth-duration -frequency for the state of Oklahoma
- Pennsylvania - Note we have developed PDT-IDF curves from the NOAA Atlas data and we use the PDT-IDF Curves for our Precipitation values.
- Puerto Rico - TP-42

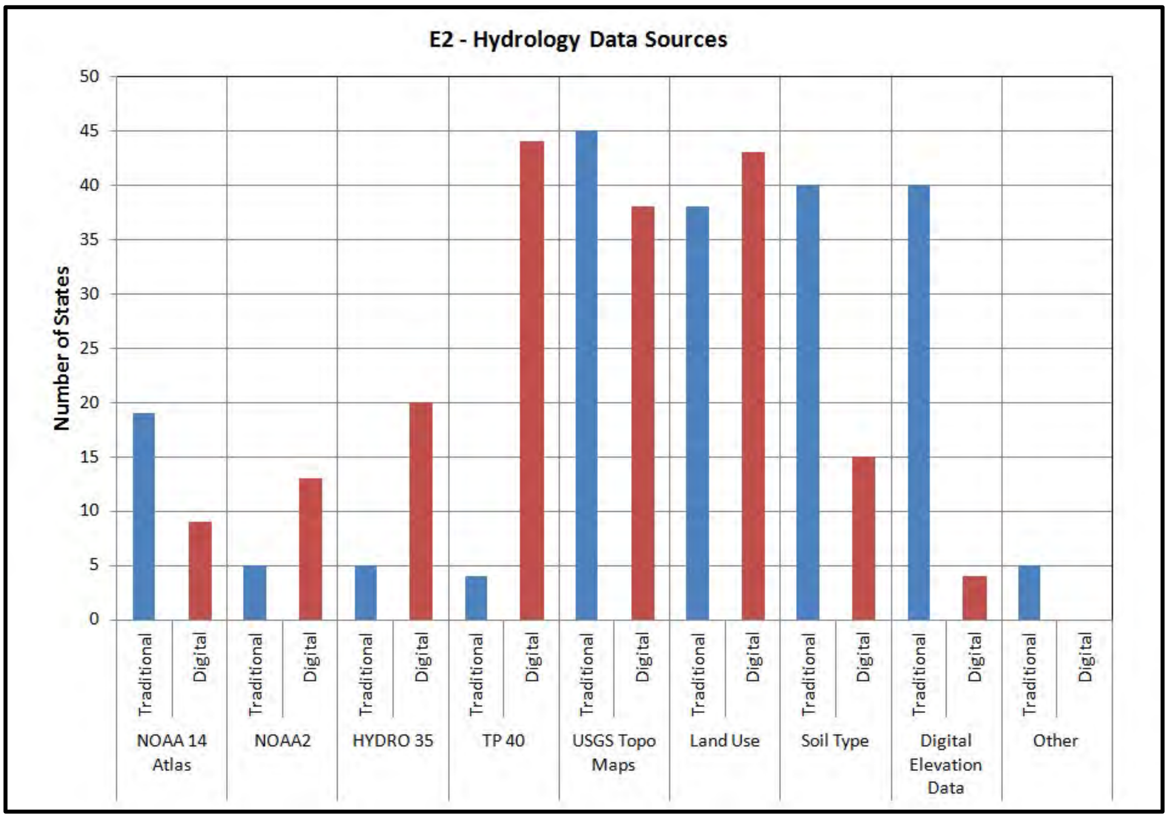


Figure 5.2.1 Number of states using either traditional or digital methodologies for collecting hydrology data from the various sources listed.

Table 5.2.1 Various Hydrology Data Sources used by states.

E2 – Hydrology Data Sources																		
	NOAA 14		NOAA 2		Hydro 35		TP 40		USGS TOPO Maps		Land Use		Soil Type		Digital Elevation Data		Other	
State	Traditional	Digital	Traditional	Digital	Traditional	Digital	Traditional	Digital	Traditional	Digital	Traditional	Digital	Traditional	Digital	Traditional	Digital	Traditional	Digital
AL					■	■			■	■	■	■	■	■		■		
AK									■	■		■		■		■	■	■
AZ		■							■	■	■	■	■	■		■		
AR					■		■		■		■		■					
CA		■	■						■	■	■	■	■	■		■		
CO	■		■		■				■	■	■	■	■	■				
CT					■		■		■	■	■	■	■	■	■	■		
DE	■			■					■	■	■	■	■	■		■		
FL		■							■	■			■	■		■		
GA									■	■	■	■	■	■	■	■		
HI	■								■	■			■		■	■		
ID	■		■						■		■		■		■			
IL									■	■			■			■		
IN		■							■	■	■	■	■	■		■		
IA	■						■			■	■	■	■	■	■	■		
KS	■				■		■		■	■	■	■	■	■		■	■	■
KY	■	■							■	■	■	■	■	■		■		
LA					■		■		■	■	■	■	■	■	■	■		
ME							■		■	■	■	■	■	■		■		
MD	■	■					■		■	■	■	■	■	■	■	■		
MA	■			■	■		■			■		■		■		■		
MI							■		■	■	■	■	■	■				
MN					■		■		■	■	■	■	■	■		■		
MS									■	■								
MO		■						■	■	■		■	■	■		■		
MT	■								■	■	■	■	■	■	■	■		
NE							■		■		■		■		■			
NV	■	■	■		■		■		■	■	■	■	■	■	■	■		
NH				■	■	■	■	■	■	■	■	■	■	■		■		■
NJ	■	■	■	■	■	■			■	■	■	■	■	■			■	■
NM		■	■							■		■	■	■		■		
NY	■						■		■	■	■	■	■	■		■		
NC		■							■	■	■	■	■	■		■		
ND						■		■		■				■		■		
OH		■					■		■									
OK											■		■					
OR			■	■					■	■	■	■	■	■				
PA		■							■	■	■	■	■	■		■		■
PR	■	■							■	■	■	■	■	■	■	■	■	
RI									■		■		■			■		
SC		■			■		■		■	■	■	■	■	■	■	■		
SD						■	■		■	■		■		■		■		
TN	■	■							■	■	■	■	■	■		■		
TX	■				■		■		■	■	■	■	■	■		■		
UT		■								■		■		■		■		
VT							■		■	■	■	■	■	■		■		
VA		■								■	■	■						
WA			■						■	■	■		■	■	■	■		
WV		■							■	■	■	■	■	■				
WI							■	■	■	■	■	■	■	■	■	■		
WY			■						■	■	■	■	■		■	■		

6.0 Roadway Drainage Design

This chapter covers the typical practices of the 50 states and Puerto Rico in roadway drainage design. The chapter is divided into six sections based on the roadway drainage subject of the questionnaire. The section topics cover allowable spread, inlet types, storm drain calculations, drainage of traffic barriers, bridge deck drainage, and storm water management.

6.1 Allowable spread

Allowable spread is often used as the design constraint that determines the spacing of roadway inlets for on-grade sections. Concerns with driver impact from splash and hydroplaning provide the justification for setting spread limits. Mitigating factors include design spread, number of lanes, and availability of shoulders or parking lanes.

Question F.1

F. Roadway Drainage Design
   1. Maximum Allowable Spread In Travel Lane

	No Encroachment	3 ft	4 ft	½ Lane	Other
Sections With Full Shoulders	☐	☐	☐	☐	☐
Sections With Permanent Parking Lane	☐	☐	☐	☐	☐
Sections With One Lane Each Direction	☐	☐	☐	☐	☐
Sections With 2 or More Lanes Each Direction	☐	☐	☐	☐	☐

Response:

The total of all states using each of the identified encroachment limits are shown in Figure 6.1.1. The individual response of states for each of the lane conditions stated are found in Figures 6.1.2 through 6.1.5. A few states have listed more than one allowed encroachment limit for a given number of lanes indicating that other criteria such as design speed and lane width may be included as spread criteria.

Specific State Comments to Clarify Responses:

- Missouri - Interstate/Major arterials - no encroachment in travel lane. Consider 1/2 lane if posted speed <+ 45 mph. Minor arterials - 1/2 lane or <= 12 feet total.
- New Jersey - Our maximum allowable spread in the travel lane is 1/3 of the travel lane.
- Texas - Ponding limited to: IH & controlled highway = 1/2 outer lane ponded; other highways = outer lane ponded; local roadway = one lane completely open.

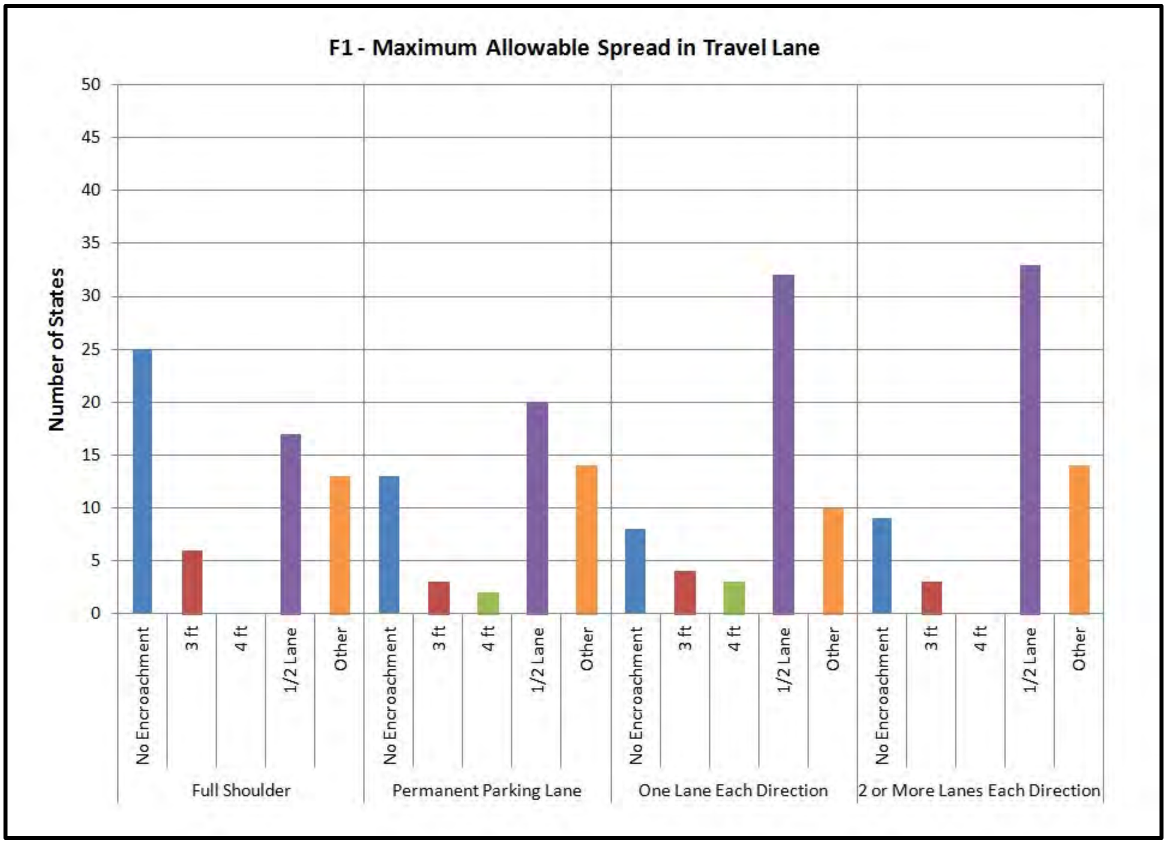


Figure 6.1.1 Maximum allowable spread used by states. Some states may have indicated more than one response.

Table 6.1.1 Maximum allowable spread allowed by states.

	F1 – Maximum Allowable Spread in Travel Lane																			
	Sections With Full Shoulders					Sections With Permanent Parking Lane					Sections With One Lane Each Direction					Sections With 2 Or More Lanes Each Direction				
State	No Encroachment	3 ft	4 ft	1/2 Lane	Other	No Encroachment	3 ft	4 ft	1/2 Lane	Other	No Encroachment	3 ft	4 ft	1/2 Lane	Other	No Encroachment	3 ft	4 ft	1/2 Lane	Other
AL	X			X	X									X	X				X	X
AK	X	X		X	X				X	X	X	X		X	X	X	X	X	X	X
AZ				X					X					X						X
AR				X					X					X						X
CA	X			X		X			X		X			X		X			X	
CO					X			X		X					X				X	
CT				X					X					X					X	
DE	X					X								X					X	
FL	X					X								X					X	
GA	X								X					X					X	
HI					X					X					X					X
ID				X					X					X					X	
IL	X					X							X						X	
IN	X							X					X						X	
IA	X					X								X					X	
KS	X								X			X				X				
KY	X	X		X		X	X		X		X	X		X		X	X		X	
LA				X					X		X								X	
ME	X					X								X		X				
MD	X								X					X	X				X	X
MA	X						X							X					X	
MI	X								X					X					X	
MN	X					X								X					X	
MS					X					X					X					X
MO					X					X					X					X
MT					X					X	X								X	
NE				X					X					X					X	
NV	X								X					X		X				
NH				X						X					X					X
NJ					X					X					X					X
NM				X					X					X					X	
NY				X					X					X					X	
NC	X					X					X								X	
ND				X					X					X					X	
OH																				
OK	X									X			X						X	
OR					X					X					X					X
PA	X					X								X					X	
PR					X					X				X					X	
RI																				
SC	X	X		X										X		X			X	
SD				X	X					X				X					X	X
TN	X					X								X					X	
TX					X					X	X									X
UT	X					X								X					X	
VT		X							X					X		X				
VA	X	X							X					X					X	
WA	X					X								X		X				
WV		X					X					X					X			
WI				X					X					X					X	
WY					X					X	X									X

6.2 Pavement Inlets

This section covers the specific types of drainage inlets that are used and the frequency of their use. The question identifies curb openings as either fixed length or adjustable length as needed and whether an additional drop in the gutter line is provided at curb openings. Slotted drains are listed as a single type and grate inlets are specified as being one of six types listed. A final part of the question asks about the use of combination inlets.

<u>Question F.2</u>

2. Inlets Used

Curb Opening

	Routinely	Occasionally	Rarely	Never
Fixed Length	○	○	○	○
Adjustable Length As Needed	○	○	○	○
Additional Gutter Drop at Opening	○	○	○	○

Slotted Drain

	Routinely	Occasionally	Rarely	Never
	○	○	○	○

Grates

	Routinely	Occasionally	Rarely	Never
Parallel Bar	○	○	○	○
Perpendicular Bar	○	○	○	○
Curved Vane	○	○	○	○
Tilt Bar	○	○	○	○
Diagonal Bar	○	○	○	○
Reticuline Bar	○	○	○	○
Other	○	○	○	○

Combination

	Routinely	Occasionally	Rarely	Never
Curb Opening and Grate	○	○	○	○
Grate and Slotted Drain	○	○	○	○
Other	○	○	○	○

Response:

Figure 6.2.1 is a bar chart showing the number states that use each of the inlet types specified. Table 6.2.1shows which states use each of the respective inlet types.

Other Grates Used:

- California – Bicycle Proof
- South Carolina – Checker-board patterned
- Vermont – Cast Iron Type D

Other Combination Inlet Used:

- California – Grate and Trench Drain Combination
- Nevada – trench drain combined with other inlet types
- New Mexico – MDI

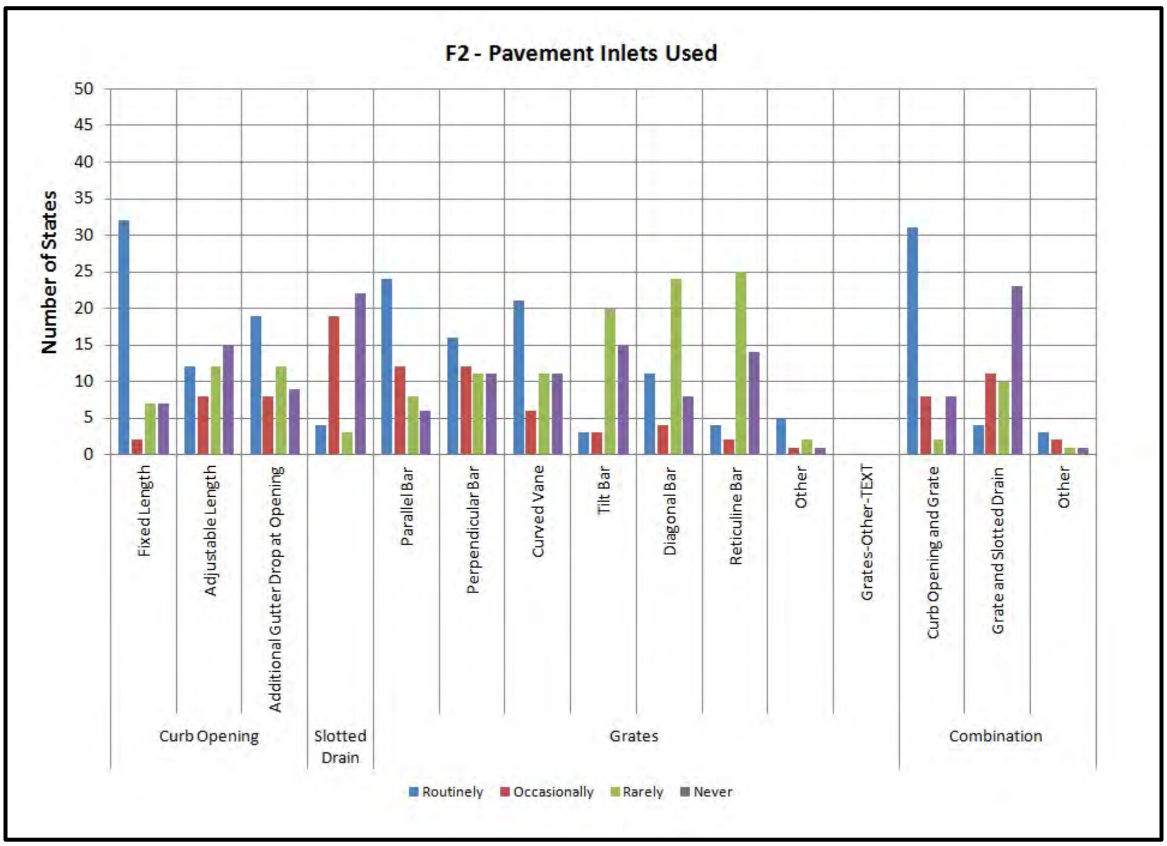


Figure 6.2.1 Number of states that use each of the inlet types specified.

Table 6.2.1 Types of pavement inlets used by states and their frequency of use.

F2 – Pavement Inlet Types Used

State	Curb Open Inlets												Slotted Drains			
	Fixed Length				Adjust-able Length As Needed				Additional Gutter Drop At Opening							
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL	■						■		■					■		
AK	■							■	■							■
AZ					■				■				■			
AR				■	■				■							■
CA	■							■	■				■			
CO	■				■				■				■			
CT				■				■			■					■
DE				■				■				■				■
FL	■					■			■							■
GA	■				■					■						
HI	■						■				■					■
ID	■					■				■						■
IL	■						■		■					■		
IN			■				■				■			■		
IA	■					■						■		■		
KS		■				■				■						■
KY	■					■			■					■		
LA			■		■				■							■
ME				■				■				■				■
MD	■				■				■							■
MA														■		
MI	■															■
MN		■						■	■					■		
MS	■							■				■				■
MO	■							■			■			■		
MT			■				■				■			■		
NE			■		■				■					■		
NV	■				■				■				■			
NH			■				■				■					■
NJ	■						■			■				■		
NM	■				■					■				■		
NY			■				■				■					■
NC	■							■	■					■		
ND	■						■				■			■		
OH	■								■						■	
OK	■				■							■				■
OR	■					■				■				■		
PA	■						■				■			■		
PR	■					■				■				■		
RI																
SC	■						■				■			■		
SD	■							■				■				■
TN	■						■				■				■	
TX			■		■							■				■
UT	■							■	■							
VT				■				■				■			■	
VA				■	■				■							■
WA	■							■	■							■
WV	■							■		■						■
WI				■				■				■				■
WY	■					■					■			■		

State	Grates																											
	Parallel Bar				Perpendicular Bar				Curved Vane				Tilt Bar				Diagonal Bar				Reticuline Bar				Other			
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL	■						■		■						■				■				■				
AK			■					■	■				■				■							■				
AZ	■				■					■			■							■				■				
AR	■				■				■										■				■					
CA	■						■				■					■			■					■	■			
CO	■				■				■								■								■			
CT	■				■						■				■				■				■				
DE		■						■				■					■							■				
FL				■	■							■				■			■		■							
GA	■				■				■				■						■					■			■	
HI	■				■						■					■			■				■					
ID	■				■							■				■				■				■				
IL			■				■			■					■		■						■					
IN		■				■			■						■				■				■					
IA	■					■						■				■				■				■				
KS		■				■					■				■				■				■				■	
KY	■				■				■																			
LA	■				■						■				■				■			■						
ME		■				■				■																		
MD				■		■			■									■			■							
MA	■						■		■						■				■		■							
MI		■				■				■																		
MN		■						■	■						■			■					■					
MS	■				■							■				■				■				■				■
MO	■							■	■						■				■				■					
MT			■			■			■							■		■					■					
NE	■						■		■							■	■						■			■		
NV	■						■					■			■		■						■					
NH		■				■			■						■		■						■					
NJ	■							■			■				■					■			■					
NM	■				■					■				■						■				■	■			
NY		■				■					■				■				■		■							
NC			■				■				■				■		■						■					
ND				■				■	■							■	■							■				
OH	■							■				■				■	■							■				
OK		■				■			■					■				■				■						
OR	■				■						■				■				■				■					
PA			■		■							■				■	■						■		■			
PR		■				■											■											
RI																												
SC			■				■				■								■				■		■			
SD			■				■		■							■			■				■					
TN				■				■	■						■				■				■					
TX		■			■							■				■				■				■				
UT	■							■		■					■				■				■					
VT				■				■				■				■			■					■				
VA	■						■				■				■		■						■					
WA		■					■		■						■				■				■					
WV	■					■						■		■						■				■				
WI			■		■				■						■		■						■					
WY				■				■	■							■			■				■					

State	Combination											
	Curb Opening and Grate				Grates and Slotted Drains				Other			
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL	■							■				
AK	■							■				
AZ	■				■							
AR		■						■				
CA	■					■				■		
CO	■				■				■			
CT	■							■				
DE	■							■				
FL	■							■				
GA	■							■				■
HI				■				■				
ID		■						■				
IL	■				■							
IN	■					■						
IA	■					■						
KS		■						■				
KY	■					■						
LA	■						■					
ME		■										
MD	■							■				
MA		■						■				
MI	■							■				
MN		■						■				
MS				■				■				
MO				■			■					
MT	■					■						
NE			■				■					
NV	■				■				■			
NH			■					■				
NJ	■					■				■		
NM	■					■			■			
NY	■							■				
NC	■							■				
ND	■					■						
OH												
OK	■							■				
OR	■					■						
PA	■						■				■	
PR				■		■						
RI												
SC	■							■				
SD	■						■					
TN	■						■					
TX				■				■				
UT		■					■					
VT				■			■					
VA				■			■					
WA				■			■					
WV		■						■				
WI	■							■				
WY	■					■						

6.3 Storm Drain Design

There are several analysis considerations involved in storm drain design. This section addresses four calculations considered vital in evaluating the adequacy of storm drains and it includes two conditions for evaluating the design hydrology for a storm drain design. Question F.3 asks states if they calculate the energy gradeline, hydraulic gradeline, tailwater elevation, and access hole energy losses either routinely, occasionally, rarely, or never to evaluate the adequacy of a storm drain design. The question also asks if the hydrology used in storm drain design is a peak discharge or a hydrograph routing and how often each is used.

<u>Question F.3</u>

3. Calculated During Storm Drain Design

	Routinely	Occasionally	Rarely	Never
Energy Grade Line	○	○	○	○
Hydraulic Grade Line	○	○	○	○
Tailwater Elevation	○	○	○	○
Access Hole/Junction Energy Loss	○	○	○	○
Via Peak Flow	○	○	○	○
Via Hydrograph Dynamic Routing	○	○	○	○

Response:

Figure 6.3.1 provides a bar chart of the states' responses for each of the calculations listed. The individual state responses are shown in Figure 6.3.2. The vast majority of states calculate the hydraulic gradeline, tailwater, and access hole energy losses using a peak discharge. A smaller majority of states also calculate the energy grade line. Since calculating the energy gradeline is a necessary component of calculating the hydraulic gradeline some states may not have marked that question correctly since it may have appeared redundant.

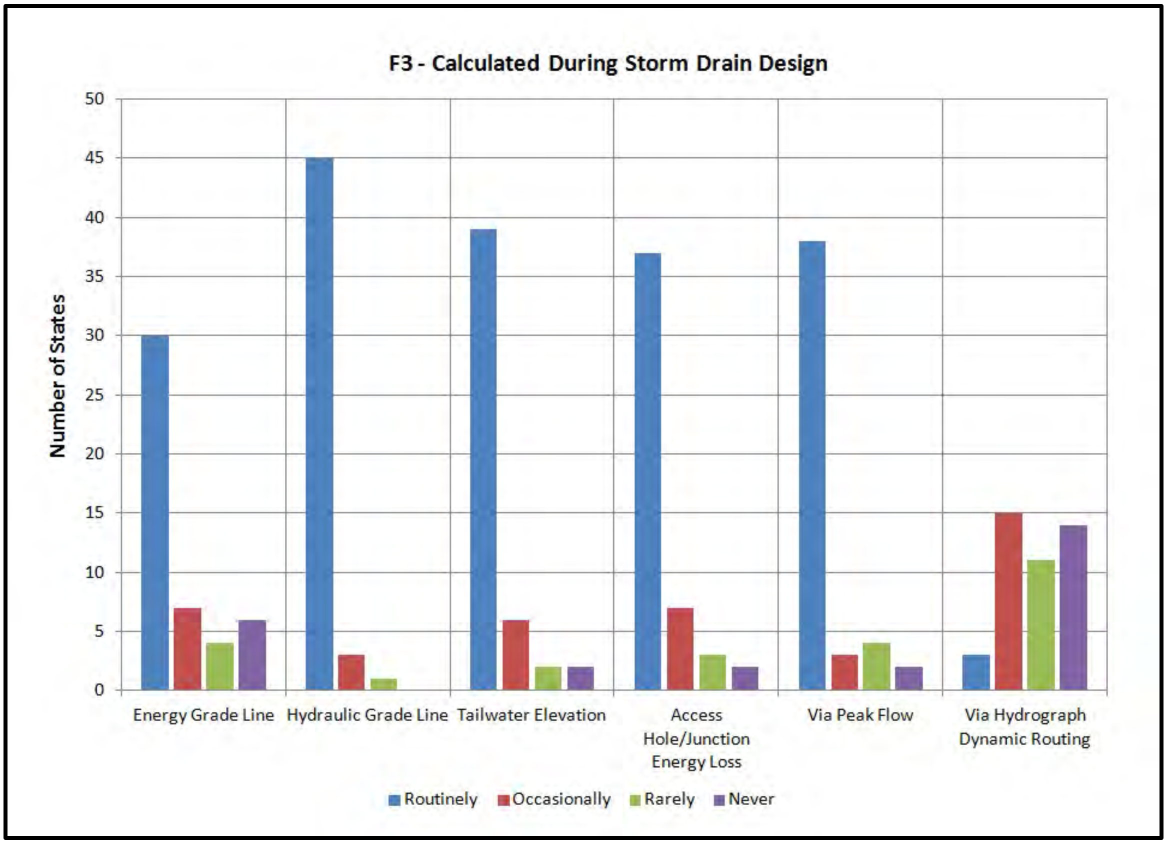


Figure 6.3.1 Number of states performing the storm drain calculations specified in Question F.3.

Table 6.3.1 Hydraulic parameters calculated in storm drain design.

F3 – Calculations Used in Storm Drain Design																								
	Energy Grade Line				Hydraulic Grade Line				Tailwater				Access Hole/ Junction Loss				Via Peak Flow				Via Dynamic Routing			
State	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL	■				■				■				■				■						■	
AK	■				■				■				■				■					■		
AZ	■				■				■				■				■							■
AR	■				■					■			■				■					■		
CA		■			■					■				■			■							■
CO	■				■				■				■							■			■	
CT	■				■				■				■											
DE	■				■				■				■				■				■			
FL				■	■				■					■			■					■		
GA	■				■				■				■				■					■		
HI			■		■				■				■				■							■
ID	■				■				■				■				■					■		
IL	■				■				■				■				■							■
IN			■		■					■					■				■				■	
IA	■				■					■			■				■					■		
KS	■				■				■				■				■				■			
KY				■	■				■				■				■							■
LA	■				■				■				■				■					■		
ME																	■							
MD	■				■				■				■				■							■
MA				■	■				■				■				■					■		
MI	■				■				■				■				■							■
MN	■				■				■				■				■					■		
MS			■				■				■				■				■				■	
MO	■				■				■				■											
MT	■				■				■					■			■						■	
NE					■				■				■				■							
NV	■				■				■				■				■						■	
NH		■				■			■					■			■							■
NJ	■				■				■				■						■				■	
NM	■				■				■				■					■			■			
NY	■				■				■				■				■							■
NC	■				■				■				■											■
ND		■			■				■				■				■					■		
OH					■				■						■									
OK	■				■				■				■				■							■
OR		■			■					■				■			■						■	
PA				■	■				■				■						■				■	
PR		■			■							■				■		■						■
RI																								
SC	■				■				■				■				■							■
SD		■			■							■	■				■							■
TN	■				■				■				■				■						■	
TX				■	■				■					■			■					■		
UT	■				■				■				■					■				■		
VT				■		■					■					■				■		■		
VA			■		■				■				■				■						■	
WA	■				■				■				■				■					■		
WV		■			■				■					■			■					■		
WI	■				■				■				■				■							
WY	■				■					■			■				■							

6.4 Traffic Barriers

Drainage through temporary and permanent traffic barriers has long been ignored in drainage design. More recently many states have been evaluating the drainage features of traffic barriers and incorporating these in roadway design. This section was included to determine the number of states that have started evaluating the drainage features of barriers.

Question F.4

4. Barriers

	Routinely	Occasionally	Rarely	Never
Is flow calculated through/under temporary construction barriers?	○	○	○	○
Is flow calculated through/under permanent traffic barriers?	○	○	○	○

Response:

Figure 6.4.1 shows that only fifteen (15) states routinely calculate flow through or under permanent traffic barriers and only six (6) states calculate flow through temporary barriers. The responses of individual states and Puerto Rico are shown in the Table 6.4.2.

Specific State Comments to Clarify Responses:

- Missouri - Usually try to collect water with drop inlets in lieu of transferring through the permanent traffic barrier.

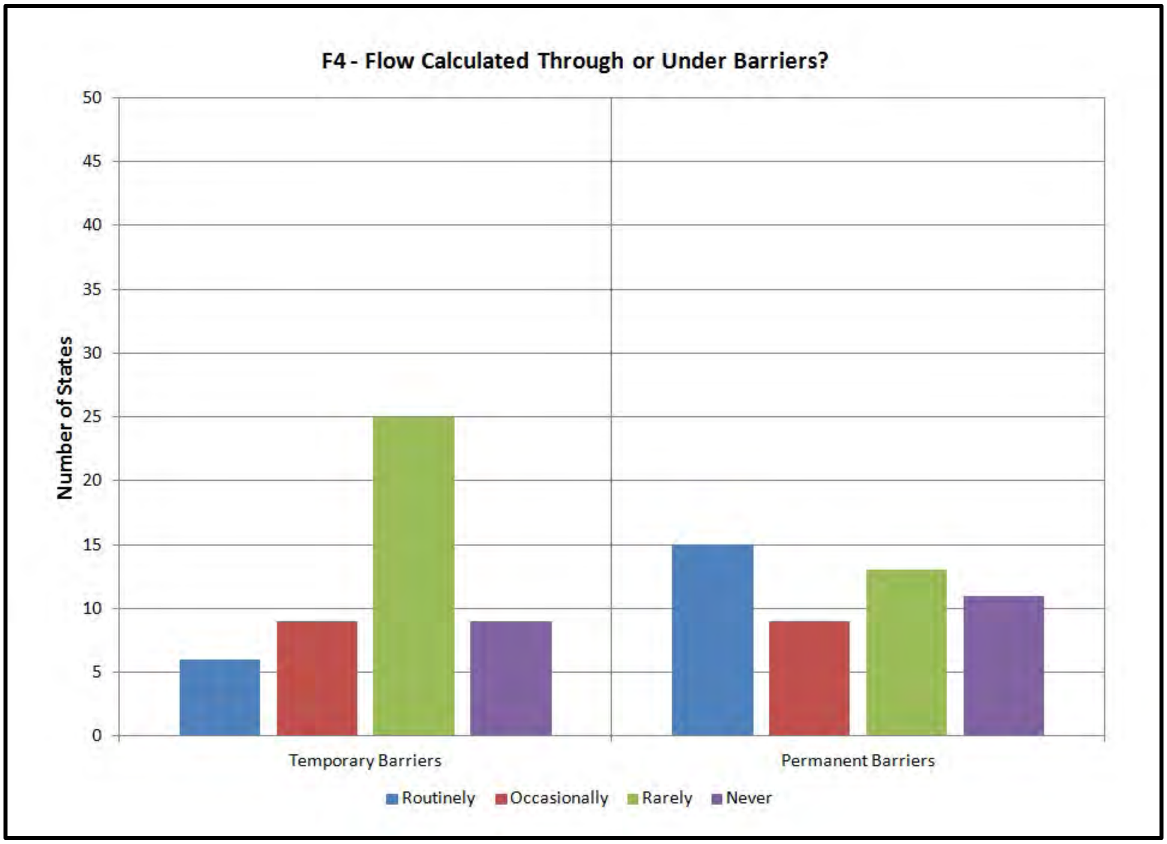


Figure 6.4.1 Number of states that calculate flow through or under traffic barriers.

Table 6.4.1 States' responses on calculation of flow through or under traffic barriers.

F4 – Is flow calculated through:								
	Temporary Construction Barriers				Permanent Traffic Barriers			
State	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL				■				■
AK				■				■
AZ			■				■	
AR		■				■		
CA		■			■			
CO			■				■	
CT			■		■			
DE		■				■		
FL	■				■			
GA				■				■
HI				■				■
ID			■				■	
IL			■			■		
IN			■		■			
IA			■					
KS		■				■		
KY				■				■
LA	■				■			
ME			■				■	
MD			■					■
MA			■			■		
MI			■				■	
MN			■					■
MS		■				■		
MO			■					■
MT			■		■			
NE	■				■			
NV		■			■			
NH			■				■	
NJ		■			■			
NM				■				■
NY			■		■			
NC	■				■			
ND			■		■			
OH								
OK			■				■	
OR	■				■			
PA			■				■	
PR		■			■			
RI								
SC			■				■	
SD			■			■		
TN				■				■
TX			■				■	
UT			■				■	
VT				■				■
VA		■				■		
WA	■				■			
WV				■		■		
WI			■				■	
WY			■				■	

6.5 Bridge Deck Drainage

This section on bridge deck drainage contains four questions that address whether bridge deck drainage is released into streams, the types of bridge deck inlet and piping systems used, and water quality treatment practices.

<u>Question F.5.a</u>

5. Bridge Deck Drainage
   a. Is bridge deck drainage released untreated into streams?

Never	Always	Routinely Except for Environmentally Sensitive Streams	Only Intermittent Streams	Other ☐
☐	☐	☐	☐	☐

Response:

Thirty-three (33) states and Puerto Rico routinely discharge directly into streams unless the stream is environmentally sensitive. Five (5) states always discharge into the stream and three (3) states never discharge directly into the stream. Two (2) states indicated that they only discharge directly into intermittent streams. A national perspective is shown in Figure 6.5.1.

Other Answers Regarding Untreated Bridge Deck Drainage Releases:

- Alaska - Route to Bridge Ends. Research ongoing.
- Delaware – Under Review
- Florida – Only as a last resort
- Michigan – Rarely
- Minnesota – Occasionally
- Montana - This is being looked at more closely now on all bridge designs and barrier types.
- Oklahoma – Not applicable
- West Virginia - Always unless prohibited by DEP.

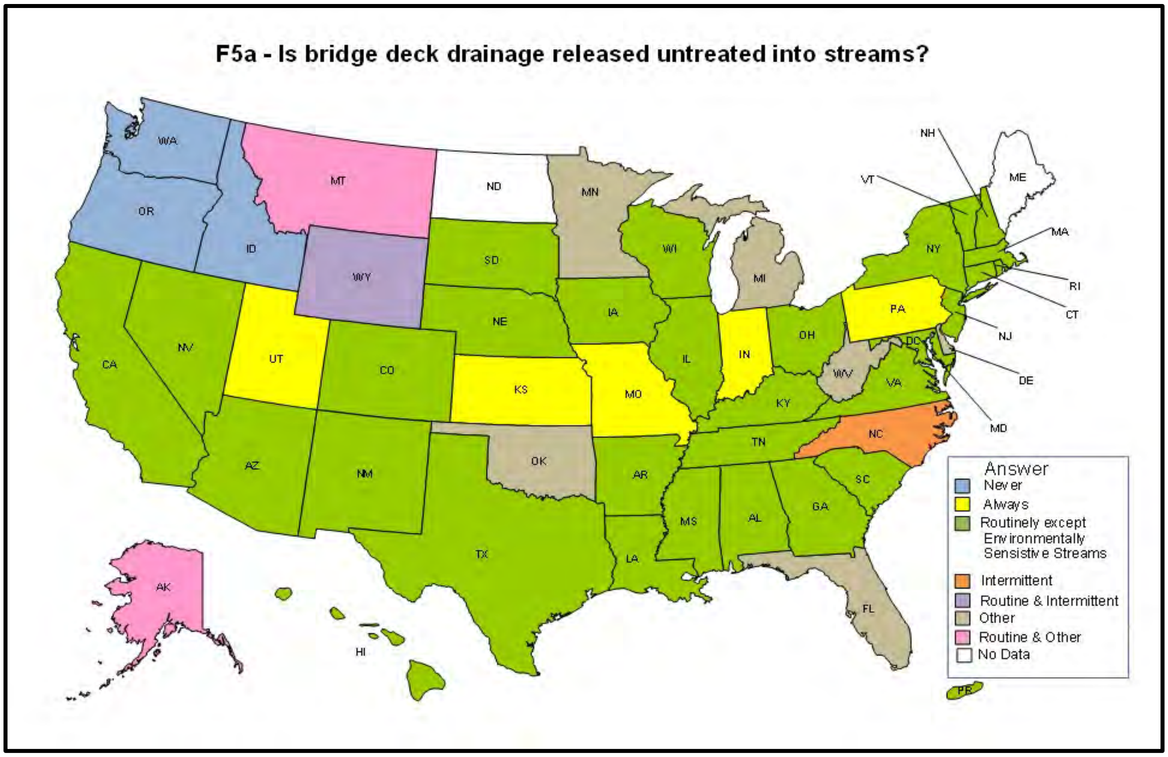


Figure 6.5.1 Bridge deck drainage release practices of states.

Question F.5.b

b. What types of bridge deck drainage do you use?
(check all that apply)

☐	Horizontal Opening in Parapet Wall		
☐	Vertical Scupper in Bridge Deck		
☐	Vertical Tube Drain in Bridge Deck		
☐	Other		

Response:

Table 6.5.1 Number of states that use each of the deck drain types shown.

Deck Drain Types	*Number States*
Horizontal Opening in Parapet Wall	24
Vertical Scupper in Bridge Deck	44
Vertical Tube Drain in Bridge Deck	29
Other	9

Other Types of Bridge Deck Drainage Used:

- Alaska - Cut holes in bridge deck. Not preferred.
- Florida - Grated bridge inlets.
- Maryland - Intercept the flow at the end of the roadway approach.
- Nebraska - Open Rail.
- New Mexico - Drain through drop inlets/rundown at the ends of bridge.
- New York – Curbless.
- Utah - It depends, all above could be used.

Table 6.5.2 Responses of each state regarding what types of bridge deck drainage is used.

F5b - What types of bridge deck drainage do you use?				
State	Horizontal Opening In Parapet Wall	Vertical Scupper In Bridge Deck	Vertical Tube Drain In Bridge Deck	Other
AL		■		
AK	■	■	■	■
AZ	■	■	■	
AR	■			
CA	■	■	■	
CO	■	■	■	■
CT		■		
DE		■		
FL	■	■	■	■
GA		■		■
HI	■	■		
ID	■	■	■	
IL		■	■	
IN		■	■	
IA		■		
KS	■	■	■	
KY	■	■	■	
LA	■	■	■	
ME				
MD	■	■		■
MA		■		
MI		■	■	
MN		■		
MS	■	■	■	
MO			■	
MT	■	■	■	
NE	■	■		■
NV	■	■	■	
NH		■	■	
NJ	■	■	■	
NM		■	■	■
NY	■	■		■
NC	■	■	■	
ND			■	
OH		■		
OK				
OR		■	■	
PA	■	■		
PR		■	■	
RI		■		
SC	■	■		
SD			■	
TN	■	■		
TX	■	■	■	
UT				■
VT		■		
VA	■	■		
WA		■	■	
WV		■	■	
WI		■	■	
WY		■	■	

Question F.5.c

c. Are closed drainage systems (piping) used on bridges?

Never	Always	Only when over railroads, roadways, or environmentally sensitive areas	Other ☐
☐	☐	☐	☐

Response:

Table 6.5.3 Number of states that use each of the deck drain types shown.

When Closed Drain Systems are Used on Bridges	*Number States*
Never	4
Always	4
Only when over railroads, roadways, or environmentally sensitive areas	37
Rarely	1
Other	4

Other Answers Regarding Use of Closed Drainage Systems on Bridges:

- Alaska – Rarely.
- Florida – As last resort.
- Kansas – At times.
- Michigan – Rarely.
- Minnesota – Rarely.

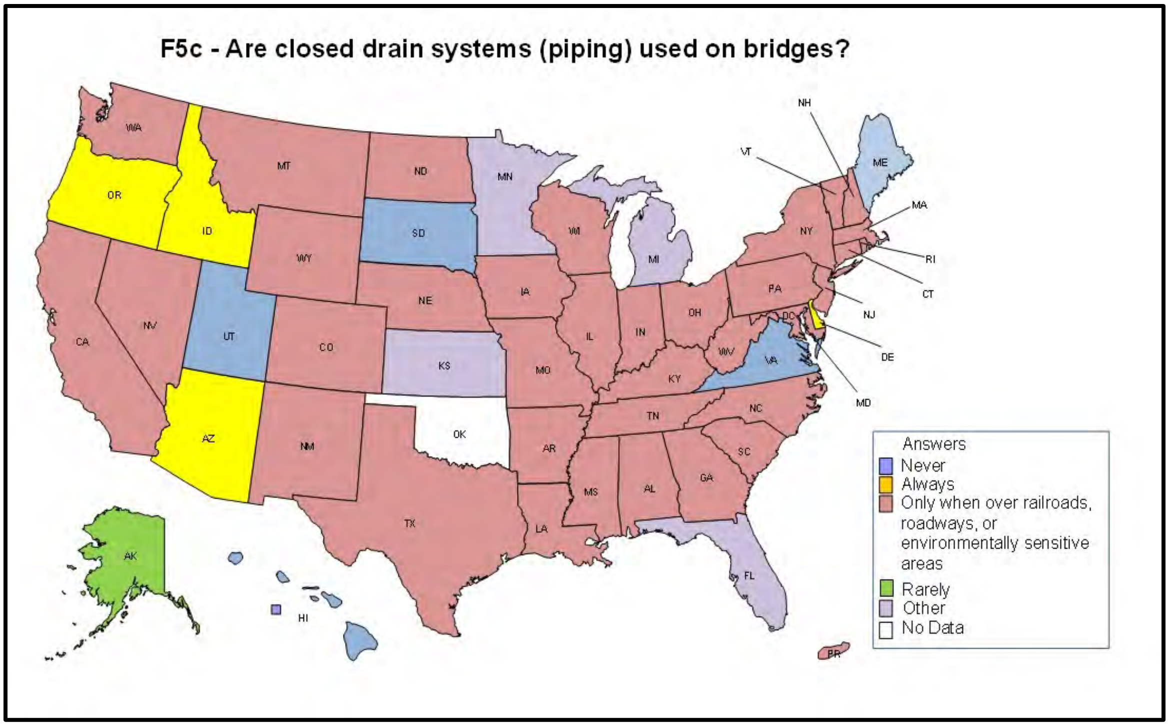


Figure 6.5.3 Conditions when states use closed drainage systems.

Question F.5.d

d. What types of water quality treatment are used for bridge deck drainage?
(check all that apply)

Detention Ponds	Deck Drain Filter	Grassed Swales	None	Other ☐
☐	☐	☐	☐	☐

Response:

Table 6.5.4 Number of states which use types of water quality treatment for bridge deck drainage.

Types of Water Quality Treatment for Bridge Deck Drainage	*Number States*
Detention Ponds	18
Deck Drain Filter	2
Grassed Swales	22
None	23
Other	8

Other Types of Water Quality Treatments Used for Bridge Deck Drainage:

- Alaska - Route to Roadway Stormwater Treatment BMP at or Beyond the end of the bridge. Discharge also to aggregate/riprap slopes.
- Delaware – Under Review.
- Nevada – Water Quality Vaults.
- New Jersey – Manufactured treatment devices.
- New Mexico - Inlet w/snout.
- North Carolina – Hazardous spill basins.

Table 6.5.5 Types of water quality treatment used for bridge deck drainage.

F5d - What types of water quality treatment are used for bridge deck drainage?					
State	Detention Ponds	Deck Drain Filter	Grassed Swales	None	Other
AL	■		■		
AK			■	■	■
AZ	■		■		
AR				■	
CA	■		■		
CO	■				■
CT				■	
DE					■
FL	■				
GA	■		■		
HI			■		
ID	■				
IL				■	
IN				■	
IA	■				
KS				■	
KY	■				
LA				■	
ME					
MD	■		■	■	
MA	■		■		
MI	■		■		
MN	■		■	■	
MS				■	
MO				■	
MT			■	■	
NE				■	
NV	■				■
NH			■		■
NJ					■
NM					■
NY				■	
NC			■		■
ND			■		
OH				■	
OK					
OR	■	■	■		
PA				■	
PR	■		■		
RI				■	
SC		■	■		
SD				■	
TN				■	
TX	■		■		
UT				■	
VT				■	
VA				■	
WA	■		■		
WV			■		
WI			■		
WY			■	■	

6.6 Storm Water Management

This section covers the stormwater management practices (BMPs) of the states for controlling run-off from highway right-of-way and the requirements placed on developers whose properties drain to highway right-of-way.

Question F.6.a

6. Storm Water Management
   a. What types of BMPs are used to control runoff volume?

		Routinely	Occasionally	Rarely	Never
Retention Basins		○	○	○	○
Detention Basins		○	○	○	○
Underground Storage Chambers		○	○	○	○
Storage in Storm Drains		○	○	○	○
Diversion		○	○	○	○
Infiltration		○	○	○	○
Other		○	○	○	○

Response:

The most commonly used BMP, as shown in Figure 6.6.1, is storage in surface ponds with thirty (30) states indicating that they use detention basins routinely and eighteen (18) states indicating that they use retention basins routinely. The BMPs used least are underground storage, diversion, infiltration, and storage in storm drains with 24 states, 23 states, 18 states, and 17 states, respectively, saying they never use them. The responses of individual states are shown in the national map in Table 6.6.1.

Other Types of BMPs Used:

- Alabama – Grassed-lined ditches.
- Delaware – Good Disconnection Practices and Greentech BMP's.
- Hawaii - Proprietary BMP devices. The Hawaii DOT developed a "Storm Water Permanent BMP Manual", effective March 2007.
- Illinois - Oversized ditches.
- Maryland - Sand Filters, Bioretentions, Swales.
- Missouri - Although not constructed for this purpose, mitigation wetlands do serve to improve stormwater management, "occasionally".

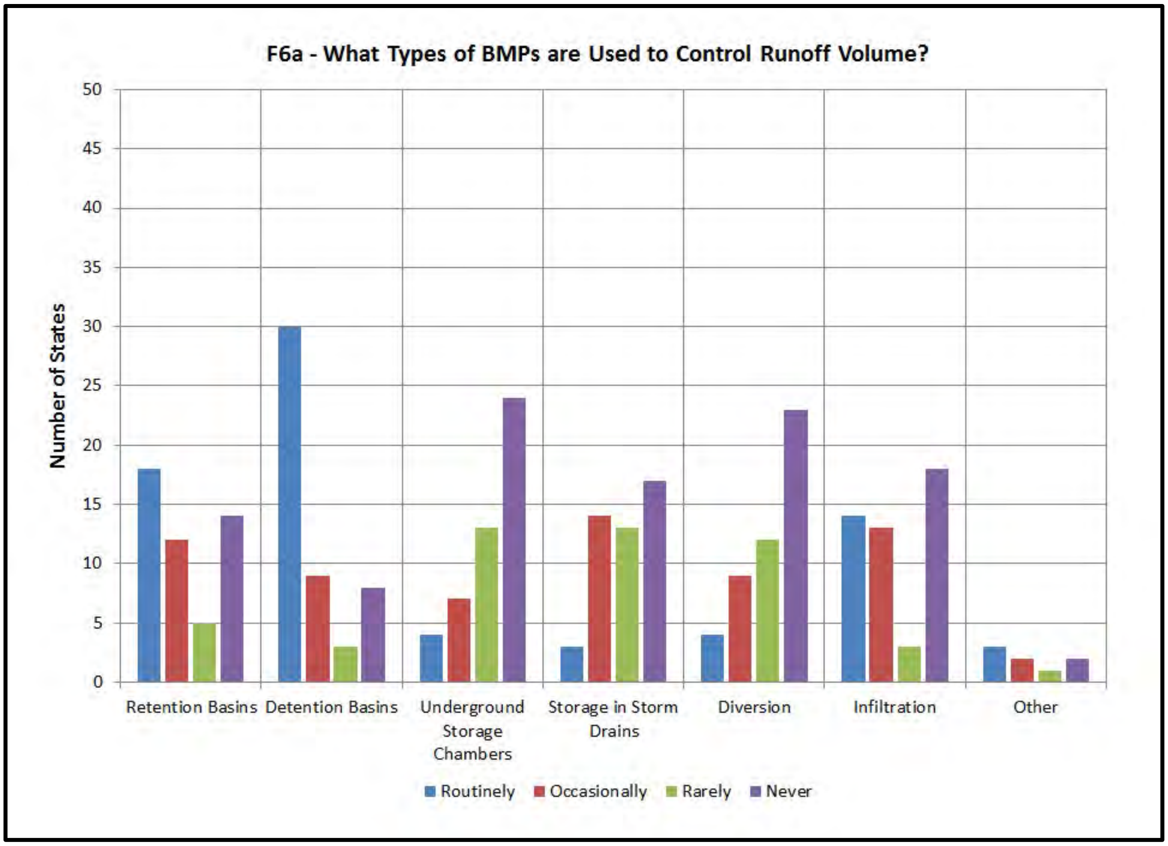


Figure 6.6.1 Frequency of usage of BMP types to control runoff volumes.

Table 6.6.1 Stormwater Management BMP usage of the states.

F6a - What types of BMPs are used to control runoff volume?																												
	Retention Basins				Detention Basins				Underground Storage Chambers				Storage in Storm Drains				Diversion				Infiltration				Other			
State	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL			X				X				X						X								X			
AK				X		X						X			X					X	X							
AZ	X				X						X				X					X	X							
AR			X				X				X					X			X				X					
CA		X				X						X		X						X		X						
CO	X				X							X			X					X				X				X
CT				X	X							X				X			X					X				
DE		X			X							X				X		X			X							
FL	X				X				X												X							
GA	X				X										X			X			X							X
HI		X				X					X				X					X				X		X		
ID		X				X				X				X						X		X						
IL			X					X				X	X						X					X	X			
IN		X			X					X				X						X				X				
IA				X				X				X				X			X					X				
KS		X						X		X						X				X				X				
KY						X				X				X														
LA				X				X				X		X				X						X				
ME				X				X										X				X						
MD	X				X							X				X		X			X				X			
MA	X				X						X				X					X	X							
MI		X			X							X				X				X				X				
MN				X	X							X			X				X			X						
MS			X				X				X				X				X				X				X	
MO				X				X				X			X				X				X					
MT		X				X				X				X				X				X						
NE				X	X						X				X				X		X							
NV	X				X				X							X				X	X							
NH	X				X							X		X				X						X				
NJ	X				X							X		X						X		X				X		
NM	X				X							X			X		X				X							
NY	X				X					X					X					X		X						
NC				X	X							X				X			X			X						
ND				X		X					X			X						X				X				
OH	X				X				X				X				X				X							
OK	X				X					X						X				X				X				
OR	X				X				X				X						X		X							
PA	X				X						X					X	X				X							
PR	X				X							X		X						X				X				
RI																												
SC				X	X						X			X						X				X				
SD		X				X					X					X				X				X				
TN				X				X			X					X		X				X						
TX		X			X						X			X						X		X						
UT	X				X							X		X				X				X						
VT			X		X							X			X					X	X							
VA		X			X							X				X				X		X						
WA	X				X							X				X			X			X						
WV				X	X							X		X						X				X				
WI		X				X						X				X			X					X				
WY				X				X				X				X				X				X				

Question F.6.b

Question F.6.b was omitted prior to distribution of the questionnaire and no further discussion is provided.

Question F.6.c (Part 1)

Storm Water Management
c. Developer Requirements

Do you have permit rules for developers who drain into a state storm drain facility?

Yes	No
○	○

Response:

Forty-two (42) states and Puerto Rico have permit rules and six (6) states do not have permit requirements for developers. Figure 6.6.2 shows the breakdown by individual respondents.

Specific State Comment to Clarify Response:

- Connecticut - Major Traffic Generator Certificates - Application Section VII Drainage Requirements. / http://www.ct.gov/dot/lib/dot/Documents/dpermits/stc_mtg.pdf
- Delaware - http://deldot.gov/information/pubs_forms/manuals/dgm/pdf/memo_2-5.pdf
- Missouri – Rule is that permit be reviewed.
- Oklahoma - Any developer who wants to discharge into ODOT easement needs to have permit from ODOT.
- Pennsylvania - Highway Occupancy Permit. Unless specifically authorized by the permit, the permittee shall not: (i) alter the existing drainage pattern or the existing flow of drainage water; or (ii) direct additional drainage of surface water onto or into the highway right-of-way or highway facilities in a way which would have a detrimental effect on the highway or highway facilities. If the analysis indicates that the available capacity of the highway drainage system will not be adequate due to an increase in the flow rate or flow velocity, or that there will be an increase in the flow rate or flow velocity from the developed property, the drainage impact report shall include a description of proposed actions which will remedy the identified deficiencies, including hydraulic computations, arranged by location and type of remedy.

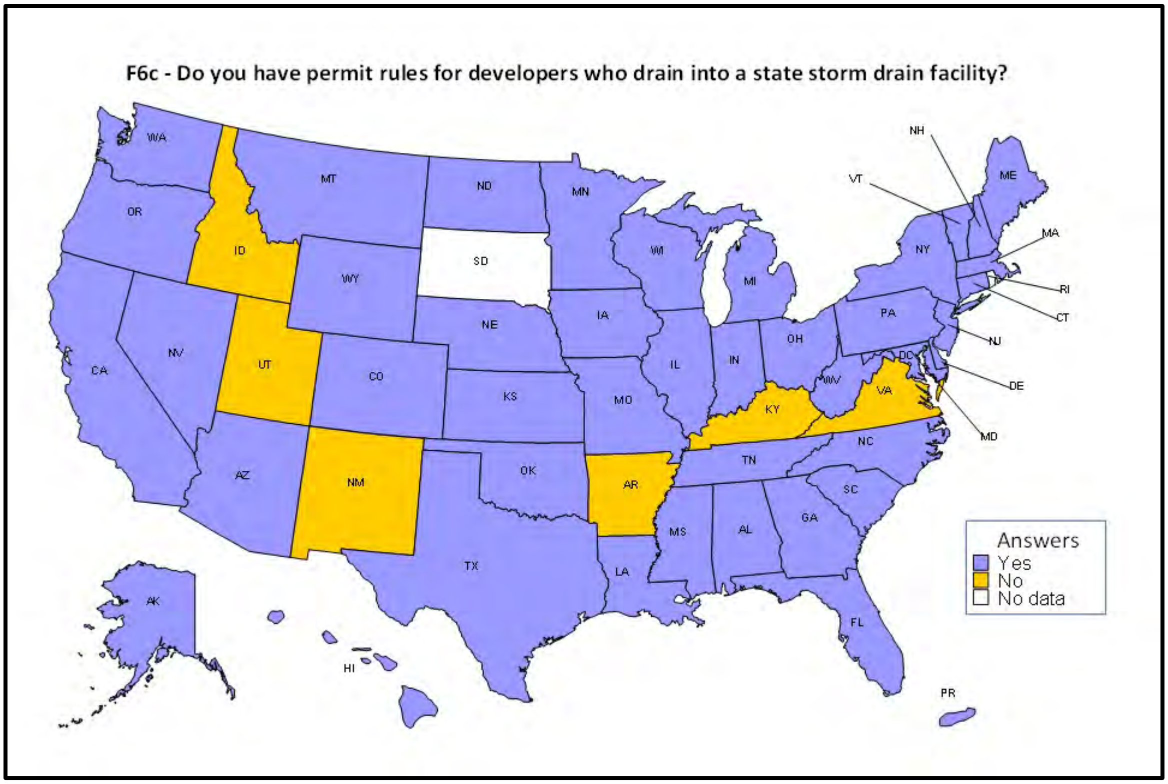


Figure 6.6.2 State responses to whether each has permit rules for developers.

<u>Question F.6.c</u> (Part 2)

What discharge restrictions do you place on developers?
$Q_{post\text{-}project} <= Q_{pre\text{-}project}$
(check all that apply)

2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Other
☐	☐	☐	☐	☐	☐	☐

Q/acre

Yes	No
○	○

Other

Response:

Twenty-two (22) states and Puerto Rico responded that their rules impose restrictions on more than one frequency. The number of states that impose restrictions on the frequencies specified are shown in Table 6.6.2. The response of individual states can be seen in Table 6.6.3.

Table 6.6.2 Discharge Restrictions Placed on Developers (multiple answers allowed)

Discharge Restrictions Placed on Developers	*Number States*
2 year	16
5 year	12
10 year	28
25 year	16
50 year	18
100 year	17
Other	11

Figure 6.6.3 shows that only three (3) states impose a discharge restriction based on discharge per acre but that twelve (12) states did not reply to this question.

Other Discharge Restrictions Placed on Developers:

- Arizona - We have no set frequency stipulation for post vs. predevelopment flow, instead we enforce the local policy in the area. ADOT has an Access Management policy in development, which will address this issue.
- Arkansas - Depends on Capacity of Highway System. We often review off ROW developments that connect to our storm drain system, but do not restrict runoff from these developments unless highway storm drain system is not capable of conveying additional runoff.
- California - Developer must conform to same requirements applicable to DOT project. Must consider inclusion of permanent BMP's, but under current guidelines that may or may not lead to project specific inclusion.
- Colorado - Post development release rate should be at predevelopment historic flow rate.
- Connecticut - May accept increase in discharge if state drainage system is adequate for additional flow and no downstream impacts are anticipated.
- Delaware – Water Quality. http://deldot.gov/information/business/drc/pd_files/plan_development/e-and-s_checklist_may-2009.pdf
- Georgia - If the predeveloped site does not discharge any stormwater onto the highway system, 1 cfs runoff onto the highway system R/W is allowed for the postdeveloped condition.

- Hawaii - The post-development water quantity and quality drainage conditions shall be equal to or less than the pre-development conditions.
- Illinois - The Appendix of the Drainage Manual details rules & regs for developers. These focus on offset\proximity from the ROW line and relative depths of Q100 detention / retention with respect to IDOT property.
- Maryland - Governed by regulatory requirements.
- Montana - Developers are required to limit flows to the historic levels at the 2 year event. The developers are also required to evaluate the 100 year event for risk of flooding to the highway or downstream properties.
- Nevada - No adverse effects to NDOT facilities.
- North Carolina - Risk assessment to highway facility.
- North Dakota - Evaluated on a case by case basis.
- Pennsylvania - If it can reasonably be anticipated that there will be an increase in the flow of water onto the highway or into highway drainage facilities as a result of action by the applicant, or that there will be an increase in the flow of water onto the property of some other person as a result of any action authorized by the permit, a drainage control plan shall be submitted with the application. If it can reasonably be anticipated that there will be an increase in the flow of water onto the property of some other person as a result of action, authorized by the permit, a drainage release shall be submitted with the application. If a drainage release cannot be obtained from any affected property owner, the Department may nonetheless issue a permit if it determines that there is no reasonable and prudent alternative available to the applicant and the applicant executes an indemnification agreement acceptable to the Department. Unless specifically authorized by the permit, the permittee shall not: (i) alter the existing drainage pattern or the existing flow of drainage water; or (ii) direct additional drainage of surface water onto or into the highway right-of-way or highway facilities in a way which would have a detrimental effect on the highway or highway facilities.
- Tennessee - Developed drainage no greater than undeveloped condition.
- Utah - Not to exceed predeveloped flows.
- Virginia – None.
- Wisconsin – The owner of land that directly or indirectly discharges stormwater upon a state trunk highway or connecting highway shall submit to the department a drainage analysis and a drainage plan that assures to a reasonable degree, appropriate to the circumstances, that the anticipated discharge of stormwater upon a state trunk highway or connecting highway following the development of the land is less than or equal to the discharge preceding the development and that the anticipate discharge will not endanger or harm the travelling public, downstream properties, or transportation facilities.

Table 6.6.3 State responses regarding discharge restrictions placed on developers.

F6c (Part 2) - What discharge restrictions do you place on developers?							
State	2 year	5 year	10 year	25 year	50 year	100 year	Other
AL	X						
AK							X
AZ							X
AR							X
CA							
CO	X	X	X	X	X	X	
CT	X	X	X	X	X	X	
DE	X		X			X	X
FL		X	X	X	X	X	
GA	X	X	X	X	X	X	
HI			X				
ID							
IL			X			X	
IN			X		X		
IA			X				
KS				X	X	X	
KY			X				
LA			X				
ME			X		X		
MD							X
MA	X		X			X	
MI			X				
MN						X	
MS	X				X		
MO							X
MT	X		X			X	
NE				X	X		
NV		X	X	X			
NH			X	X			
NJ	X		X			X	
NM	X						
NY			X			X	
NC							X
ND							X
OH			X				
OK	X	X	X	X	X	X	
OR	X	X	X	X	X		
PA							
PR			X	X	X		
RI							
SC	X	X	X	X	X	X	
SD							
TN					X		
TX	X	X	X	X	X	X	
UT							X
VT	X	X	X	X	X	X	
VA							X
WA	X	X	X	X	X		
WV			X	X	X		
WI							X
WY		X				X	

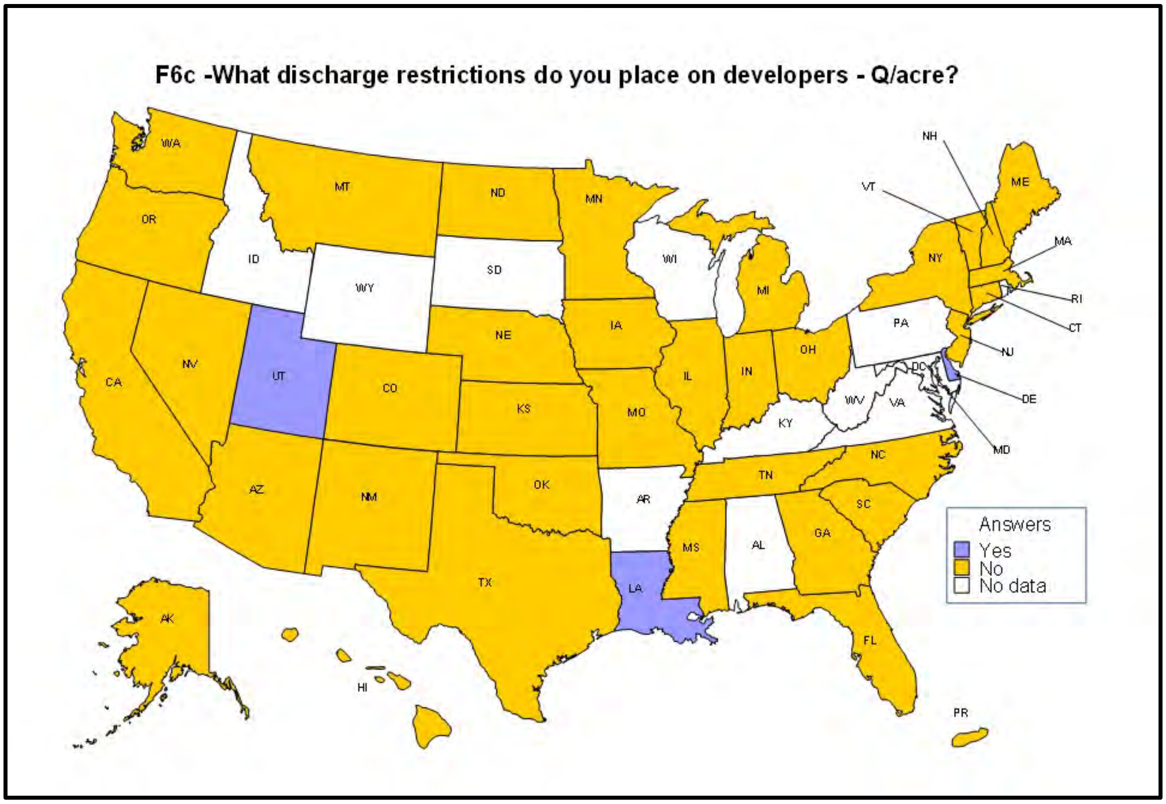


Figure 6.6.3 States that use a discharge restriction on developers based on a ratio of discharge per acre.

Question F.6.c (Part 3)

Who reviews developer permit applications and drainage documents?

Bridge Hydraulics Section	Roadway Section	Design Section	Maintenance Section	Utilities Section	Other
☐	☐	☐	☐	☐	☐

Response:

Table 6.6.4 shows that the office responsible for reviewing developer's drainage permits is pretty evenly divided among the states. Table 6.6.5 shows the individual breakdown by state.

Table 6.6.4 Section responsible for reviewing permit applications and drainage documents (multiple answers allowed)

Section Responsible for Reviewing Permit Applications and Drainage Documents	*Number States*
Bridge Hydraulics Section	19
Roadway Section	18
Design Section	13
Maintenance Section	12
Utilities Section	12
Other	17

Others Responsible for Reviewing Permit Applications and Drainage Documents:

- Alaska - Regional Hydraulics Engineer consulted by utilities section.
- Arizona - Roadway Drainage,
- Delaware – Team Support.
- Kansas – District Offices.
- Kentucky – Drainage Branch.
- Louisiana – District Offices.
- Maine – Environmental Office.
- Maryland – Access Permits Division.
- Michigan – TSC.
- Minnesota - District Hydraulics.
- Montana – Traffic.
- New Mexico - The developer permit applications/subdivision review is done by Drainage Design Bureau. We don't have Bridge Hydraulic Section.
- New York – The Regional Permit Engineer will forward the permit application to the appropriate group for review. This case would include the Regional Hydraulic Engineer or design group, or Main Office Hydraulics or Design.
- North Carolina – Hydraulics Unit.
- South Carolina - When requested, the Hydraulic Design Support Office.
- Texas – District Design.
- Wisconsin – Access Management.

Table 6.6.5 A national depiction of which office within a DOT reviews permit applications for development of adjacent properties.

	F6c (Part 4) - Who reviews developer permit applications and drainage documents?					
State	Bridge Hydraulics Section	Roadway Section	Design Section	Maintenance Section	Utilities Section	Other
AL				■		
AK					■	■
AZ		■		■		■
AR		■				
CA					■	
CO		■			■	
CT	■	■	■	■	■	
DE			■			■
FL	■			■		
GA		■	■			
HI	■					
ID		■				
IL	■			■		
IN	■					
IA	■					
KS		■				■
KY						■
LA		■	■	■	■	■
ME				■		■
MD	■	■				■
MA	■			■		
MI	■					■
MN					■	■
MS		■				
MO			■			
MT	■				■	■
NE	■	■	■			
NV	■	■	■	■	■	
NH			■		■	
NJ	■					
NM						■
NY						■
NC						■
ND	■					
OH		■				
OK		■				
OR			■			
PA		■	■			
PR	■	■	■			
RI		■				
SC						■
SD						
TN	■	■				
TX						■
UT					■	
VT	■					
VA			■			
WA			■	■	■	
WV	■			■	■	
WI						■
WY	■			■		

Question F.6.c (Part 4)

Does the State experience frequent highway flooding problems caused by discharge from private property onto highway right-of-way?

Yes	No
○	○

Additional Comments:

Response:

Only fifteen (15) states reported that they experience frequent highway flooding problems caused by stormwater runoff from private property. Figure 6.6.4 provides a breakdown of the individual state responses.

Specific State Comments to Clarify Responses:

- Colorado - Flooding and sediment from upstream properties are problems in areas where the roadway are at lower elevation than the adjacent properties.
- Pennsylvania - Yes, but it is a minor problem considered a nuisance.
- Wisconsin - WisDOT has a few isolated cases where this problem exist.

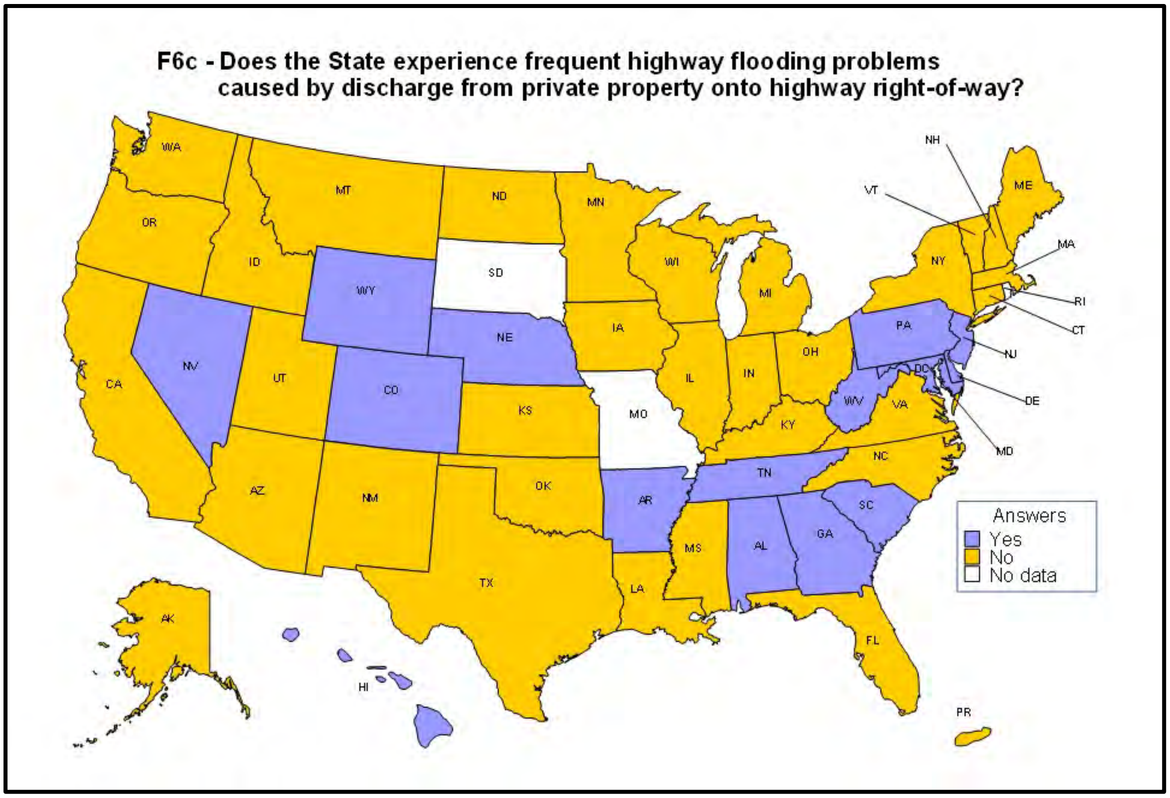


Figure 6.6.4 Identification of states that experience frequent highway flooding problems caused by stormwater discharges from private property.

7.0 Culverts

This chapter contains four sections on culverts that include hydraulic design criteria, outlet conditions, maintenance, and innovative culvert features.

7.1 Hydraulic Design Criteria

This first section of the culvert chapter addresses the hydraulic design criteria used by states for new culvert design. There is only one question in this section and it includes a large range of possible design criteria. A distinction is made between culverts less than or equal to a 48-inch diameter and those larger than a 48-inch diameter.

Question G.1

G. Culverts
   1. Hydraulic Design Criteria
      (check all that apply)

		Culverts > 48 inches	Culverts <= 48 inches
Headwater-to-Culvert-Rise Ratio		☐	☐
Impacts to Upstream Property		☐	☐
Impacts to Downstream Property		☐	☐
Buried Invert		☐	☐
Maximum Slope		☐	☐
Tailwater		☐	☐
Low Points in Roadway Profile		☐	☐
Outlet Velocity		☐	☐
Environmental Considerations		☐	☐
Stream Migration		☐	☐
Stream Channel Vertical Instability		☐	☐
Other		☐	☐

Response:

Figure 7.1.1 provides a bar chart displaying the number of states that use the culvert design criteria listed in question G.1.

Other Hydraulic Design Criteria:

- Alaska - Fish Passage. Hydraulic Design of Culverts - not in manual but do consider in design impacts downstream and maximum slope.
- California - Fish Passage.
- Colorado - Erosion at downstream of culverts.

- Illinois - Non-hydraulic issues are not greatly affecting culvert hydraulic design. Not yet. Vast majority of culvert designs involve subcritical flow and outlet control. Key criteria is backwater.
- Indiana – Backwater.
- Maine – Fish Passage.
- Maryland – Natural Flow Distribution.
- Minnesota – Fish Passage.
- Montana – Level of Service Evaluation.
- Pennsylvania - Our BD-632M references depressed and baffled culvert requirements.
- Puerto Rico – Freeboard.

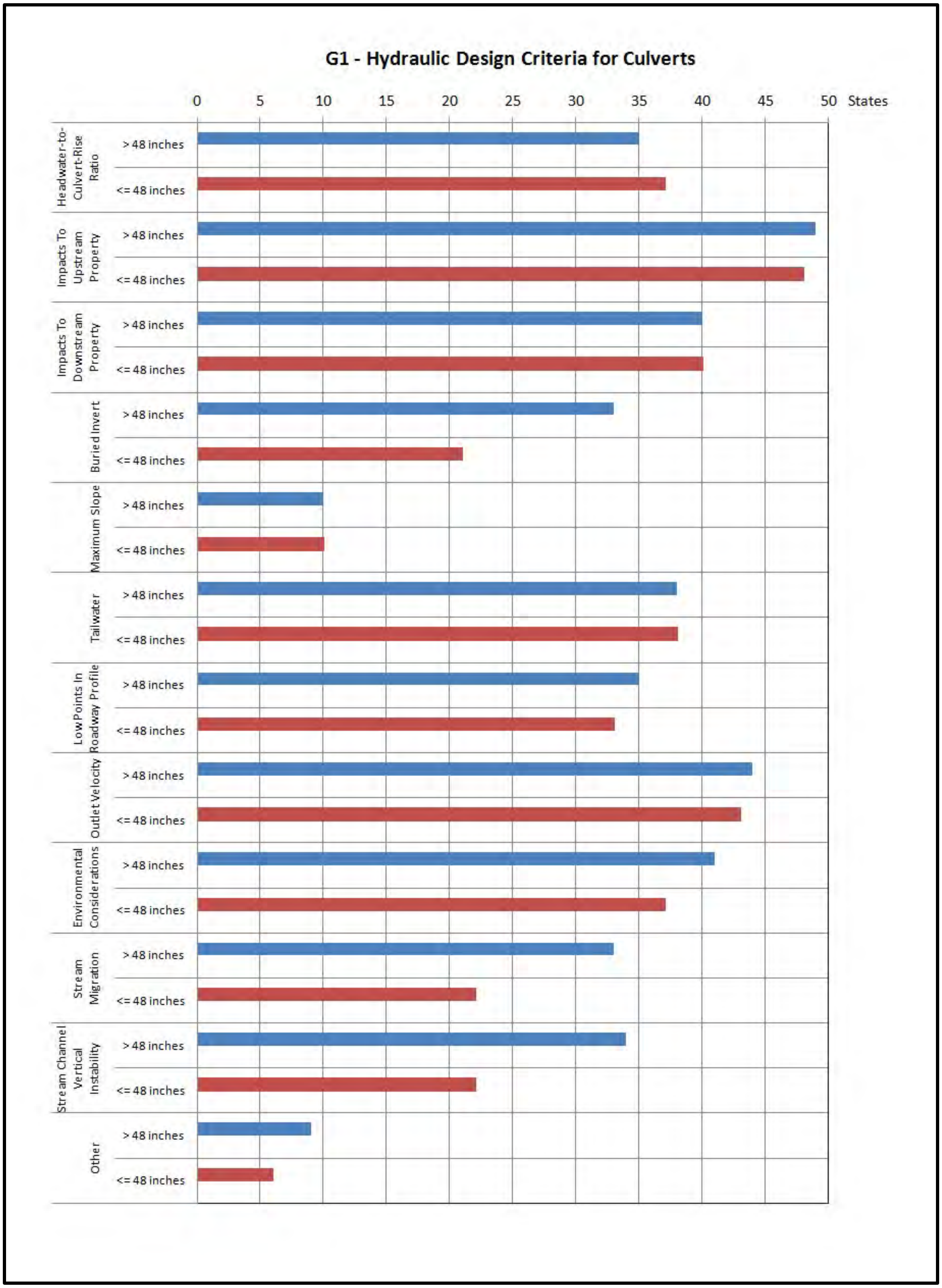


Figure 7.1.1 Number of states using each of the design criteria listed.

Table 7.1.1 Individual state hydraulic design criteria for culverts.

G1 – Hydraulic Design Criteria for Culverts

State	Headwater-to-Culvert-Rise Ratio		Impacts To Upstream Property		Impacts To Downstream Property		Buried Invert		Maximum Slope		Tailwater		Low Points In Roadway Profile		Outlet Velocity		Environmental Considerations		Stream Migration		Stream Channel Vertical Instability		Other	
	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches	> 48 inches	<= 48 inches
AL			■	■	■	■	■				■	■			■	■	■				■			
AK	■	■	■	■			■				■	■			■	■	■	■	■	■	■		■	
AZ	■	■	■	■	■	■							■		■	■	■	■	■	■	■	■		
AR	■	■	■	■							■	■	■	■	■	■	■		■		■			
CA	■	■	■	■	■	■		■			■	■			■	■	■	■			■	■	■	■
CO	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
CT	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■		■	■		
DE			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
FL			■	■	■	■									■	■								
GA	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
HI	■	■	■	■	■	■							■	■	■	■	■	■						
ID	■	■	■	■	■	■					■	■			■	■	■	■	■	■	■	■		
IL			■	■	■	■	■	■			■	■	■	■	■	■			■	■	■	■		
IN			■	■			■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■
IA	■	■	■	■							■		■		■				■					
KS	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■		■			
KY			■	■											■	■								
LA			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
ME	■	■					■						■	■			■	■					■	■
MD		■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■		■	
MA	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■	■	■		
MI			■	■			■	■			■	■	■	■	■	■	■	■	■	■	■	■		
MN			■	■	■	■	■				■	■	■	■	■	■	■		■		■		■	
MS	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■				
MO	■	■	■	■	■	■									■	■					■			
MT	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
NE	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■						
NV	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■		
NH	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■						
NJ	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
NM	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■		■		■	■
NY	■	■	■	■	■	■	■	■									■	■						
NC	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■		■			
ND	■	■	■	■			■				■	■	■	■	■	■			■					
OH	■	■	■	■	■	■					■	■			■	■								
OK	■	■	■	■	■	■							■	■	■	■	■	■						
OR	■	■	■	■	■	■	■	■	■	■	■	■			■	■					■	■		
PA	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■	■				
PR	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
RI																								
SC	■	■	■	■	■	■			■	■	■	■			■	■	■	■	■	■	■	■		
SD			■		■		■										■		■		■			
TN			■	■	■	■	■				■	■	■	■	■	■					■	■		
TX			■	■											■	■	■	■	■	■				
UT	■	■	■	■	■	■					■	■	■	■			■	■	■					
VT	■	■	■	■	■	■											■	■						
VA	■	■	■	■	■	■	■	■			■	■	■	■	■	■	■	■	■		■	■		
WA	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■	■			
WV	■	■	■	■	■	■	■				■	■	■	■	■	■	■	■	■	■	■			
WI		■	■	■		■	■					■			■	■	■	■			■	■		
WY			■	■	■	■					■	■	■	■			■	■			■	■		

7.2 Design Limitations

The questions in this section address the design limitations used by states for establishing erosion protection for culvert outlets and the types of armoring or energy dissipation used.

Question G.2.a

2. Outlet Conditions
   a. Criteria/Design Limitations
      (check all that apply)

☐	Compare to Natural Stream Velocity		
☐	Permissible Velocity		
☐	Permissible Shear Stress		
☐	Other		

Response:

Table 7.2.1 provides a comparison of the number of states that have established criteria based on a comparison of the culvert outlet velocity to the natural stream velocity, a permissible velocity, or the permissible shear stress. A national perspective showing the response of individual states is shown in Table 7.2.2.

Table 7.2.1 Number of states using velocity limitation criteria at culvert outlets (multiple answers allowed)

Culvert Outlet Conditions Criteria/Design Limitations	*Number States*
Compare to Natural Stream Velocity	37
Permissible Velocity	37
Permissible Shear Stress	23
Other	5

Other Culvert Outlet Conditions Criteria/Design Limitations:

- Alaska - Tier I Culvert Criteria calls for dynamically stable substrate up to Q50 . Shear stress is used as the basis but velocity criteria could be used too.
- Illinois - Existing culvert performance.
- Maryland - Stable Channel Geometry.
- Michigan - Compare to existing velocity.
- Wyoming - Scour depth analysis and existing conditions.

Table 7.2.2 Culvert outlet velocity criteria used by respective states.

G2a Culvert Outlet Conditions – Criteria/Design Limitations				
State	Compare to Natural Stream Velocity	Permissible Velocity	Permissible Shear Stress	Other
AL	■	■		
AK	■	■	■	■
AZ	■	■	■	
AR	■			
CA		■		
CO	■	■		
CT	■	■	■	
DE	■	■	■	
FL			■	
GA	■	■	■	
HI	■	■		
ID		■		
IL	■			■
IN	■	■		
IA		■		
KS	■	■		
KY	■	■		
LA	■	■	■	
ME				
MD	■	■	■	■
MA	■	■	■	
MI				■
MN	■	■		
MS	■	■	■	
MO	■	■		
MT	■	■	■	
NE	■	■		
NV	■	■	■	
NH	■	■		
NJ	■	■	■	
NM	■	■		
NY				
NC	■		■	
ND	■	■	■	
OH		■	■	
OK	■	■		
OR		■	■	
PA	■			
PR	■	■	■	
RI				
SC	■		■	
SD				
TN		■		
TX	■	■	■	
UT	■			
VT	■			
VA	■	■		
WA		■	■	
WV	■	■	■	
WI		■	■	
WY	■			■

Question G.2.b

b. Do you use energy dissipators?

Routinely	Occasionally	Rarely	Never
○	○	○	○

Which do you use?

	Routinely	Occasionally	Rarely	Never
Riprap Basin	○	○	○	○
Increased Pipe Resistance	○	○	○	○
Rigid Boundary Basin	○	○	○	○
Impact Basin	○	○	○	○
Drop Structure	○	○	○	○
Stilling Well	○	○	○	○
Multi-cell Culvert Dissipator	○	○	○	○
Other	○	○	○	○

Response:

Figure 7.2.1 provides a bar chart that shows the number of states using each of the dissipator types listed in question G.2.b. The frequency of use of energy dissipators by each state and Puerto Rico is shown in Table 7.2.3.

Other Dissipators Used:

- Alabama – SAF, Contra Costa.
- Illinois - Energy dissipaters are rarely used and outlet protection is atypical.
- Montana - Riprap aprons are also used routinely.
- Ohio - Tied concrete block mat.

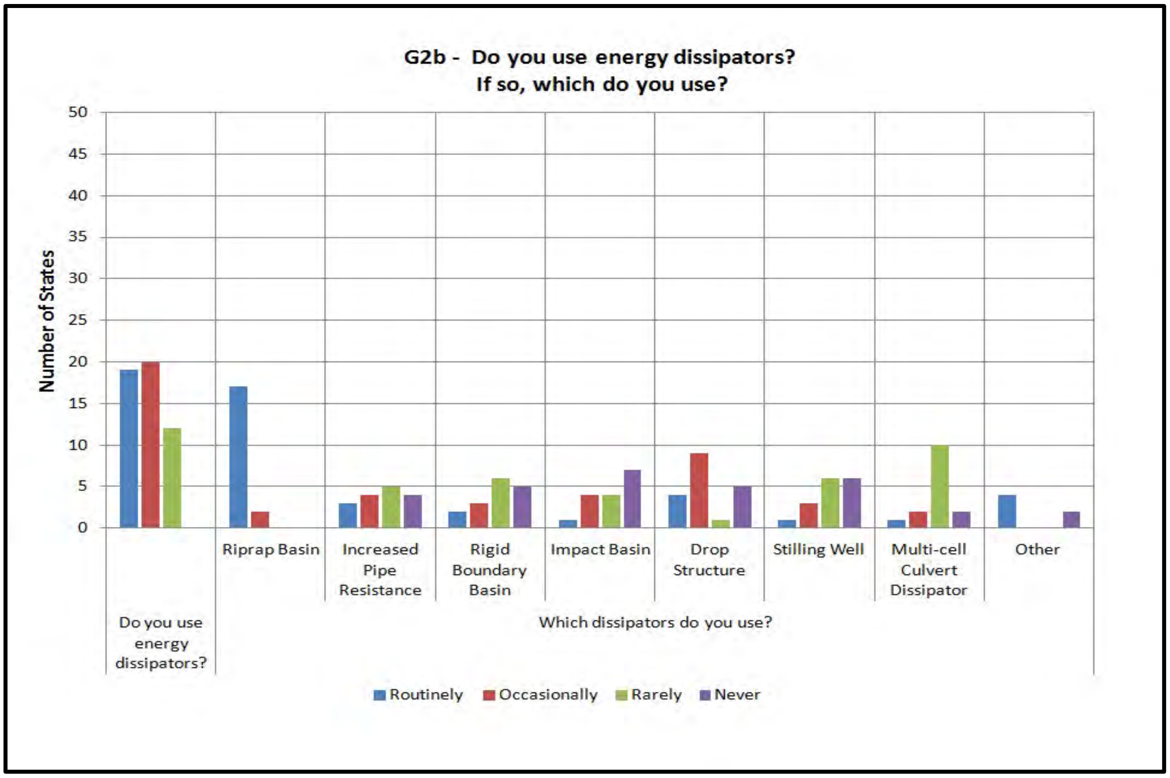


Figure 7.2.1 Number of states using the various types of energy dissipators listed.

Table 7.2.3 Individual state responses regarding use of energy dissipators.

G2b – Energy Dissipators

Which energy dissipators do you use?

State	Do you use energy dissipators?				Riprap Basin				Increased Pipe Resistance				Rigid Boundary Basin				Impact Basin				Droop Structure				Stilling Well				Multi-Cell Culvert Dissipator				Other			
	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL	■				■						■				■			■						■			■										■
AK	■				■				■						■				■					■				■			■					
AZ	■				■							■				■		■				■								■						
AR		■																																		
CA		■																																		
CO		■																																		
CT	■				■				■						■				■			■					■				■					
DE	■				■									■						■				■	■							■				
FL		■																																		
GA	■				■																■					■							■			
HI	■				■						■					■				■		■					■				■					
ID		■																																		
IL			■																																	
IN		■																																		
IA		■																																		
KS		■																																		
KY	■				■																	■														
LA			■																																	
ME			■																																	
MD		■																																		
MA		■																																		
MI			■																																	
MN			■																																	
MS		■																																		
MO	■					■				■					■					■				■			■				■					
MT	■					■				■				■						■		■				■					■		■			
NE	■				■				■					■				■			■						■				■					
NV	■				■							■	■				■				■					■			■							
NH			■																																	
NJ	■				■						■				■			■				■						■				■				■
NM	■				■					■						■				■	■							■			■		■			
NY			■																																	
NC		■																																		
ND		■																																		
OH	■				■					■												■											■			
OK		■																																		
OR	■				■							■				■			■			■						■			■					
PA		■																																		
PR	■				■							■				■				■				■				■		■						
RI			■																																	
SC	■				■						■		■							■			■					■			■					
SD		■																																		
TN			■																																	
TX		■																																		
UT		■																																		
VT			■																																	
VA	■				■						■				■				■			■					■				■					
WA			■																																	
WV		■																																		
WI		■																																		
WY			■																																	

7.3 Maintenance

This section asks states about their agencies' management of culvert inventories and their use of culvert liners and trenchless technology.

Question G.3.a

3. Maintenance
   a. Do you have procedures in place to manage your inventory of culverts smaller than 20-foot wide?

Yes	No
○	○

Do these procedures include:
(check all that apply)

☐	Inspection Program
☐	Inventory Database
☐	Software-based Asset Management System

Response:

Table 7.3.1 indicates that only 26 respondents said their agency has procedures for managing their culvert inventory and it also shows the number of states who use either an inspection program, an inventory data base, and/or a software-based asset management system. Table 7.3.2 is a national map that identifies which states have procedures for culvert management and what type of procedures are used.

Table 7.3.1 Number of states indicating the use of specific procedures for the management of small culverts (multiple answers allowed)

Management of Culverts Smaller than 20-feet Wide	*Number States*
Do you have procedures in place to manage your inventory of culverts smaller than 20-feet wide?	26
Procedures include:	
Inspection Program	22
Inventory Database	24
Software-based Asset Management System	10

Specific State Comments to Clarify Responses:

- Alaska - Begun inventorying culverts with span greater than 10 feet as minor structures on NBI. Small culverts may be inventoried at the regional level (design and/or maintenance sections). We have a maintenance management system for roadside appurtenances but intermittent on larger culverts.
- Montana - Additional clarification regarding culvert inventories. District maintenance personnel keep various informal lists and spreadsheets of culverts in their district. Culverts larger than 8 foot in diameter are kept in an inventory data base.
- Pennsylvania - Yes, BMS2 contains data for all culverts with 8 feet or greater spans

Table 7.3.2 Identification of states that have management systems for culverts smaller than 20 feet and the types of systems used.

G3a - Culvert Maintenance				
State	Do you have procedures in place to manage your inventory of culverts smaller than 20-foot wide?	Do these procedures include: Inspection Program	Inventory Database	Software-based Asset Management System
AL				
AK	■	■	■	■
AZ				
AR				
CA	■	■	■	
CO	■	■	■	
CT	■	■	■	■
DE				
FL				
GA	■	■	■	
HI	■	■	■	■
ID				
IL	■	■	■	
IN	■	■	■	
IA				
KS	■	■	■	■
KY				
LA				
ME	■	■		■
MD	■	■	■	
MA	■	■	■	
MI				
MN	■	■	■	■
MS				
MO				
MT	■	■	■	
NE				
NV				
NH				
NJ	■	■	■	
NM				
NY	■	■	■	■
NC				
ND				
OH	■	■	■	
OK				
OR	■	■	■	
PA	■	■	■	■
PR				
RI				
SC	■		■	
SD				
TN	■	■	■	
TX				
UT	■	■	■	
VT	■	■	■	■
VA	■			■
WA	■		■	
WV	■		■	
WI				
WY				

Question G.3.b

b. Do you use culvert liners for repairs?

Routinely	Occasionally	Rarely	Never
○	○	○	○

Response:

The responses show that twelve (12) states routinely use culvert liners, twenty-seven (27) states occasionally use liners and eleven (11) states and Puerto Rico rarely use culvert liners. Figure 7.3.4 provides a national perspective on the use of culvert liners by the states and Puerto Rico.

Specific State Comments to Clarify Responses:

- Pennsylvania – Occasionally, D9 uses culvert liners a lot and a few of the other districts including 89 and 10 are using them.

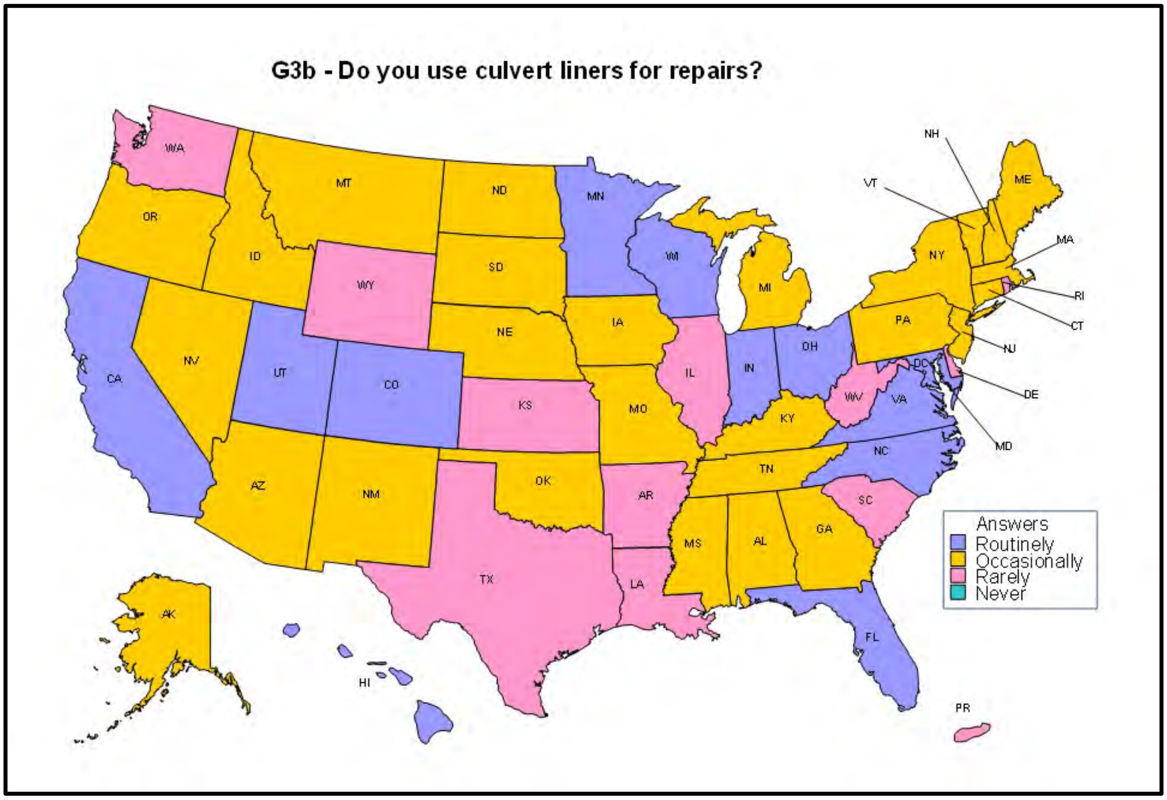


Figure 7.3.1 Identification of states that use culvert liners and the frequency of use.

Question G.3.c

c. Do you use trenchless culvert replacement techniques? (e.g. pipe bursting, pipe jacking, etc.)

Routinely	Occasionally	Rarely	Never
○	○	○	○

Response:

The responses shows that only 7 states use trenchless technology on a routine bases, nineteen (19) states use trenchless technology occasionally, twenty-three (23) states and Puerto Rico rarely use trenchless technology, and one state never uses it. The use by specific states is shown in Figure 7.3.2. When compared with the responses from question G.3.b. it can be observed that most routine trenchless users also routinely use culvert liners while most routine users of culvert liners use trenchless technology at least occasionally.

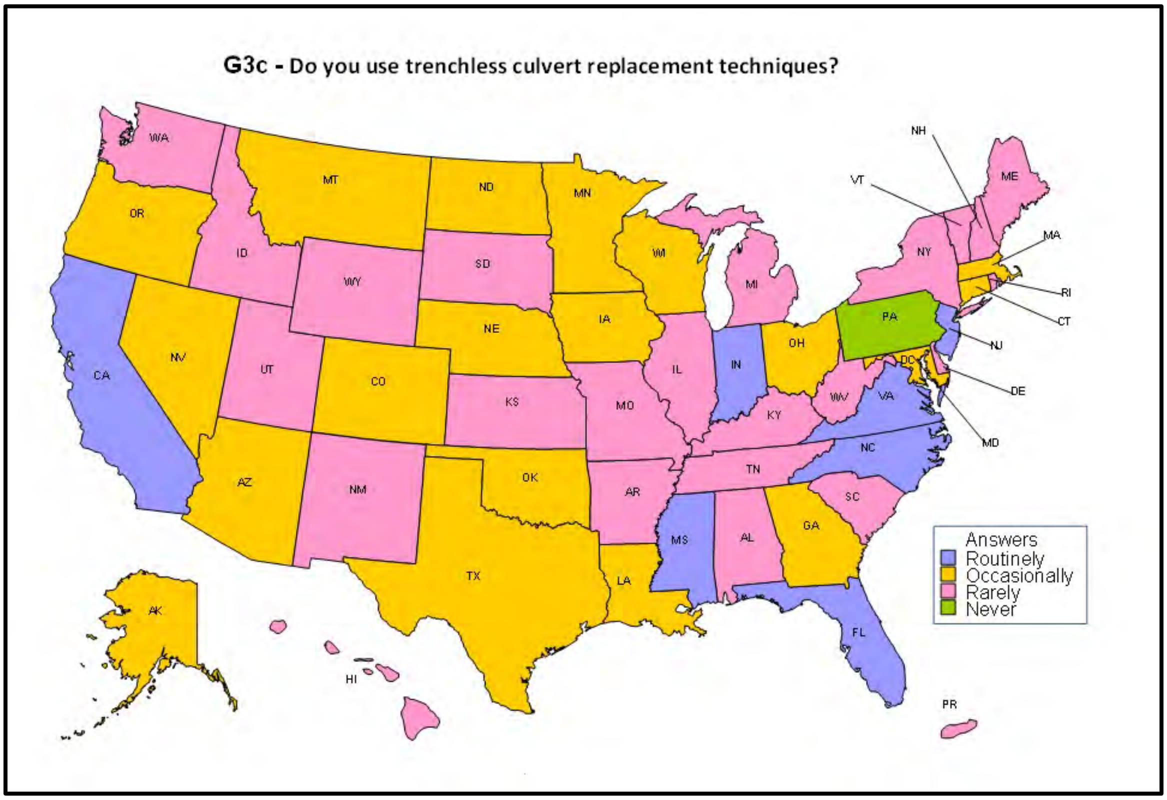


Figure 7.3.6 States that use trenchless technology and the frequency of use.

7.4 Innovative Culvert Features

This question provides a list of six innovative culvert features and asks states to indicate which features they use routinely, occasionally, rarely, or never. A follow-up question asks if the states account for energy losses when using either safety grates or debris control structures affixed to culverts.

<u>Question G.4.a</u>

4. Innovative Culvert Features
   a. Which innovative culvert features do you use?
      (check all that apply)

	Routinely	Occasionally	Rarely	Never
Improved Inlets (side and slope tapered)	○	○	○	○
Broken-back Culverts	○	○	○	○
Embedded Culverts	○	○	○	○
3-sided Culverts	○	○	○	○
Debris Control Measures	○	○	○	○
Safety End Treatments	○	○	○	○

When using safety grates or debris racks affixed to culverts, do you account for energy losses?

Yes	No
○	○

Response:

Figure 7.4.1 provides a bar chart comparison of the number of states using each of the culvert features identified. The responses also shows that sixteen (16) states account for energy losses when using safety grates and debris racks affixed to culverts, twenty-eight (28) states do not with the remaining seven (7) states not replying to this question. The responses of individual states and Puerto Rico are shown in Table 7.4.2 indicating which states use the respective features.

Specific State Comments to Clarify Response:

- Alaska - Safety end treatments - good practice but do not have inlet coefficients.

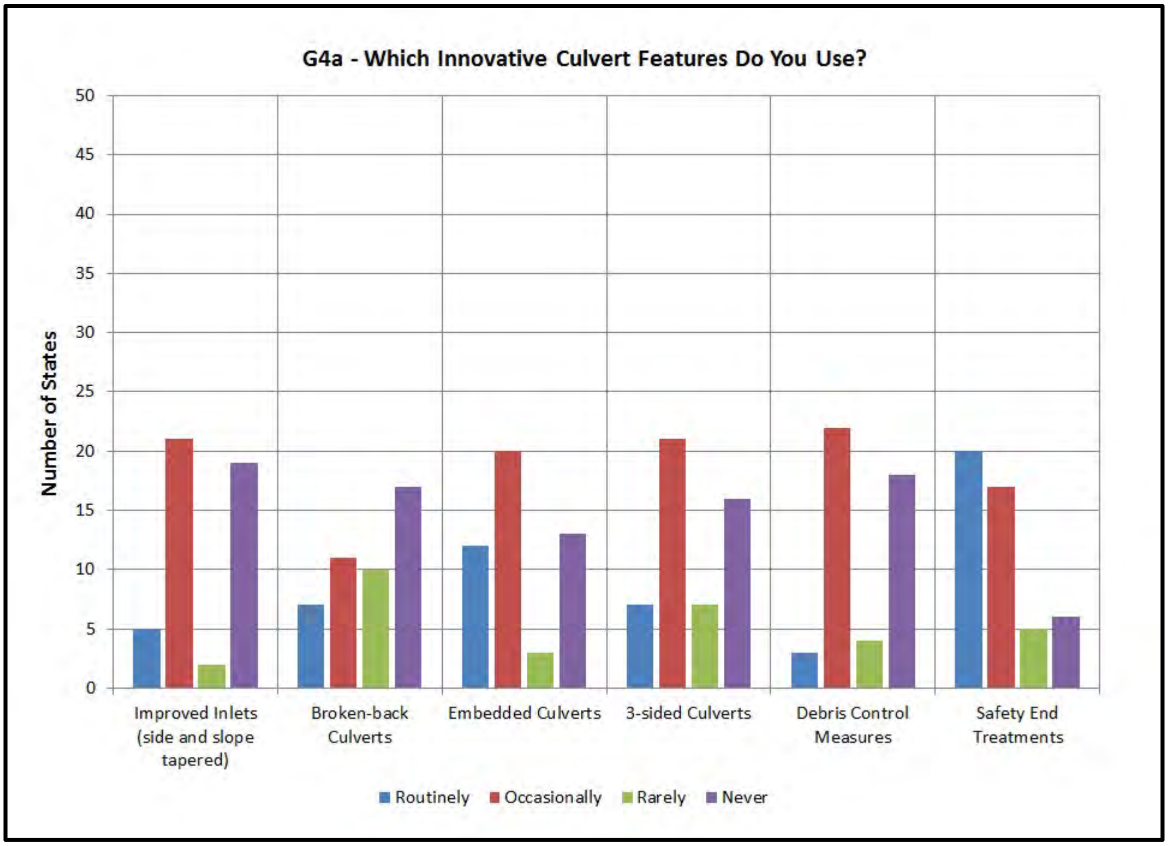


Figure 7.4.1 Number of states using the culvert features specified in question G.4.a.

Table 7.4.2 Innovative culvert features used by each state and Puerto Rico.

G4a – Innovative Culvert Features																														
	Improved Inlets (side and slope tapered)				Broken-back Culverts				Embedded Culverts				3-sided Culverts				Debris Control Measures				Safety End Treatments				Account for energy loss due to safety grate or debris racks	
State	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never	Yes	No
AL				■			■			■						■			■		■					■
AK		■						■	■							■		■				■				■
AZ		■			■							■			■					■	■					■
AR				■				■				■			■					■				■		■
CA				■				■				■				■		■						■		■
CO		■						■	■					■				■			■				■	
CT		■							■					■						■				■	■	
DE		■								■				■				■				■			■	
FL	■						■					■				■				■	■					■
GA	■					■				■				■			■				■					■
HI				■			■					■			■			■						■		■
ID				■				■				■				■		■			■				■	
IL				■				■		■				■						■		■				■
IN				■			■		■				■						■		■					■
IA	■				■					■						■				■				■		■
KS				■		■				■				■						■		■			■	
KY														■						■	■					■
LA				■				■				■				■		■				■			■	
ME														■												■
MD		■						■	■					■					■				■			
MA				■			■			■				■				■				■			■	
MI									■				■													■
MN				■				■		■				■						■	■					■
MS		■				■						■			■			■				■				■
MO		■						■			■					■						■				
MT		■				■				■						■		■				■			■	
NE		■			■				■							■				■		■				■
NV		■				■					■					■		■			■				■	
NH		■					■		■					■				■			■					■
NJ				■			■			■			■				■				■				■	
NM		■			■					■				■				■			■					■
NY			■				■		■				■					■				■			■	
NC	■					■				■				■				■			■					■
ND						■				■					■					■		■				■
OH				■	■							■	■							■			■			
OK			■			■					■				■			■			■					■
OR		■						■		■				■				■				■			■	
PA	■						■		■					■						■			■			
PR				■				■				■				■				■			■			
RI		■												■												
SC		■						■	■				■							■	■				■	
SD		■			■					■						■		■				■				■
TN		■				■				■				■			■				■					■
TX				■	■							■				■		■			■					■
UT		■				■				■						■				■		■			■	
VT		■					■		■					■					■				■			
VA		■				■				■				■						■		■				■
WA				■				■		■			■					■			■				■	
WV				■				■				■		■				■			■					■
WI				■				■		■						■		■				■				■
WY				■				■				■			■					■				■	■	

Question G.4.b

b. Which foundation types are used with 3-sided culverts?
(check all that apply)

Footings on Soil No Riprap	Footings on Soil with Riprap	Piles in Soil Not on Rock	Footings or Piles on Rock	Other ☐
☐	☐	☐	☐	☐

Additional Comments:

Response:

Table 7.4.3 provides information on the number of states using the various foundation types for 3-sided culverts. Table 7.4.4 shows the use by individual states of the foundation types.

Table 7.4.3 Number of states using each of the foundation types

Which foundation types are used with 3-sided culverts?	*Number States*
Footings on Soil No Riprap	10
Footings on Soil with Riprap	23
Piles in Soil Not on Rock	20
Footings or Piles on Rock	33
Other	10

Specific State Comments to Clarify Responses:

- Alaska – Four sided culverts. 3 sided culverts - not use with footings on soil with or without riprap. Environmentals desire such design.
- Arizona – Do not use three-sided culverts.
- Colorado - The footing shall be lower that the calculated scour depth.
- Hawaii – Never used.
- Illinois - 3-sided culverts are rarely used when pile-supported foundation is required.
- New York – Invert Slab.
- North Carolina – Three-sided culverts founded on scour resistant rock less than 5' below surface.
- Oklahoma – Not Applicable.
- South Dakota - Three sided culverts are more like short vertical abutment bridges.
- Utah – It depends on the calculated scour depth.
- Wyoming – Not allowed.

Table 7.4.4 States using 3-sided culverts with foundation types used identified.

G4b – 3-Sided Culvert Use and Foundation Type									
State	3-Sided Culverts Use				Foundation Types Used with 3-Sided Culverts				
	Routinely	Occasionally	Rarely	Never	Footings On Soil No Riprap	Footings On Soil With Riprap	Piles in Soil Not On Rock	Footings Or Piles On Rock	Other
AL				X				X	
AK				X			X	X	X
AZ			X						X
AR			X					X	
CA				X		X	X	X	
CO		X				X	X		X
CT		X				X	X	X	
DE		X			X	X		X	
FL				X		X	X		
GA		X					X	X	
HI			X						X
ID				X					
IL		X			X	X	X	X	
IN	X					X	X	X	
IA				X			X		
KS		X						X	
KY		X							
LA				X					
ME		X						X	
MD		X			X	X		X	
MA		X				X		X	
MI	X				X	X	X	X	
MN		X			X	X	X	X	
MS			X						
MO				X				X	X
MT				X	X	X	X	X	
NE				X					
NV				X		X		X	
NH		X				X		X	
NJ	X					X	X	X	
NM		X			X		X	X	
NY	X						X	X	X
NC		X							X
ND			X						
OH	X					X	X	X	
OK			X						X
OR		X				X		X	
PA		X				X		X	
PR				X	X	X	X	X	
RI		X							
SC	X				X			X	
SD				X			X	X	
TN		X						X	
TX				X	X	X		X	
UT				X					X
VT		X				X			
VA		X				X	X	X	
WA	X					X			
WV		X						X	
WI				X			X	X	
WY			X						X

8.0 Bridges

This chapter presents the national state of practice findings for issues directly related to bridges. There are five sections that include Bridge Design Criteria, Plans of Action, Countermeasures, and Documentation.

8.1 Design Criteria

The bridge design criteria are broken up into eight questions related to bridge sizing criteria, analysis methodologies, and the stream environment.

Question H.1.a

H. Bridges
   1. Design Criteria
      a. What is your freeboard criteria?

	No Criteria	1 foot	2 foot	Site Dependent	Other	
Interstate	☐	☐	☐	☐		
Major Arterial	☐	☐	☐	☐		
Minor Arterial	☐	☐	☐	☐		
Local	☐	☐	☐	☐		

Response:

Figure 8.1.1 is a bar chart showing the overall response to freeboard criteria on each of the highway systems. Table 8.1.1 shows the break down by states for freeboard criteria used on Interstates, major arterials, minor arterials, and local systems respectively.

The figure and table indicate a variation in freeboard criteria used around the country with no specific trend in regional areas. Two feet of freeboard is the most common freeboard used in the categories of interstate and major and minor arterials and site dependent is the most common freeboard selected for local agencies but in each case it is with less than half the respondents reporting the same criteria. Complicating a comparison of state practices was the absence of a response from seven states.

Other Freeboard Criteria Used:

- Alaska – 3 feet for Interstate, Major Arterial, Minor Arterial, and Local Roads. May need more for navigational reasons.
- Arizona – 3 feet for Interstate and Major Arterial Roads.
- Arkansas – 1.5 feet for Interstate, Major Arterial, Minor Arterial, and Local Roads.
- Georgia – 0.5 feet for Local Roads.

- Illinois – 3 feet for Interstate, Major Arterial, and Minor Arterial Roads. At the recent AASHTO TC meeting, Larry & Phil T mentioned Federal CFR requirement tying funding to minimum backwater. At one (distant) time, 1ft minimum for Q100 was part of design process, but not anymore. Assuming freeboard refers to roadway low chord\beam, routinely use 2 ft for Q50 event. 1ft. for Locals.
- Iowa – 3 feet for Interstate, Major Arterial, and Minor Arterial Roads.
- Montana – FEMA floodplain regulations for Interstate, Major Arterial, Minor Arterial, and Local Roads.
- Pennsylvania - Interstate - No criteria, PDM page 10-13 (50-year); Major arterial - No criteria, PDM page 10-13 (50-year); Minor arterial- No criteria, PDM page 10-13 (25-year); Local -No criteria, PDM page 10-13 (10-year). We do not have a specific freeboard criteria but we do strive to pass the design storms for the above listed events without having water on the travelway.
- Washington - 3 feet for Interstate and Major Arterial Roads.

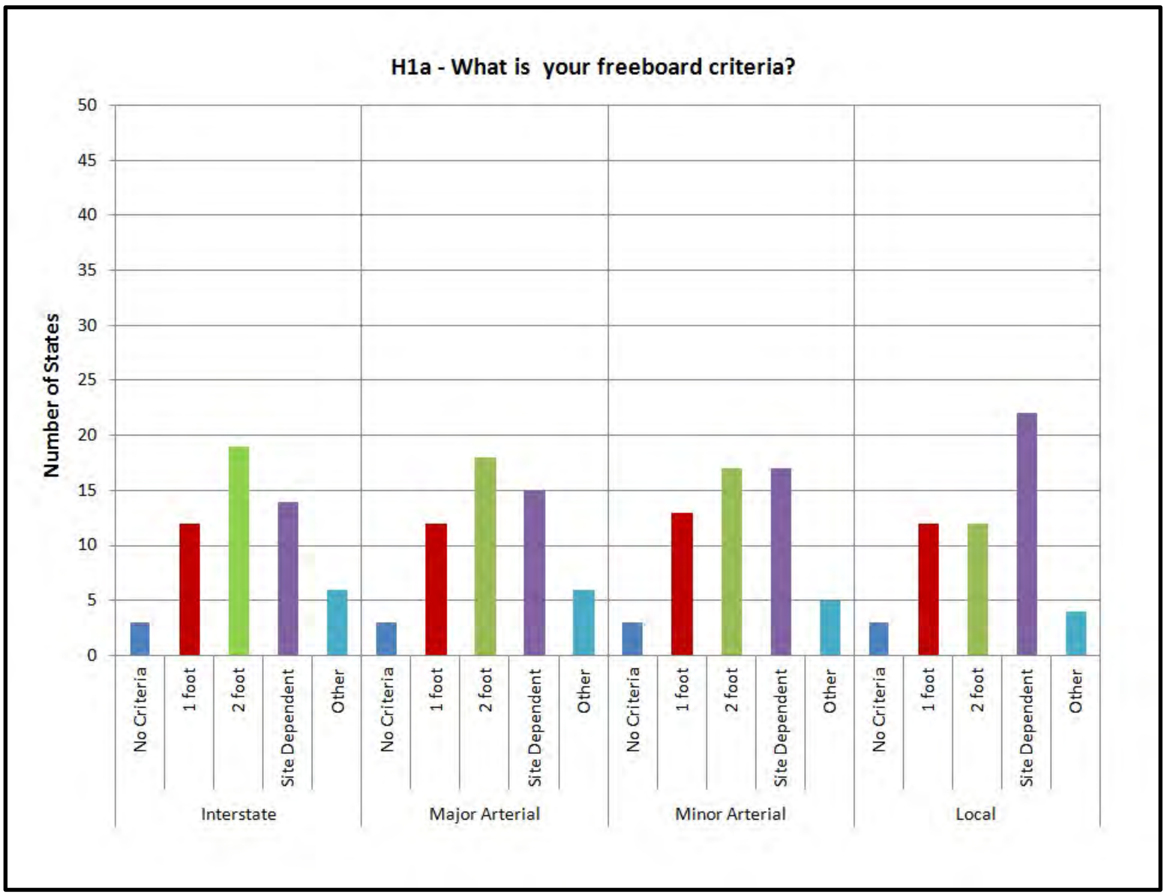


Figure 8.1.1 Number of states using the freeboard criteria listed for interstates, major arterials, minor arterials, and local systems.

Table 8.1.1 Freeboard criteria used for bridges by each of the states.

H1a – What is your freeboard criteria?																				
	Interstates					Major Arterials					Minor Arterials					Local Roads				
State	No Criteria	1-Foot	2-Foot	Site Dependent	Other	No Criteria	1-Foot	2-Foot	Site Dependent	Other	No Criteria	1-Foot	2-Foot	Site Dependent	Other	No Criteria	1-Foot	2-Foot	Site Dependent	Other
AL			■					■					■					■		
AK				■	■				■	■				■	■				■	■
AZ					■					■		■					■			
AR					■					■					■					■
CA			■					■					■					■		
CO				■					■					■					■	
CT				■					■					■					■	
DE		■					■					■					■			
FL			■					■					■					■		
GA		■					■					■								
HI			■					■					■					■		
ID			■					■					■					■		
IL					■					■					■				■	
IN			■	■				■	■				■	■				■	■	
IA					■					■					■					
KS			■						■					■					■	
KY			■					■					■						■	
LA		■					■					■							■	
ME		■					■					■							■	
MD	■					■					■					■			■	
MA			■					■						■					■	
MI				■					■					■						
MN				■					■					■					■	
MS				■					■					■					■	
MO				■					■					■					■	
MT		■		■	■		■		■	■		■		■	■		■		■	■
NE		■		■			■		■			■		■			■		■	
NV				■					■					■					■	
NH		■					■					■					■			
NJ		■					■					■					■			
NM			■					■					■					■		
NY			■					■					■					■		
NC			■					■					■				■			
ND		■					■					■					■			
OH					■					■					■					■
OK																				
OR		■					■					■					■			
PA	■					■					■					■				
PR			■					■					■				■			
RI	■					■					■					■				
SC				■					■					■					■	
SD			■					■					■						■	
TN				■					■					■					■	
TX			■					■					■							
UT			■					■					■					■		
VT		■					■					■					■			
VA		■					■					■					■			
WA					■					■				■					■	
WV			■					■					■					■		
WI			■					■	■				■	■				■	■	
WY			■	■				■					■					■		

Question H.1.b

b. Are stream stability assessments routinely conducted as part of the design process?

	Yes	No
Lateral Migration	○	○
Vertical Migration	○	○

How far are assessments conducted?

	Edge of Right-of-Way	One Bridge Length	Multiple of Bridge Lengths	Based on Site Characteristics	Other
Upstream	☐	☐	☐	☐	☐
Downstream	☐	☐	☐	☐	☐

Response:

Figure 8.1.2 provides number of states that perform lateral and vertical stream stability assessments during the design process and the distance upstream and downstream the stability assessments are conducted. Table 8.1.2 shows the results of individual state responses.

Specific State Comments to Clarify Responses:

- New Jersey - We do stream stability assessments 500 feet upstream and downstream of all stream crossings, bridges or culverts.
- Pennsylvania - Lateral migration - Occasionally, DM-2 Chap 10 Page 10-68 discusses including comments on stream stability in the H&H report and DM-4, Chap 7 discusses consideration of lateral migration in relation to scour analysis.

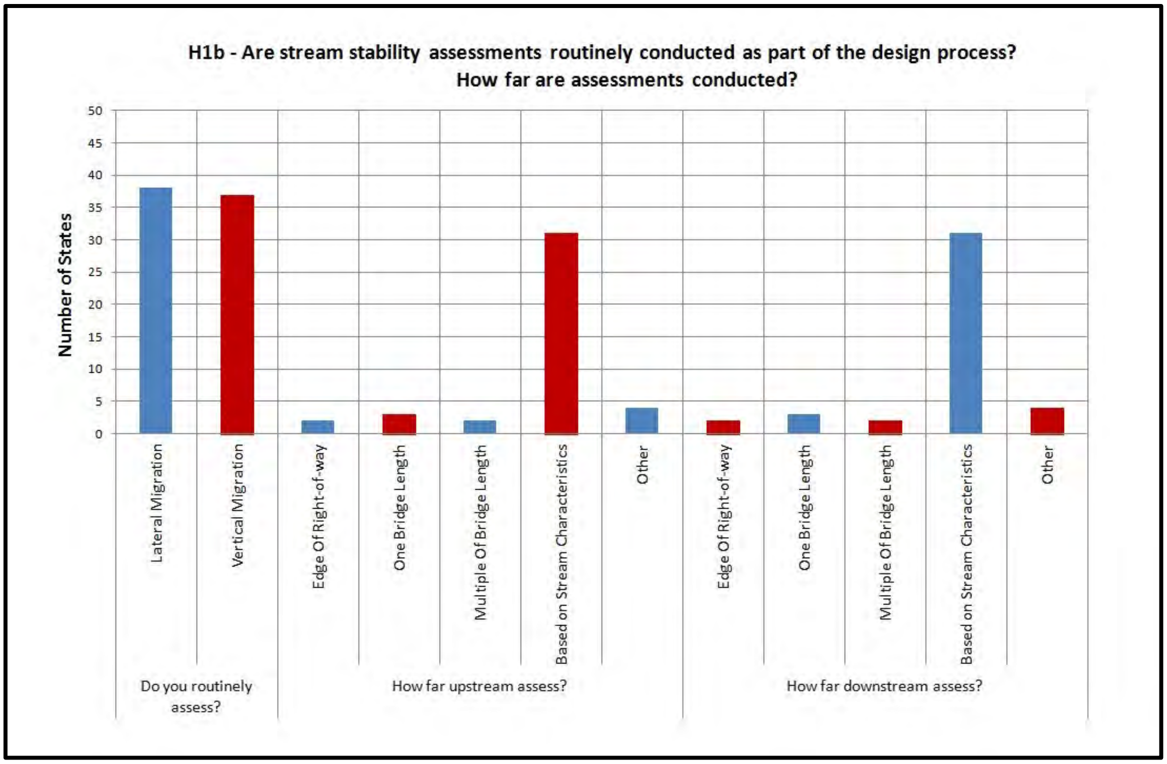


Figure 8.1.2 Number of states that conduct lateral and vertical migration assessments and the distance upstream and downstream.

Table 8.1.2 Individual state responses regarding stream assessments.

H1b - Are stream stability assessments routinely conducted as part of the design process? How far are assessments conducted?												
	Conduct Migration Assessments		Distance Upstream Assessment Conducted					Distance Downstream Assessment Conducted				
State	Lateral	Vertical	Edge of Right-of-Way	One Bridge Length	Multiple of Bridge Lengths	Based on Site Characteristics	Other	Edge of Right-of-Way	One Bridge Length	Multiple of Bridge Lengths	Based on Site Characteristics	Other
AL	■	■				■					■	
AK	■	■				■					■	
AZ	■	■				■					■	
AR	■	■		■					■			
CA	■	■			■				■			
CO	■	■				■					■	
CT	■	■				■					■	
DE	■	■				■	■				■	■
FL	■	■				■					■	
GA	■		■					■				
HI												
ID	■	■				■					■	
IL	■	■				■					■	
IN	■	■				■					■	
IA	■	■				■					■	
KS	■	■				■					■	
KY												
LA	■	■		■		■			■		■	
ME												
MD	■	■				■					■	
MA	■	■				■					■	
MI		■	■					■				
MN	■	■				■						
MS												
MO	■	■										
MT	■	■				■	■				■	■
NE	■	■				■					■	
NV	■	■				■					■	
NH												
NJ	■	■					■					■
NM	■	■				■					■	
NY	■	■				■					■	
NC	■	■				■					■	
ND												
OH												
OK												
OR	■	■		■						■		
PA	■						■					■
PR	■	■				■					■	
RI												
SC	■	■				■					■	
SD	■	■				■					■	
TN	■	■				■					■	
TX		■			■					■		
UT												
VT	■					■					■	
VA	■	■				■					■	
WA	■	■				■					■	
WV	■	■				■					■	
WI												
WY	■	■				■					■	

<u>Question H.1.c</u>

c. Is debris/ice accumulation routinely considered for:

	Yes	No
Freeboard	○	○
Pier or Abutment Scour	○	○
Pier or Abutment Alignment	○	○

Response:

Table 8.1.3 provides information on the number of states that consider debris and ice accumulation during bridge design and Table Figure 8.1.4 shows the response of individual states and Puerto Rico.

Table 8.1.3 Number of states that consider debris and ice accumulation during bridge design (multiple answers allowed).

Debris and Ice Accumulation Considered:	*Number States*
Freeboard	28
Pier or Abutment Scour	21
Pier or Abutment Alignment	32

Specific State Comments to Clarify Responses:

- Alaska - Ice and debris considered but have not set standard.

Table 8.1.4 States that consider debris or ice accumulation for freeboard, pier or abutment scour, and pier or abutment alignment.

H1c - Is debris/ice accumulation routinely considered for:			
State	**Freeboard**	**Pier or Abutment Scour**	**Pier or Abutment Alignment**
AL			
AK	■		■
AZ		■	
AR			
CA			
CO	■	■	■
CT			
DE	■		
FL		■	
GA	■		
HI			
ID	■		
IL		■	■
IN	■		■
IA	■		
KS	■	■	■
KY			
LA	■	■	■
ME	■	■	■
MD		■	■
MA	■	■	■
MI			■
MN			
MS			■
MO			■
MT	■	■	■
NE	■	■	■
NV	■	■	■
NH	■		
NJ	■	■	■
NM	■	■	■
NY	■		■
NC			■
ND			
OH	■		■
OK			
OR	■	■	■
PA	■	■	■
PR	■		■
RI			
SC	■	■	■
SD	■	■	■
TN	■		■
TX			■
UT			
VT	■	■	■
VA			
WA			■
WV		■	■
WI	■	■	■
WY	■		■

Question H.1.d

d. What methodologies are used for determining scour?

		Noncohesive Soil	Cohesive Soil	Rock
HEC 18 Equations		☐	☐	☐
Results of HEC 18 Equations Modified by Engineering Judgment		☐	☐	☐
State Developed Equations		☐	☐	☐
Results of State Equations Modified by Engineering Judgment		☐	☐	☐
Engineering Judgment Only		☐	☐	☐
Other		☐	☐	☐

Response:

Figure 8.1.3 provides a bar chart showing the number of states that selected each of the methodologies listed for estimating scour under the various soil conditions. The responses of each of the states is shown in Table 8.1.5 for the soil conditions of non-cohesive, cohesive, and rock.

Other Scour Methods Used:

- Illinois - Training, $$ and reduced staff constitute large obstacle in path of acquiring in-house unsteady or 2D modeling capabilities.
- Maryland - SHA Abscour (uses elements of HEC 18 and other), Annandale method for Rock.
- Massachusetts - HEC-25 Procedures for Tidal Bridges.
- Montana - Tractive force analysis, Annandale methodology for erodiblity of rock.
- Nebraska - USGS Data.
- Vermont - HEC 18 via HEC-RAS.
- Wyoming - Equilibrium depth and armoring similar to HEC-6.

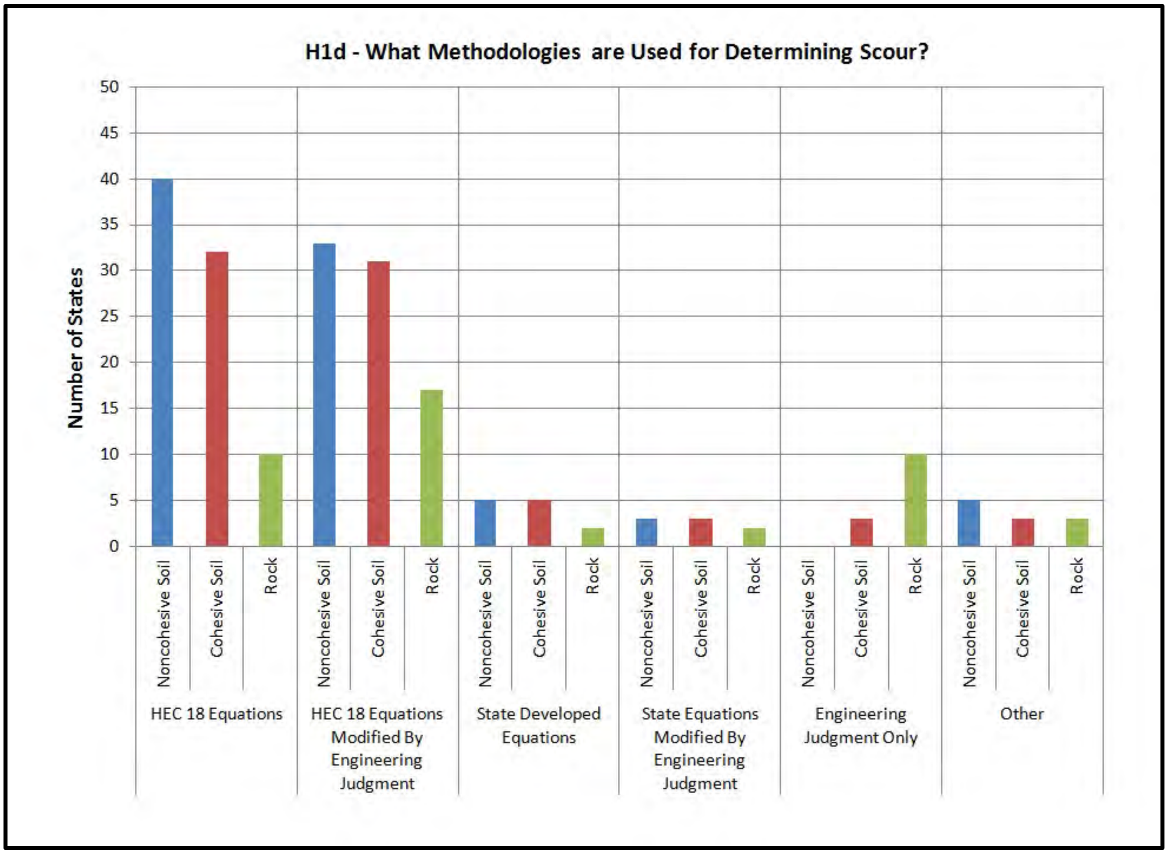


Figure 8.1.3 Number of states using each of the scour prediction methodologies.

Table 8.1.4 Methodologies used by respective states for estimating scour in various soil conditions.

	H1d - What methodologies are used for determining scour?																	
	HEC 18 Equations			Results of HEC 18 Equations Modified by Engineering Judgment			State Developed Equations			Results of State Equations Modified by Engineering Judgment			Engineering Judgment Only			Other		
State	Noncohesive Soil	Cohesive Soil	Rock	Noncohesive Soil	Cohesive Soil	Rock	Noncohesive Soil	Cohesive Soil	Rock	Noncohesive Soil	Cohesive Soil	Rock	Noncohesive Soil	Cohesive Soil	Rock	Noncohesive Soil	Cohesive Soil	Rock
AL	■	■	■		■	■		■										
AK	■													■	■			
AZ	■	■		■	■													
AR	■			■														
CA	■	■		■	■		■	■		■	■							
CO	■			■			■		■	■		■						
CT	■	■	■	■	■	■												
DE	■	■	■															
FL							■	■	■									
GA	■	■		■	■													
HI	■	■	■	■	■	■												
ID	■	■		■	■													
IL	■	■			■	■												
IN	■	■				■												
IA	■	■		■	■		■	■							■			
KS	■	■				■												
KY	■	■																
LA	■	■		■	■													
ME	■	■		■	■					■	■							
MD																■	■	■
MA				■	■	■										■		
MI	■	■	■	■	■	■												
MN	■	■	■												■			
MS	■			■														
MO	■	■		■	■										■			
MT	■	■																■
NE				■	■										■	■		
NV	■	■		■	■													
NH				■	■													
NJ	■	■	■	■	■	■										■	■	■
NM	■			■	■	■												
NY	■	■													■			
NC	■	■		■	■													
ND	■	■																
OH	■	■		■	■													
OK																		
OR	■	■		■	■													
PA				■	■	■												
PR	■	■	■	■	■	■												
RI				■	■	■												
SC	■	■		■	■		■	■							■			
SD	■				■	■								■	■			
TN	■	■																
TX				■		■					■	■						
UT	■	■	■															
VT	■	■		■	■											■	■	
VA				■	■	■												
WA	■													■	■			
WV				■	■										■			
WI	■	■	■	■	■	■												
WY	■			■														

Question H.1.e

e. Is sediment transport considered?

Yes	No
○	○

Response:

The responses show that seventeen (17) states and Puerto Rico consider sediment transport in their evaluation for scour, thirty-two (32) states do not and one (1) state did not respond. Figure 8.1.4 displays the individual response of the states and Puerto Rico.

Specific State Comments to Clarify Responses:

- Montana - Sediment transport models are not implemented by the Hydraulics Section but we have had USGS perform a sediment transport analysis for the MDT.

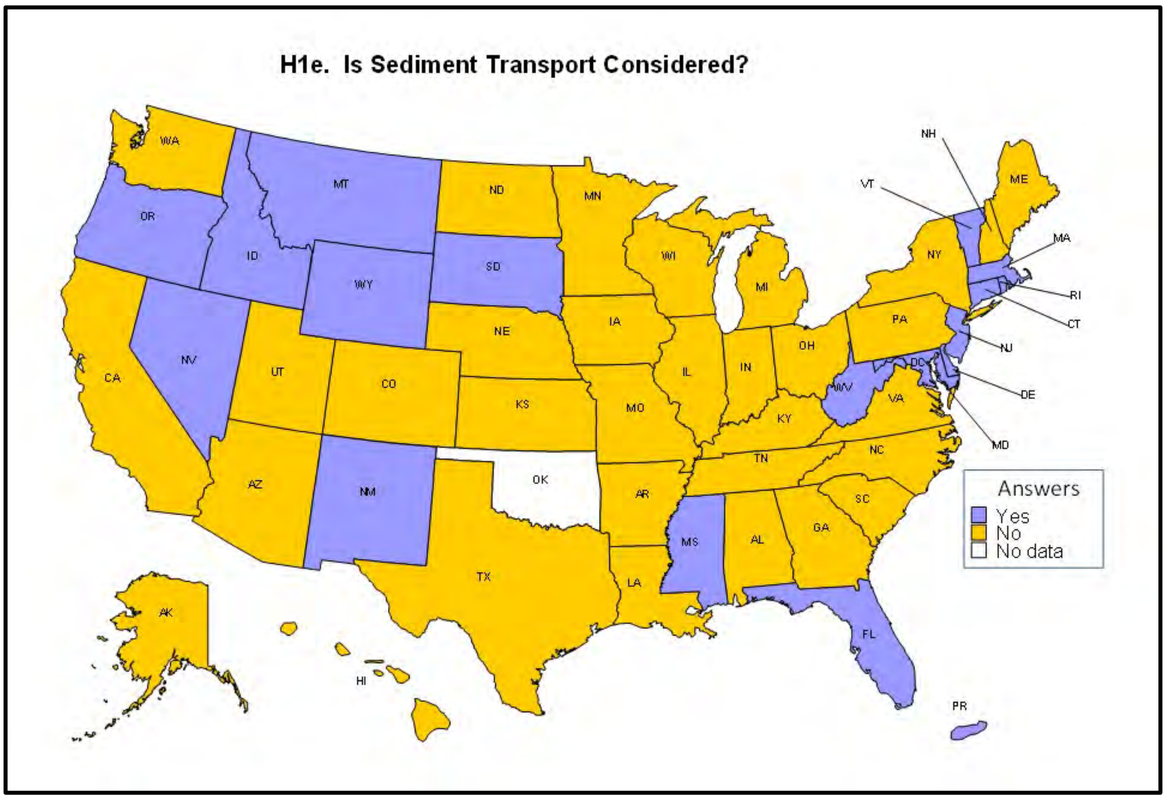


Figure 8.1.4 States that consider sediment transport in bridge design.

Question H.1.f

f. What types of hydraulic models are used?

	Routinely	Occasionally	Never
1D Steady Flow	☐	☐	☐
1D Unsteady Flow	☐	☐	☐
2D Steady Flow	☐	☐	☐
2D Unsteady Flow	☐	☐	☐
3D Steady/Unsteady Flow	☐	☐	☐
Physical Model	☐	☐	☐
Sediment Transport	☐	☐	☐

Response:

Figure 8.1.5 provides a bar chart that shows the number of states using each of the listed hydraulic computer model types. The responses of individual states and Puerto Rico are shown in Table 8.1.5.

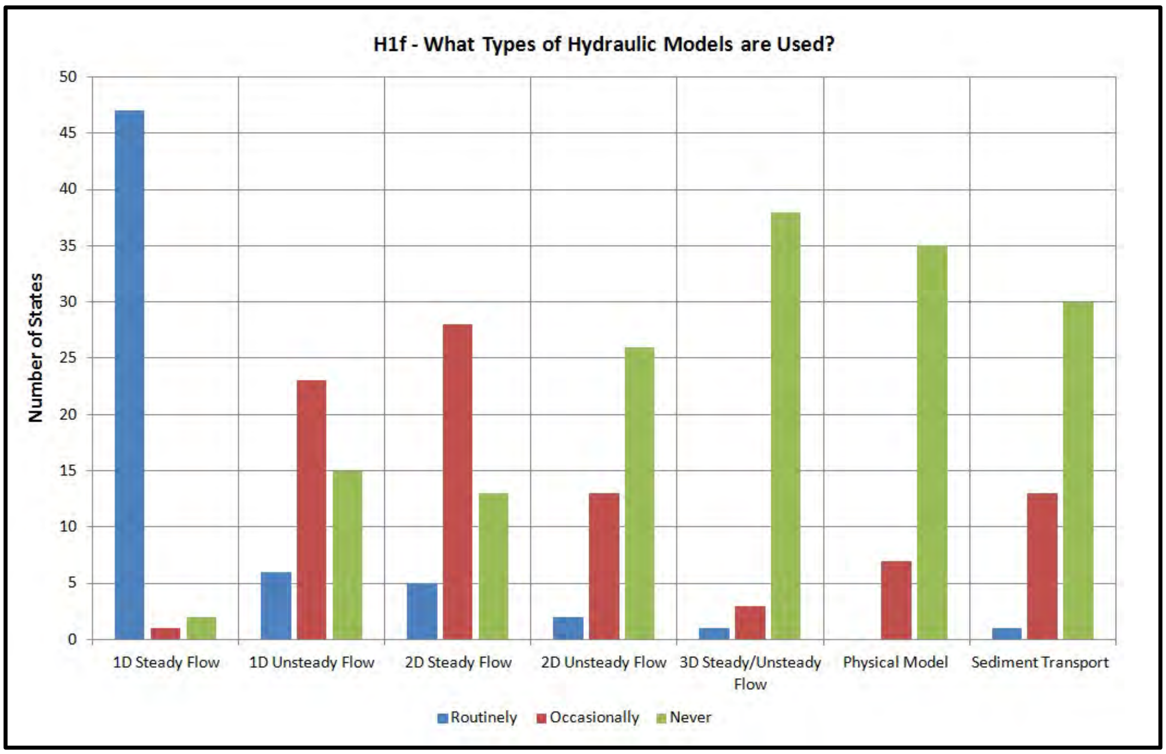


Figure 8.1.5 Number of states using the various hydraulic models listed.

Table 8.1.5 Hydraulic models used by each state in bridge design.

	H1f - What types of hydraulic models are used?																				
	1D Steady Flow			1D Unsteady Flow			2D Steady Flow			2D Unsteady Flow			3D Steady/ Unsteady Flow			Physical Model			Sediment Transport		
State	Routinely	Occasionally	Never	Routinely	Occasionally	Never	Routinely	Occasionally	Never	Routinely	Occasionally	Never	Routinely	Occasionally	Never	Routinely	Occasionally	Never	Routinely	Occasionally	Never
AL	■					■						■			■			■			■
AK	■				■			■				■		■				■			■
AZ	■					■			■			■			■			■		■	
AR	■				■			■			■				■			■			■
CA	■				■			■													
CO	■			■				■			■				■			■			■
CT	■				■			■			■				■			■		■	
DE	■			■																	
FL	■			■				■		■					■		■			■	
GA	■				■						■										
HI	■					■	■					■			■			■			■
ID	■				■			■			■				■		■			■	
IL	■					■			■			■			■			■			■
IN	■																				
IA	■					■		■				■			■			■			■
KS	■				■				■			■			■		■				■
KY	■					■			■			■			■			■			■
LA	■				■			■			■				■			■			■
ME	■					■			■			■			■			■			■
MD	■				■			■						■			■			■	
MA	■			■				■			■				■			■		■	
MI	■						■								■			■			■
MN	■				■			■				■			■		■				■
MS	■				■				■			■			■		■				■
MO	■					■		■				■			■			■			■
MT	■																			■	
NE	■				■				■			■			■			■			■
NV		■				■			■			■			■			■		■	
NH	■					■			■			■			■			■			■
NJ			■			■	■			■			■					■			■
NM	■				■		■					■			■		■			■	
NY	■				■			■				■			■			■		■	
NC	■			■				■			■				■			■			■
ND	■							■													
OH	■					■			■			■			■			■			■
OK																					
OR	■				■				■			■			■			■			■
PA	■				■			■				■			■			■			■
PR	■				■			■			■				■			■		■	
RI			■			■	■				■				■			■			■
SC	■				■			■			■				■			■			■
SD	■				■			■				■			■			■			■
TN	■							■													
TX	■				■			■				■			■			■		■	
UT	■				■			■				■			■			■			■
VT	■					■			■			■			■			■			■
VA	■			■				■			■				■			■			■
WA	■				■			■			■				■			■			■
WV	■					■		■				■		■				■		■	
WI	■				■				■			■			■			■			■
WY	■							■											■		

Question H.1.g

g. What is your sizing criteria for bridge length?

		Yes	No
Hydraulic Considerations		○	○
Scour Considerations		○	○
Stream Instability Considerations		○	○
Environmental Considerations		○	○
Navigation Considerations		○	○
Other		○	○

Response:

Table 8.1.6 provides a comparison of the sizing criteria used by state highway departments. All states responding indicated that hydraulic considerations are used as bridge sizing criteria and the majority of states indicated that all criteria types listed are considered in the sizing of bridge structures.

Table 8.1.6 Number of states that use the various sizing criteria for determining bridge length (multiple answers allowed).

Sizing Criteria for Bridge Length	*Number States*
Hydraulic Considerations	48
Scour Considerations	38
Stream Instability Considerations	41
Environmental Considerations	43
Navigation Considerations	40
Other	10

Other Sizing Criteria Used for Bridge Length:

- Alabama - Terrain & Road Geometrics.
- Alaska - Pedestrian/bicycle paths, FEMA, Wildlife passage.
- Arizona – Political. We do many things based on the waterway characteristic, some of which are not covered here in this questionnaire.
- Delaware - http://deldot.gov/information/pubs_forms/manuals/bridge_atlas/index.shtml.
- Hawaii - Width of existing channel.
- Kansas - Several others.
- Maryland - Stream Morphology and Channel Stability.
- Missouri - Geotechnical considerations.

- Montana - FEMA floodplain regulations.
- New Jersey - Railroad location.
- New York - Structural criteria. Stream stability is evaluated at bridge replacements routinely. If there are identified head cuts or lateral migration, for example, countermeasures are proposed to alleviate or at least arrest the progression of instability.
- Puerto Rico - Geographic Consideration.

8.2 Plans of Action

This section contains only one question however it contains a field of five questions concerning Plans of Action, POAs, for scour critical bridges. This is a multi-part question concerning the bridge scour program and asks if the parties responsible for various aspects of the scour program are located in the state DOT central office or district office. The last part of this question asks if the agency uses an interdisciplinary approach to developing, implementing, and maintaining POAs for scour critical bridges.

Question 8.2

2. Plans of Action

	Central Office	District Office	Other
Who is responsible for managing the scour evaluation program?	☐	☐	
Who is responsible for developing POAs for scour critical bridges?	☐	☐	
Who is responsible for implementing POAs for scour critical bridges	☐	☐	
Who is responsible for maintaining POAs for scour critical bridges?	☐	☐	

Is there an interdisciplinary approach to developing, implementing, and maintaining POAs for scour critical bridges?

Yes	No
○	○

Response:

Figure 8.2.1 provides a bar chart showing the number of states that place responsibility for various aspects of POAs in the central office or in district offices. Table 8.2.1 displays the individual responses of states for managing the scour program and for using an interdisciplinary approach. The results of the question on using an interdisciplinary approach to developing, implementing, and maintaining POAs indicate that thirty-nine (39) states and Puerto Rico use an interdisciplinary approach for developing, implementing, and maintaining POAs for scour critical bridges.

Other Entities Responsible for POA:

- Alabama – The bridge owner for implementing and maintaining POAs.
- Alaska – Hydraulics squad in the bridge section is lead on scour. USGS assists with POA implementation.
- Illinois - Once a heavy Central Office hand in scour eval\management\POA, but District now owns the program. IDOT likely to employ BridgeWatch by 2010. BW may be run from Central Office.
- Nebraska – Counties for developing, implementing, and maintaining POAs.
- Pennsylvania - Central Office provides program guidelines and oversight. Each District manages the POAs for its own bridges.
- Puerto Rico – Regional Office for maintaining POAs.

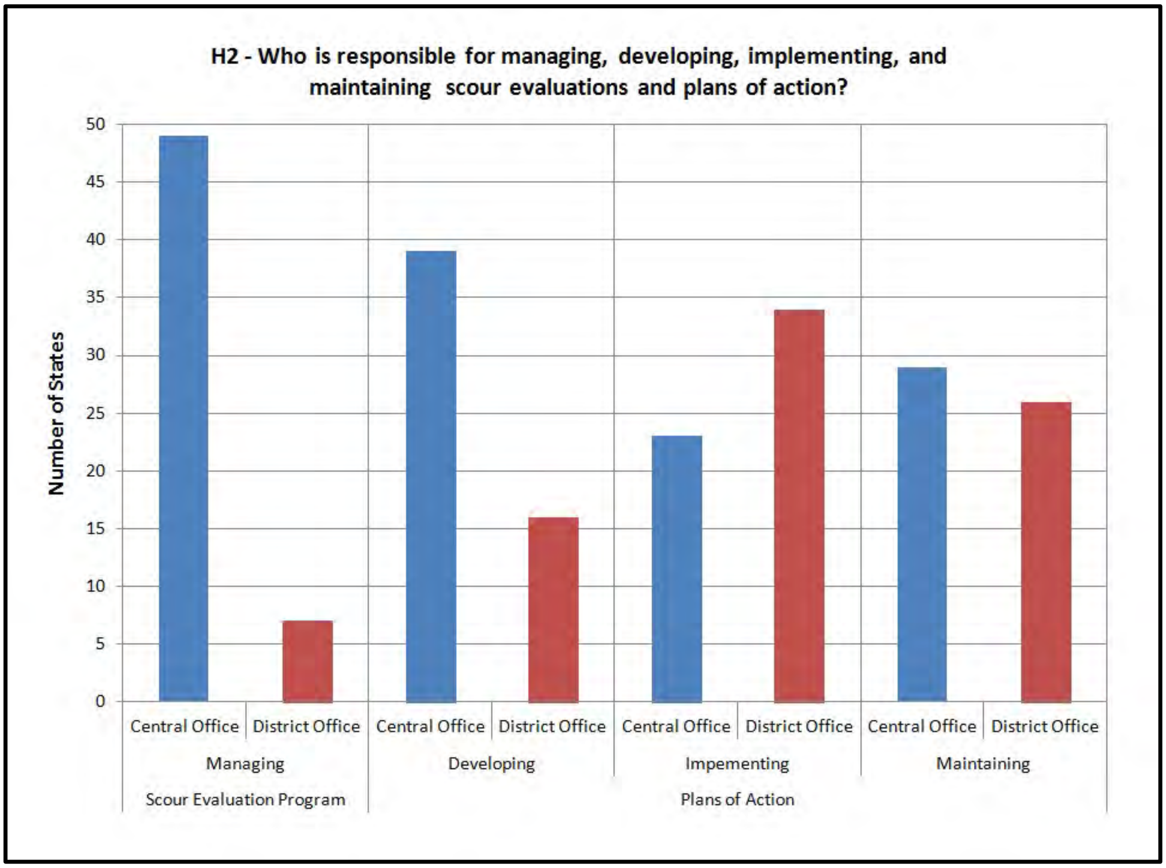


Figure 8.2.1 Number of states that have the responsible parties for managing the various aspects of the scour program in the central office and those that are located in the district.

Table 8.2.1 Response of individual states regarding management of Plans of Action and the use of an interdisciplinary team.

H2 – Plans of Action									
	Who is responsible for:								Is there an interdisciplinary approach?
	managing the scour evaluation program?		developing POAs for scour critical bridges?		implementing POAs for scour critical bridges?		maintaining POAs for scour critical bridges?		
State	Central Office	District Office	Central Office	District Office	Central Office	District Office	Central Office	District Office	
AL	■		■			■		■	■
AK	■		■		■		■		■
AZ	■		■			■		■	■
AR	■		■			■	■		■
CA	■		■		■		■		
CO	■	■	■	■	■	■	■	■	■
CT	■		■		■		■		■
DE		■		■		■		■	
FL	■	■		■		■		■	■
GA	■		■		■		■		
HI	■		■	■		■		■	■
ID	■		■		■		■		■
IL	■	■		■		■		■	■
IN	■			■		■		■	
IA	■		■			■	■		■
KS	■		■		■	■	■		■
KY	■		■		■		■		
LA	■	■	■		■	■	■	■	■
ME	■		■		■		■		■
MD	■		■		■		■		■
MA	■		■		■	■	■		■
MI	■		■	■		■		■	■
MN	■		■			■	■		■
MS	■		■			■		■	■
MO	■		■		■	■	■	■	
MT	■		■		■		■		■
NE	■		■			■		■	■
NV	■		■			■	■		■
NH	■		■		■		■		■
NJ	■		■		■		■		■
NM	■		■		■	■	■		■
NY	■			■		■		■	■
NC	■		■			■		■	■
ND	■		■		■		■		
OH	■			■		■		■	
OK									
OR	■		■		■			■	■
PA	■	■		■		■		■	■
PR	■		■		■		■	■	■
RI	■		■		■		■		
SC	■		■			■	■		■
SD	■		■	■		■	■	■	■
TN	■		■			■	■		■
TX	■			■		■		■	■
UT	■		■		■	■	■		■
VT	■		■			■		■	■
VA	■		■			■		■	■
WA	■		■		■		■		■
WV	■	■		■		■		■	■
WI	■			■		■		■	
WY	■			■		■		■	■

8.3 Countermeasures

This section contains one question addressing the types of scour and stream stability countermeasures used by the various highway departments.

<u>Question 8.3</u>

3. Countermeasures
   a. What countermeasures do you use or are planning to use?

	Routinely	Occasionally	Rarely	Never
Bendway Weirs/Stream Barbs	○	○	○	○
Soil Cement	○	○	○	○
Wire Enclosed Riprap Mattresses	○	○	○	○
Articulated Concrete Block System	○	○	○	○
Grout Filled Mattresses	○	○	○	○
Concrete Armor Units	○	○	○	○
Grout/Cement Filled Bags	○	○	○	○
Rock Riprap At Piers and Abutments	○	○	○	○
Spurs	○	○	○	○
Guide Banks	○	○	○	○
Check Dams/Drop Structures	○	○	○	○
Revetments	○	○	○	○
Fixed Scour Instrumentation	○	○	○	○
Other	○	○	○	○

Additional Comments:

Response:

Figure 8.3.1 provides a bar chart showing the number of states using the various countermeasure types and their frequency of use. The response of individual states and Puerto Rico are displayed in Table 8.3.1.

Other Countermeasures Planning on Using:

- Alaska – Replacement.
- Arizona – Concrete Flooring.
- Illinois - Primary countermeasure remains engineered riprap. Degradation, channel migration, & other such systemic stream issues are no typically encountered.

- New Mexico - Stream restoration at upstream, such as rock vanes and vegetation.
- Pennsylvania - Grout filled mattresses - These are typically only used as emergency repair not countermeasure design.
- West Virginia – Rock Vanes.

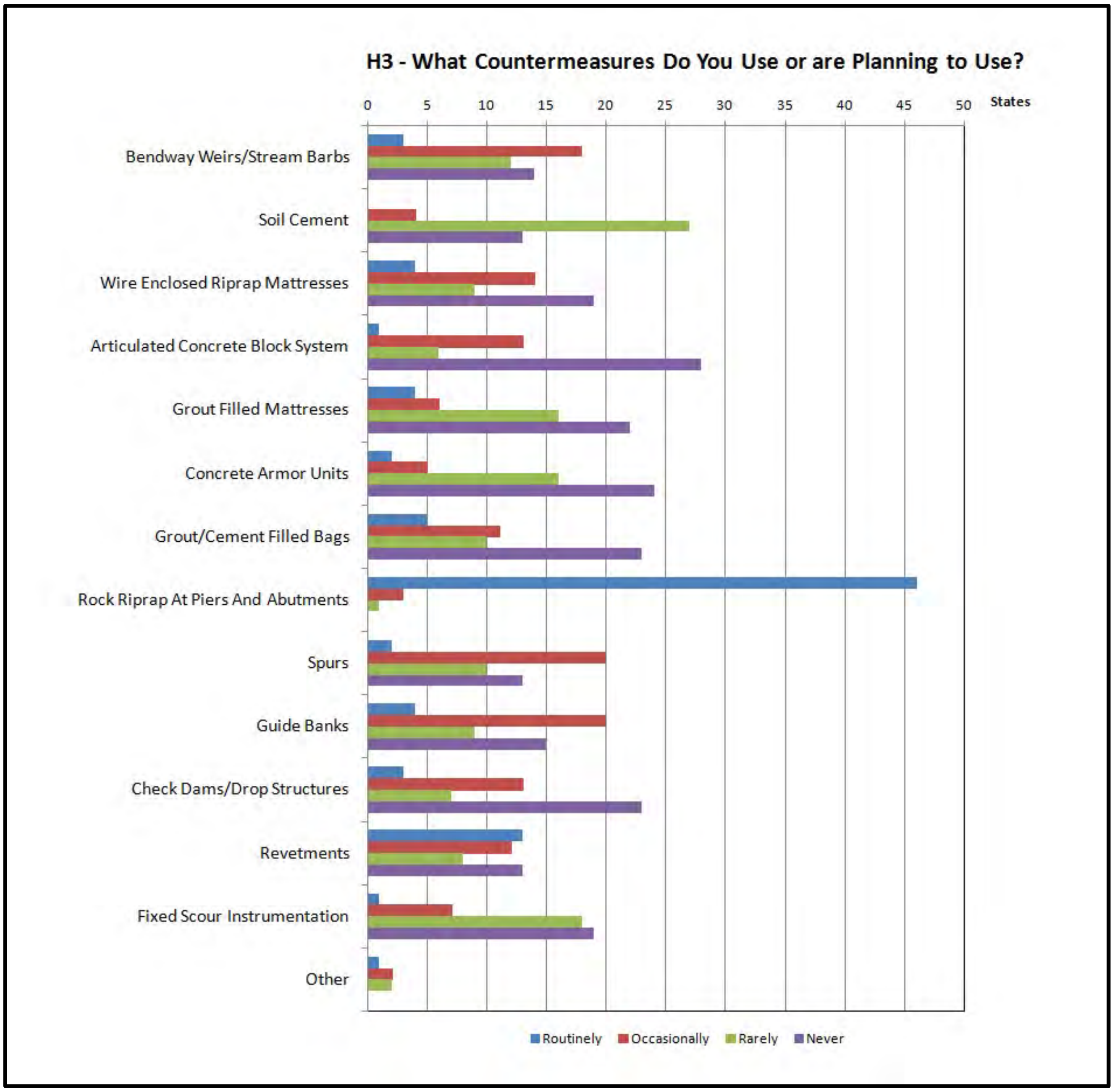


Figure 8.3.1 Frequency of use of the various countermeasures by highway departments.

Table 8.3.1 States' frequency of use of countermeasure types.

H3 – What countermeasures do you use or are planning to use?

State	Bendway Weirs\Stream Barbs	Soil Cement	Wire Enclosed Riprap Mattresses	Articulated Concrete Block System	Grout Filled Mattresses	Concrete Armor Units	Grout/Cement Filled Bags	Rock Riprap at Piers and Abutments	Spurs	Guidebanks	Check Dams\ Drop Structures	Revetments	Fixed Scour Instrumentation	Other
AL	Occasionally	Rarely	Rarely	Never	Rarely	Rarely	Occasionally	Routinely	Occasionally	Occasionally	Never	Rarely	Never	
AK	Occasionally	Never	Rarely	Never	Never	Occasionally	Occasionally	Routinely	Occasionally	Routinely	Occasionally	Routinely	Routinely	Occasionally
AZ	Never	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Never	Rarely	Occasionally	Occasionally	Occasionally	Occasionally	Rarely	
AR	Occasionally	Rarely	Never	Never	Never	Rarely	Rarely	Routinely	Occasionally	Occasionally	Never	Routinely	Never	
CA	Occasionally	Rarely	Never	Never	Rarely	Never	Rarely	Routinely	Occasionally	Occasionally	Never	Occasionally	Occasionally	
CO	Routinely	Rarely	Never	Never	Never	Never	Rarely	Routinely	Routinely	Routinely	Routinely	Routinely	Rarely	
CT	Never	Never	Never	Occasionally	Never	Never	Occasionally	Routinely	Never	Never	Never	Routinely	Never	
DE			Never	Never		Never	Occasionally	Routinely		Never		Never		
FL	Never	Rarely	Occasionally	Routinely	Routinely	Routinely	Rarely	Routinely	Never	Never	Never	Routinely	Never	
GA					Occasionally		Never	Routinely		Occasionally				
HI	Rarely	Never	Never	Never	Never	Never	Occasionally	Routinely	Rarely	Rarely	Never	Never	Occasionally	
ID	Routinely	Never	Never	Never	Never	Rarely	Never	Routinely	Occasionally	Occasionally	Never	Never	Never	
IL	Never	Rarely	Occasionally	Never	Rarely	Never	Never	Routinely	Never	Never	Occasionally	Routinely	Rarely	
IN	Occasionally	Never	Never	Never	Never	Never	Never	Routinely	Never	Never	Never	Never	Never	
IA	Occasionally	Rarely	Never	Occasionally	Routinely	Never	Routinely	Routinely	Occasionally	Routinely	Occasionally	Routinely	Never	
KS	Occasionally	Rarely	Never	Rarely	Rarely	Never	Never	Routinely	Occasionally	Occasionally	Occasionally	Occasionally	Never	Occasionally
KY	Rarely			Never	Never			Routinely						
LA	Rarely	Rarely	Never	Never	Rarely	Never	Never	Routinely	Never	Never	Rarely	Routinely	Never	
ME					Routinely	Routinely	Routinely	Routinely						
MD	Rarely	Rarely	Rarely	Rarely	Rarely	Rarely	Routinely	Occasionally	Rarely	Rarely	Rarely	Never	Never	
MA	Rarely	Occasionally	Routinely	Never	Routinely	Never	Routinely	Routinely	Rarely	Never	Never	Routinely	Occasionally	
MI	Never			Never			Never	Routinely		Never	Never		Never	
MN	Never	Rarely	Never	Never	Never	Rarely	Never	Routinely	Never	Occasionally	Never	Never	Never	
MS	Never	Never	Never	Never	Never	Never	Never	Routinely	Occasionally	Routinely	Never	Never	Never	
MO	Never	Rarely	Occasionally	Never	Rarely	Never	Never	Occasionally	Occasionally	Occasionally	Rarely	Occasionally		
MT	Occasionally		Occasionally	Occasionally	Rarely	Never	Never	Routinely	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	
NE	Occasionally	Never	Occasionally	Occasionally	Never	Never	Never	Routinely	Occasionally	Occasionally	Occasionally	Occasionally	Rarely	
NV	Never	Never	Occasionally	Occasionally	Rarely	Occasionally	Rarely	Routinely	Occasionally	Occasionally	Occasionally	Occasionally	Rarely	
NH	Occasionally	Rarely	Never	Never	Never	Rarely	Never	Routinely	Rarely	Rarely	Never	Never	Never	
NJ	Rarely	Rarely	Routinely	Occasionally	Never	Never	Never	Routinely	Rarely	Occasionally	Routinely	Rarely	Never	
NM	Occasionally	Never	Routinely	Never	Never	Never	Never	Routinely	Occasionally	Occasionally	Occasionally	Occasionally	Rarely	Routinely
NY	Occasionally	Rarely	Rarely	Rarely	Rarely	Never	Occasionally	Routinely	Occasionally	Occasionally	Routinely	Routinely	Never	
NC	Rarely	Rarely	Occasionally	Never	Never	Occasionally	Never	Routinely	Never	Never	Rarely	Rarely	Rarely	
ND	Never	Rarely	Rarely	Rarely	Rarely	Rarely	Rarely	Routinely	Rarely	Rarely	Never	Never	Rarely	
OH	Rarely	Rarely	Never	Occasionally	Never	Rarely	Never	Routinely	Never	Never	Never	Rarely	Rarely	
OK														
OR	Occasionally	Occasionally	Occasionally	Never	Occasionally	Rarely	Occasionally	Routinely	Routinely	Rarely	Occasionally	Routinely	Occasionally	
PA	Never	Rarely	Never	Occasionally	Never	Never	Routinely	Routinely	Never	Never	Never	Never	Rarely	Rarely
PR	Never	Never	Routinely	Never	Never	Never	Never	Routinely	Never	Never	Never	Routinely	Never	
RI	Rarely	Rarely	Rarely	Never	Never	Never	Occasionally	Routinely	Rarely	Rarely	Rarely	Rarely	Occasionally	
SC	Never	Rarely	Occasionally	Never	Rarely	Never	Never	Routinely	Occasionally	Occasionally	Never	Never	Rarely	
SD	Occasionally	Rarely	Never	Never	Never	Rarely	Rarely	Routinely	Occasionally	Occasionally	Occasionally	Occasionally	Rarely	
TN	Occasionally	Rarely	Occasionally	Never	Never	Rarely	Rarely	Routinely	Occasionally	Occasionally	Never	Occasionally	Rarely	
TX	Rarely	Never	Occasionally	Occasionally	Never	Never	Never	Routinely	Never	Rarely	Never	Occasionally	Rarely	
UT	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Occasionally	Never	
VT	Never	Rarely	Rarely	Rarely	Rarely	Rarely	Never	Routinely	Rarely	Rarely	Rarely	Rarely	Rarely	Rarely
VA	Occasionally	Never	Occasionally	Occasionally	Occasionally	Never	Occasionally	Routinely	Occasionally	Occasionally	Never	Never	Never	
WA	Routinely	Rarely	Never	Never	Rarely	Rarely	Rarely	Routinely	Never	Never	Never	Never	Rarely	
WV	Rarely	Rarely	Rarely	Occasionally	Rarely	Rarely	Never	Routinely	Rarely	Never	Occasionally	Routinely	Rarely	
WI	Rarely	Rarely	Rarely	Rarely	Occasionally	Rarely	Occasionally	Routinely	Rarely	Rarely	Rarely	Rarely	Occasionally	
WY	Occasionally	Never	Never	Never	Rarely	Rarely	Rarely	Routinely	Never	Never	Never	Rarely	Rarely	

9.0 Floodplain Management

The national state of practice for design of encroachments in FEMA regulated floodplains are presented in this chapter. The chapter is divided into five sections with a total of seven questions.

9.1 Location Studies

<u>Question I.1</u>

I. Floodplain Management
   1. Are Location Hydraulic Studies developed for environmental documents?

Yes	No
○	○

Response:

Thirty-three (33) states and Puerto Rico prepare Location Hydraulic Studies for environmental documents. Figure 9.1.1 displays individual responses.

Specific State Comments to Clarify Responses:

- South Dakota - Locations hydraulic studies have been developed for environmental documents, but not on a routine basis.

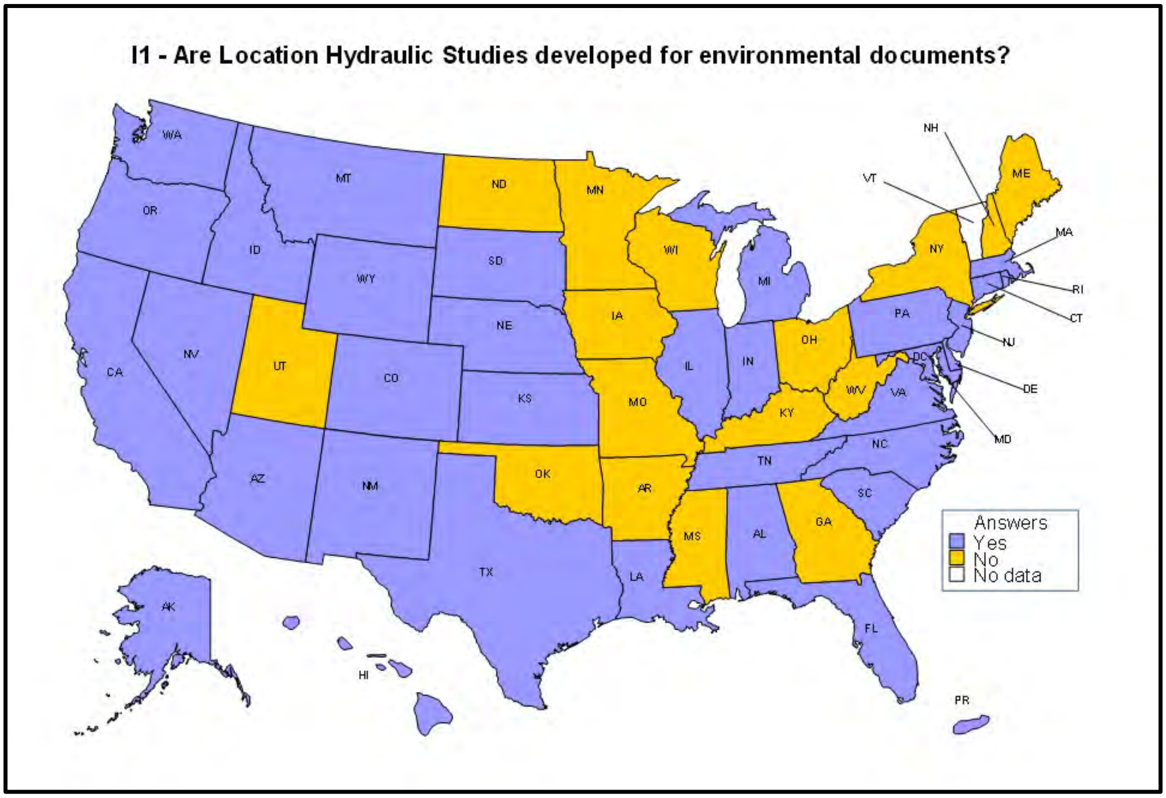


Figure 9.1.1 States that prepare Location Hydraulic Studies for environmental documents.

9.2 FEMA Flood Maps

The national usage of FEMA flood maps and studies for assessing the impacts of highway floodplain encroachments is addressed by question I.2.

<u>Question I.2</u>

2. Are FEMA flood maps and studies used when available for assessing changes in the floodplain due to the project?

Yes	No
○	○

Response:

Responses show that all fifty (50) states use FEMA flood maps and studies.

9.3 Allowable Floodplain Rise

This question provided a list of six specific criteria for restrictions to floodplain rise above the base flood elevation and asked states to identify which, if any, of these criteria were established by law or executive order in their state. If different criteria were applicable, then an option for choosing "other" was available.

Question I.3

3. What criteria have been established by law or executive order restricting floodplain rise for base flood elevations?

No Criteria	No Rise	Rise < 0.1 foot	Rise < 0.5 foot	Rise Equal to Minimum FEMA Criteria	Local Ordinances	Other ☐
☐	☐	☐	☐	☐	☐	☐

Response:

Figure 9.3.1 provides a bar chart showing the number of states that are required to follow the various criteria listed. Table 9.3.1 contains the responses of each state and Puerto Rico. Twenty (20) states have no criteria more restrictive than the FEMA regulations and sixteen (15) states and Puerto Rico have criteria that is more stringent than FEMA in all floodplains.

Specific State Comments to Clarify Responses:

- Alaska - Alaska A.D. 175
- Arizona - Floodplain requirements on us come from local flood control district. We comply with what they require.
- Idaho - Depends on if in a regulatory floodway or not.
- Illinois - DNR regs are site specific \ some > 1ft. DNR criteria vary by location in state. Routinely much tighter in 6-county Chicago area. DNR Statewide program allows agencies to replace structures over designated streams with equal or greater opening provided no upstream damages. DNR also allows IDOT to use cost risk analysis to justify selected waterway opening. No-rise limit only employed by DNR in 6-county area when existing conditions cause upstream damages. IDOT has not been sued by either upstream or downstream property owners over backwater\increased flow issues in last 15 years, easily. FIS profiles and discharges are integral component of DNR regs in 6-county area.
- Maryland - Variance may be available for increases up to 1 foot. in unimproved areas.
- Michigan - <0.01'
- Montana - State law requires a maximum 0.5 foot rise.

- Nevada - Reasonable Use Law.
- New Hampshire - NHDES Alteration of Terrain Rules (AOT) requires proposal for compensatory flood storage or conveyance that is designed to insure that "no increase in flood stages on abutting properties".
- Washington - 0.2 feet rise (state wide). We have some counties that require zero rise backwater. We also have a state regulation of 0.2 feet maximum increase in backwater.

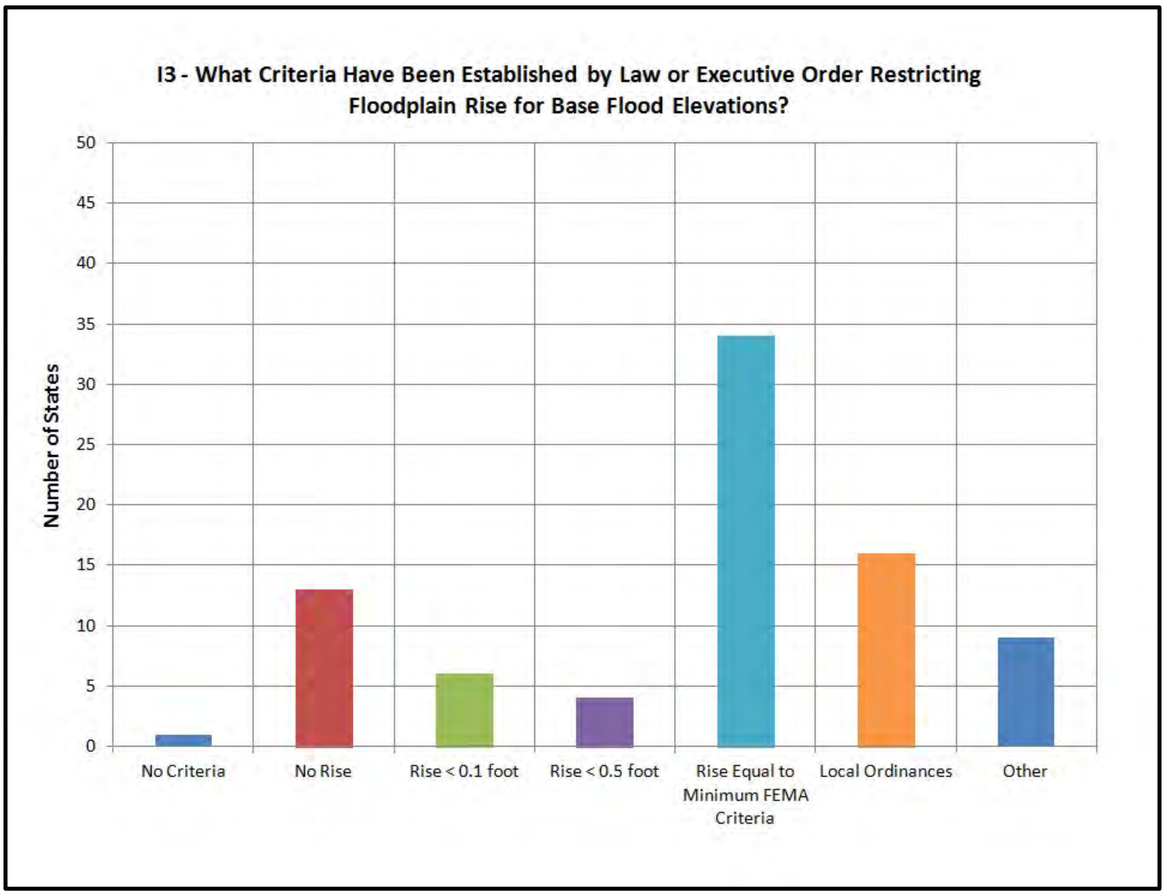


Figure 9.3.1 Number of states indicating the specific rise criteria to which subject.

Table 9.3.2 Specific floodplain rise criteria used by each state.

I3 - What criteria have been established by law or executive order restricting floodplain rise for base flood elevations?

State	No Criteria	No Rise	Rise < 0.1 Foot	Rise <0.5 Foot	Rise = Minimum FEMA Criteria	Local Ordinances	Other
AL						■	
AK		■			■	■	■
AZ					■	■	
AR						■	
CA					■		
CO					■	■	
CT					■		
DE					■	■	
FL	■						
GA					■		
HI		■					
ID		■			■	■	■
IL			■	■			■
IN			■				
IA		■					
KS					■		
KY					■	■	
LA		■			■	■	
ME					■		
MD			■				■
MA					■		
MI		■				■	■
MN				■			
MS					■		
MO					■		
MT				■			■
NE					■	■	
NV			■		■	■	■
NH		■			■		■
NJ		■					
NM					■		
NY					■		
NC					■	■	
ND					■		
OH					■		
OK					■		
OR					■		
PA					■		
PR			■	■		■	
RI					■		
SC					■		
SD		■	■		■		
TN					■		
TX					■		
UT					■		
VT		■					
VA					■	■	
WA						■	■
WV		■					
WI		■					
WY		■			■		

9.4 CLOMR and LOMR

This section of Chapter 9 addresses the use of conditional letters of map revision, CLOMRs, and letters of map revisions, LOMRs, when constructing floodplain encroachments in FEMA regulated floodplains.

Question I.4.a

4. CLOMR and LOMR
   a. If you cannot meet floodplain restriction criteria established by FEMA or the state, do you develop CLOMRs and LOMRs?

Yes	No
○	○

Question I.4.b

This is a follow-up question on the frequency use of CLOMRs and LOMRs.

b. How often do you need to develop CLOMRs and LOMRs?

Routinely	Occasionally	Rarely	Never
○	○	○	○

Response:

Figure 9.4.1 provides a bar chart showing the combined responses to questions I.4.a and b. Table 9.4.1 provides the individual response of each state and Puerto Rico to both questions.

Specific State Comments to Clarify Responses:

- Illinois - IDOT has not utilized LOMR \ CLOMR for many years- perhaps 10 - 15.
- Montana - The MDT does not currently develop LOMRS or CLOMRS for projects although the state floodplain coordinator is pushing hard for us to do so. We have taken the position that development of mapping and implementation of the regulations are the counties (local entity) responsibility. We would be willing to share our data with them if asked. I sense that individuals responsible for implementing the floodplain program would be more than happy to utilize FHWA funds to update maps.
- Vermont - NFIP is a totally new issue for us. The previous NPIF coordinator had confidence that VTrans was doing what was best for the public and let most everything slide. The new coordinator is by the book and requiring CLOMR/LOMRs. We have had 2 completed to date, both done by consultants.

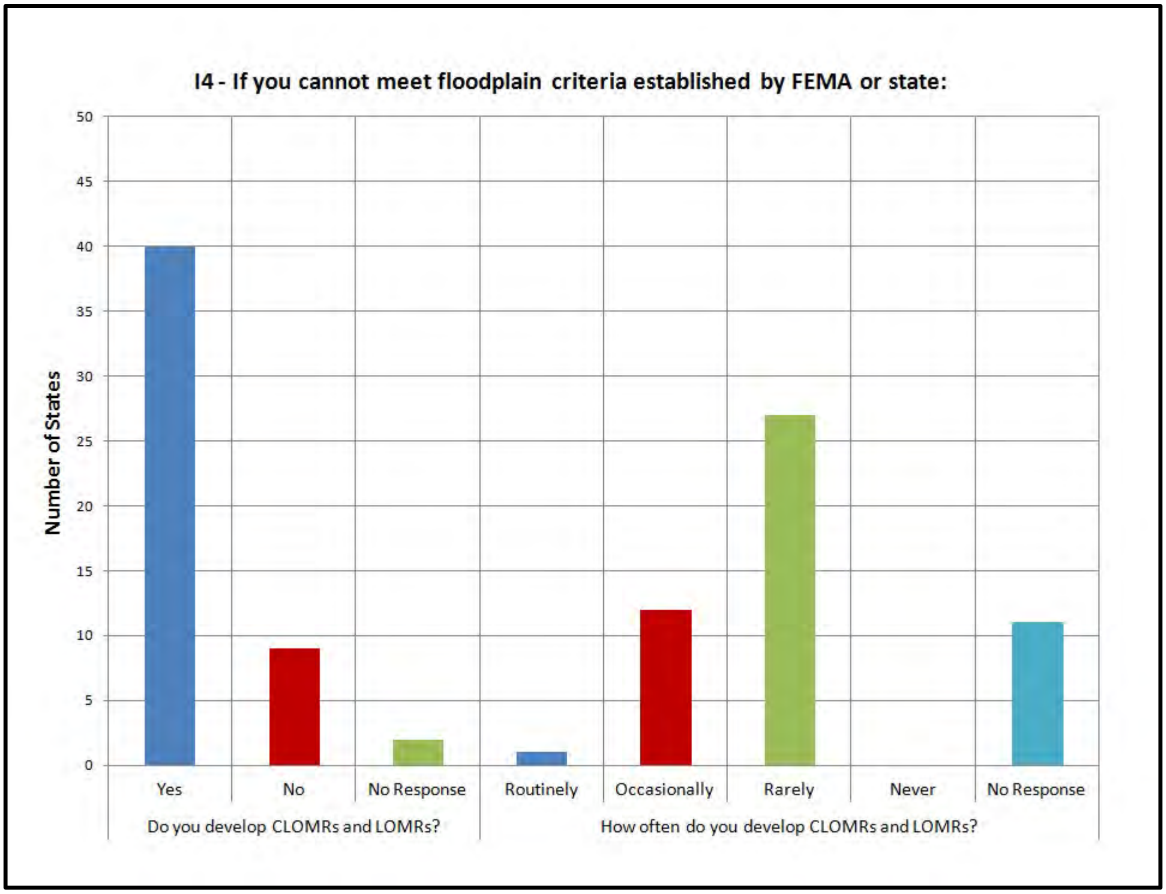


Figure 9.4.1 Number of states that develop CLOMRs and LOMRs and their frequency of use.

Table 9.4.1 State responses on the development of CLOMRs and LOMRs.

I4 – If you cannot meet floodplain restriction criteria established by FEMA or the state:					
State	Do you develop CLOMRs and LOMRs?	How often do you need to develop CLOMRs and LOMRs?			
		Routinely	Occasionally	Rarely	Never
AL	X			X	
AK	X			X	
AZ	X		X		
AR	X			X	
CA	X		X		
CO	X		X		
CT	X			X	
DE	X		X		
FL	X			X	
GA	X		X		
HI					
ID	X		X		
IL					
IN					
IA	X		X		
KS	X			X	
KY	X			X	
LA					
ME					
MD	X		X		
MA	X			X	
MI					
MN	X			X	
MS	X			X	
MO					
MT					
NE	X		X		
NV	X			X	
NH	X			X	
NJ	X			X	
NM	X			X	
NY	X			X	
NC	X	X	X		
ND					
OH	X			X	
OK	X		X		
OR	X			X	
PA	X		X		
PR	X			X	
RI	X				
SC	X		X		
SD	X			X	
TN	X			X	
TX	X			X	
UT	X			X	
VT	X			X	
VA	X			X	
WA					
WV	X			X	
WI	X			X	
WY	X			X	

9.5 No-Rise Certificates

This section consists of two questions involving the use of no-rise certificates for having no impact on the floodway.

Question I.5.a

5. No-Rise Certificate
   a. Do you develop No-Rise Certificates for having no impact on floodway surcharges, widths, or velocities?

Yes	No
○	○

Question I.5.b

   b. Do you have a form for No-Rise Certificates?

Yes	No
○	○

Additional Comments:

Response:

Twenty-two (22) states develop No-Rise Certificates for having no impact on floodways. Figure 9.5.1 displays the response of individual states and Puerto Rico.

Specific State Comments to Clarify Responses:

- Arizona - When community asks for No Rise Certification, they typically send us a copy of their No Rise Certification Form.
- Iowa - We provide local agencies a Record of Coordination that informs them that a no rise will occur due to our project. We do not obtain a local permit due to sovereign rights issues.
- Pennsylvania - No, but we forward all our H&H reports for project located in FEMA detailed study areas to FEMA Region III.
- South Dakota - We have not developed No-Rise Certificates, but have included information in the project files.
- West Virginia - We do not produce "no-rise certificates", but we do send documentation to local floodplain managers.

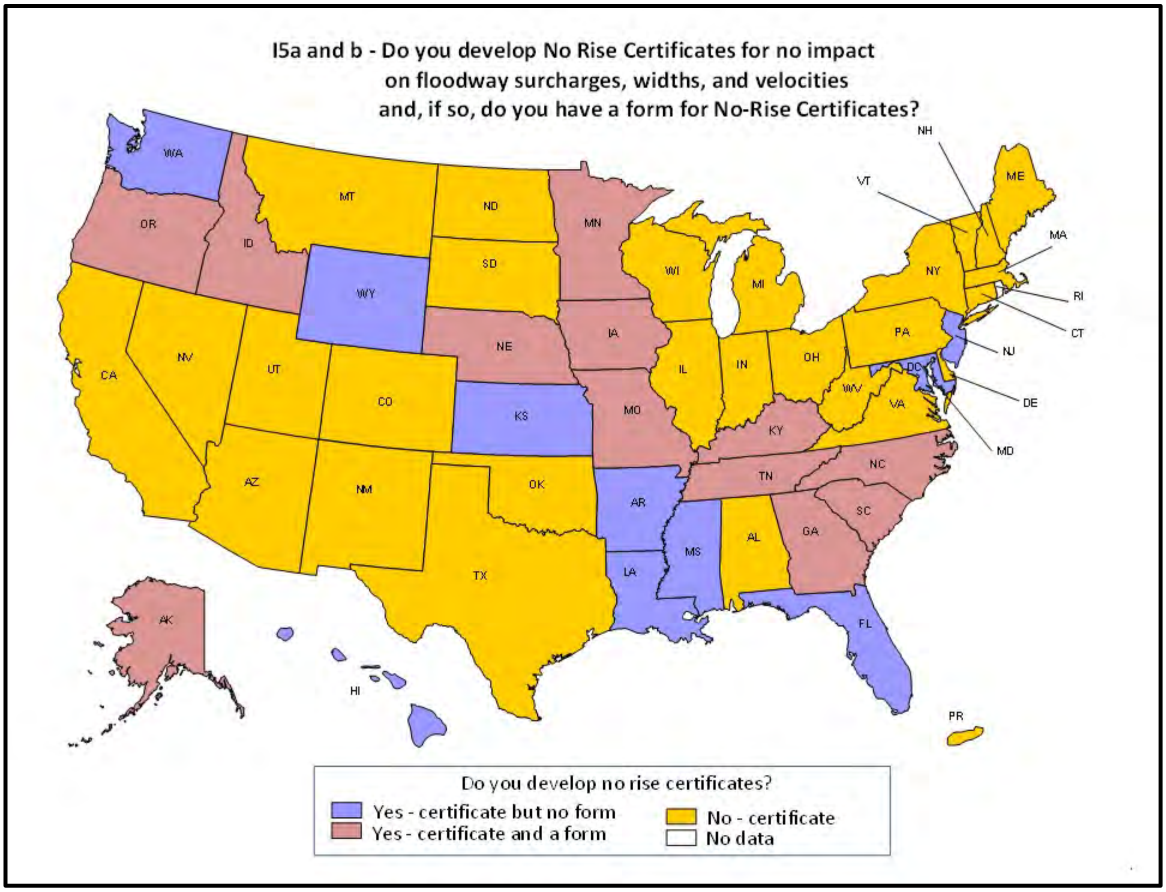


Figure 9.5.1 States' use of no-rise certificates and forms.

10.0 Environmental Hydraulics

This chapter contains four sections relating to environmental hydraulics that includes environmentally sensitive protection measures, stream mitigation requirements, aquatic organism passage, and resource agency requirements.

10.1 Environmentally Sensitive Protection Measures

This section includes two questions on the use of environmentally sensitive measures for erosion and scour protection of highway structures and/or for channel restoration.

Question J.1.a

J. Environmental Hydraulics
   1. Use of Environmentally Sensitive Protection Measures
      a. Do you use environmentally sensitive protection measures for scour and stream stability countermeasures?

	Routinely	Occasionally	Rarely	Never
Bridges, Culverts, or Roadways	○	○	○	○
Channel Restoration	○	○	○	○

Response:

Figure 10.1.1 provides a bar chart of the number of states that uses environmentally sensitive erosion protection measures and Figure 10.1.2 includes a national map showing the response of individual states and Puerto Rico.

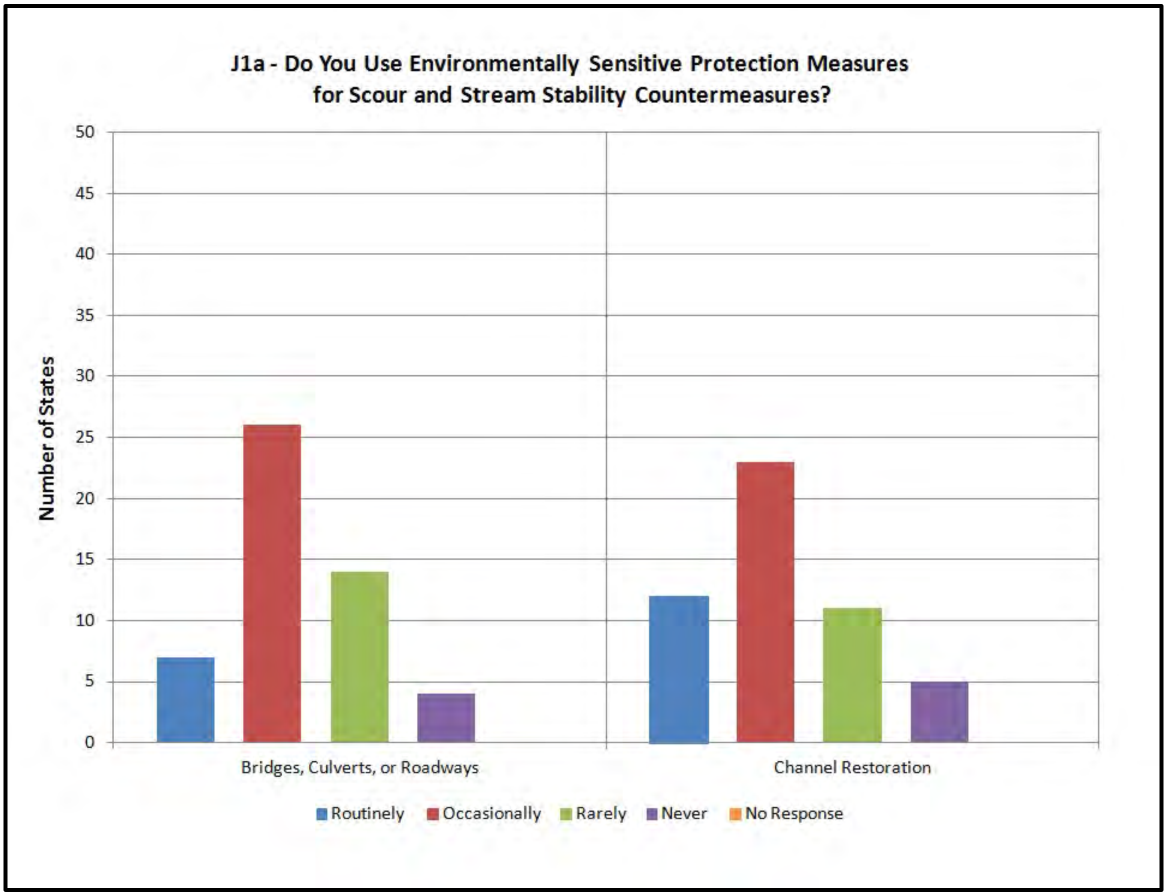


Figure 10.1.1 Number of states that use environmentally sensitive protection measures for highway structures and/or channel for restoration.

Table 10.1.1 States' use of environmentally sensitive erosion protection measures.

J1a - Do you use environmentally sensitive protection measures for scour and stream stability countermeasures?								
	Bridges, Culverts, or Roadways				Channel Restoration			
State	Routinely	Occasionally	Rarely	Never	Routinely	Occasionally	Rarely	Never
AL			■					■
AK			■		■			
AZ		■				■		
AR		■				■		
CA			■			■		
CO		■				■		
CT	■				■			
DE		■				■		
FL		■						■
GA		■			■			
HI				■				■
ID	■				■			
IL				■			■	
IN			■				■	
IA		■				■		
KS		■				■		
KY			■				■	
LA	■						■	
ME		■				■		
MD		■				■		
MA	■				■			
MI			■				■	
MN			■			■		
MS			■					■
MO			■			■		
MT		■				■		
NE		■					■	
NV		■				■		
NH			■				■	
NJ	■				■			
NM			■				■	
NY		■			■			
NC		■			■			
ND				■				■
OH				■			■	
OK			■				■	
OR		■				■		
PA		■				■		
PR			■				■	
RI		■				■		
SC		■				■		
SD		■				■		
TN	■				■			
TX		■				■		
UT		■			■			
VT			■			■		
VA		■				■		
WA	■				■			
WV		■			■			
WI		■				■		
WY		■				■		

Question J.1.b

b. Which measures do you use?

	Routinely	Occasionally	Rarely	Never
Rootwads	○	○	○	○
Brush Mattresses	○	○	○	○
Brush Layering	○	○	○	○
Fascines	○	○	○	○
Live Cribwalls	○	○	○	○
Vegetated Riprap or Gabions	○	○	○	○
Rock Vanes	○	○	○	○
Cross Vanes	○	○	○	○
W-weirs	○	○	○	○
J-hooks	○	○	○	○
Boulder Clusters	○	○	○	○
Constructed Riffles	○	○	○	○
Other	○	○	○	○

Response:

Figure 10.1.2 provides a bar chart of the number of states using each of the erosion protection measures listed. Table 10.1.2 provides the individual responses of the states.

Specific State Comments to Clarify Responses:

- Alaska – Gabions.
- Maryland - Imbicated Riprap.

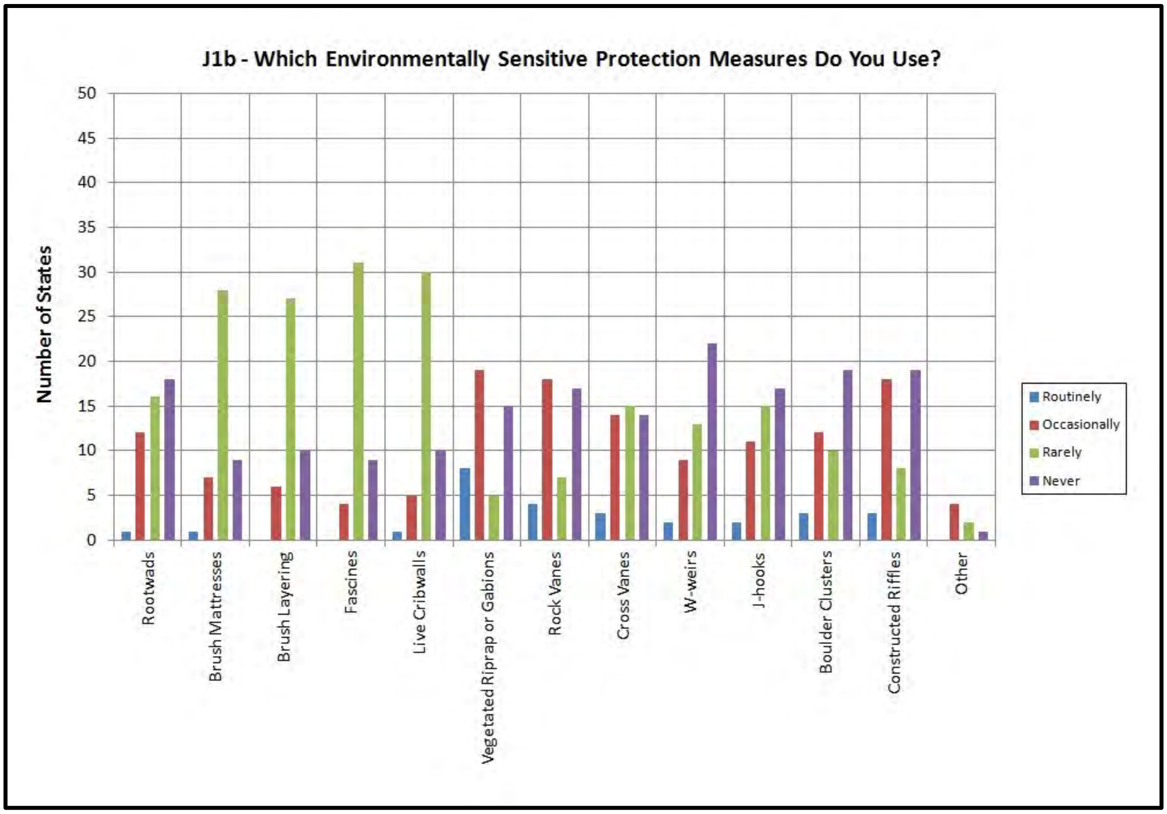
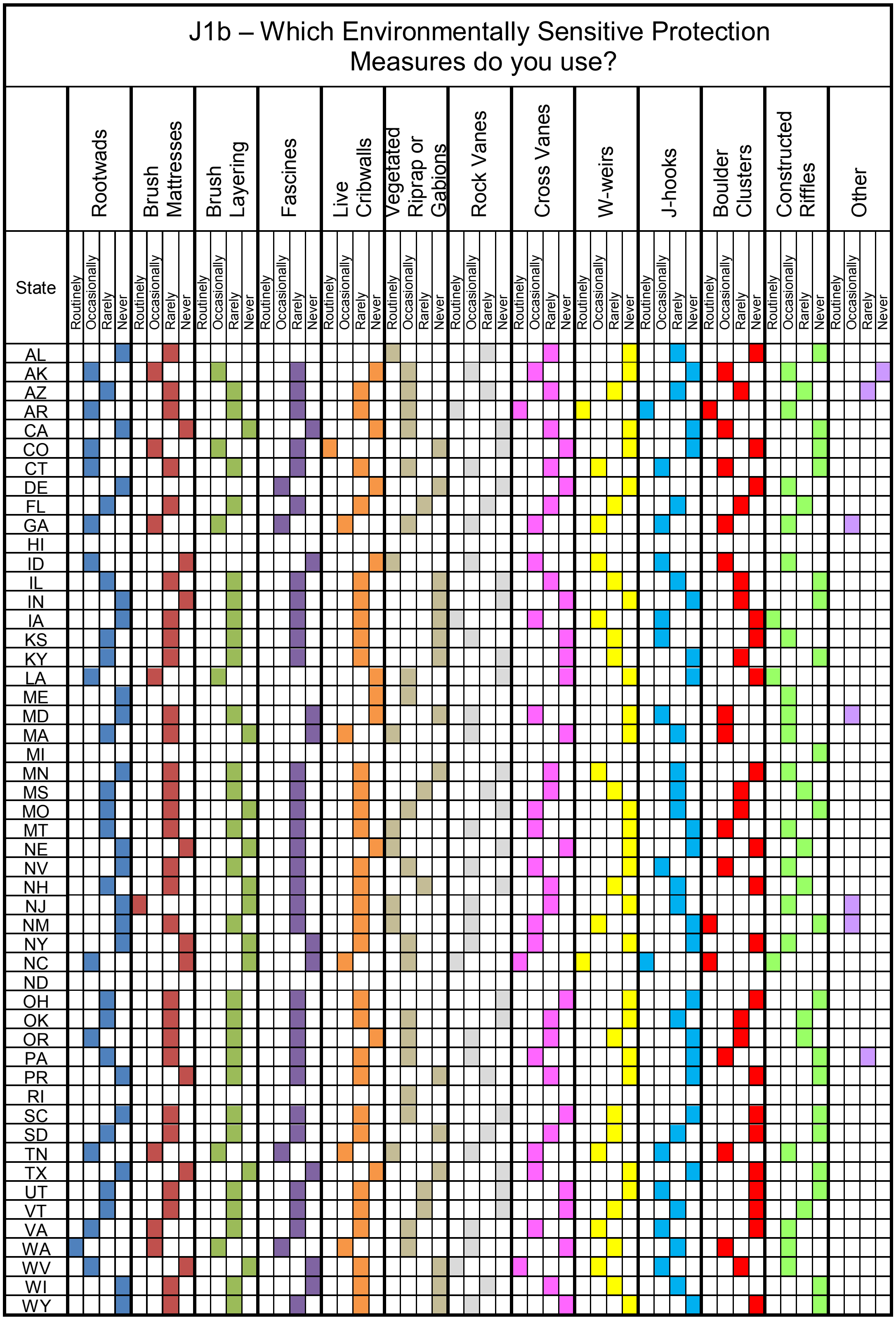


Figure 10.1.2 Number of states that use the erosion protection measures listed.

Figure 10.1.2 States' use of Environmentally Sensitive Protection Measures.



10.2 Stream Mitigation

This section contains three questions concerning stream channel mitigation using Natural Channel design.

Question J.2.a

2. Stream Mitigation (Natural Channel Design)
   a. Do you have stream mitigation requirements?

Yes	No
○	○

What is the ratio?

	1:1	2:1	3:1	Other
Onsite Ratio	○	○	○	
Offsite Ratio	○	○	○	

Response:

Figure 10.2.1 provides a bar chart showing the number of states with requirements for stream channel mitigation and the required ratios for onsite and offsite mitigation measures. Table 10.2.1 provides individual responses of the states.

Specific State Comments to Clarify Responses:

- Alaska - State does not frequently design channel restoration but consultants do. Stream mitigation requirements - in CWA Section 404 requirements. Mitigation through Title 16 of Alaska Statutes. Mitigation Ratio Stream Mitigation - based upon habitat values - USACE/EPA mitigation rule (April 2008).
- Delaware – Corps of Engineers.
- Kansas – Varies.
- Maryland – Varies.
- Texas – Up to 7:1.
- Washington – Varies.
- Wyoming – Varies.

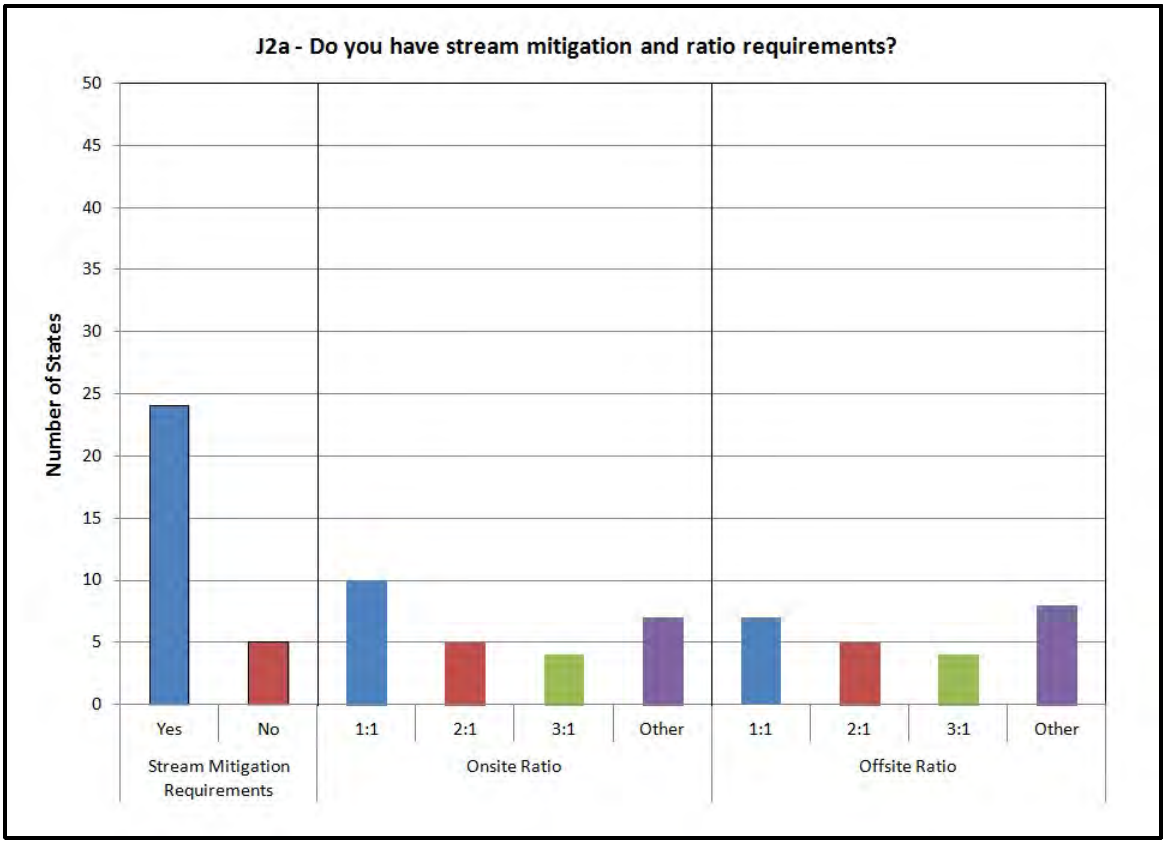


Figure 10.2.1 Number of states that have stream mitigation requirements and the required ratio for onsite and offsite mitigation.

Table 10.2.1 States that have stream mitigation requirements and requirements for onsite and offsite ratios.

J2a - Do you have stream mitigation and ratio requirements?									
State	Do you have stream mitigation requirements?	Do you have an Onsite Ratio requirements:				Do you have an Offsite Ratio requirements:			
		1:1	2:1	3:1	Other	1:1	2:1	3:1	Other
AL	■	■				■			
AK									
AZ									
AR									
CA									
CO									
CT									
DE	■				■				■
FL									
GA									
HI									
ID									
IL									
IN									
IA	■	■				■			
KS	■				■				■
KY	■		■				■		
LA	■			■				■	
ME									
MD	■				■				■
MA	■	■				■			
MI									
MN									
MS	■				■				■
MO	■	■					■		
MT									
NE	■	■							■
NV									
NH									
NJ	■	■				■			
NM									
NY									
NC	■		■					■	
ND									
OH									
OK									
OR	■	■				■			
PA	■				■				■
PR	■		■				■		
RI									
SC	■		■					■	
SD	■	■				■			
TN	■	■					■		
TX	■				■			■	
UT									
VT									
VA	■		■				■		
WA	■				■				■
WV	■	■				■			
WI									
WY	■				■				■

Question J.2.b

b. Do you have documented design guides or tools for stream mitigation?

Yes	No
○	○

If these tools are online, please provide the link:

Response:

Only eleven (11) states and Puerto Rico have documented design guidance for stream mitigation as shown in Figure 10.2.2. Only four states reported that they have online guidance. The web links provided are shown below:

- Kansas:
  http://www.ksdot.org:9080/burmatrres/kdotlib2.asp / K-TRAN research project (University of Kansas) KU-08-2: Development of Guidelines for Stream Realignment Design, and KU-09-3: Reference-Reach Methods for Stream Realignment Design.
- New Jersey:
  http://www.nj.gov/dep/landuse/announce/fhamanual20081201.pdf
- New Hampshire:
  http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-06-37.pdf
- Tennessee:
  http://www.tdot.state.tn.us/sswmp/default.htm

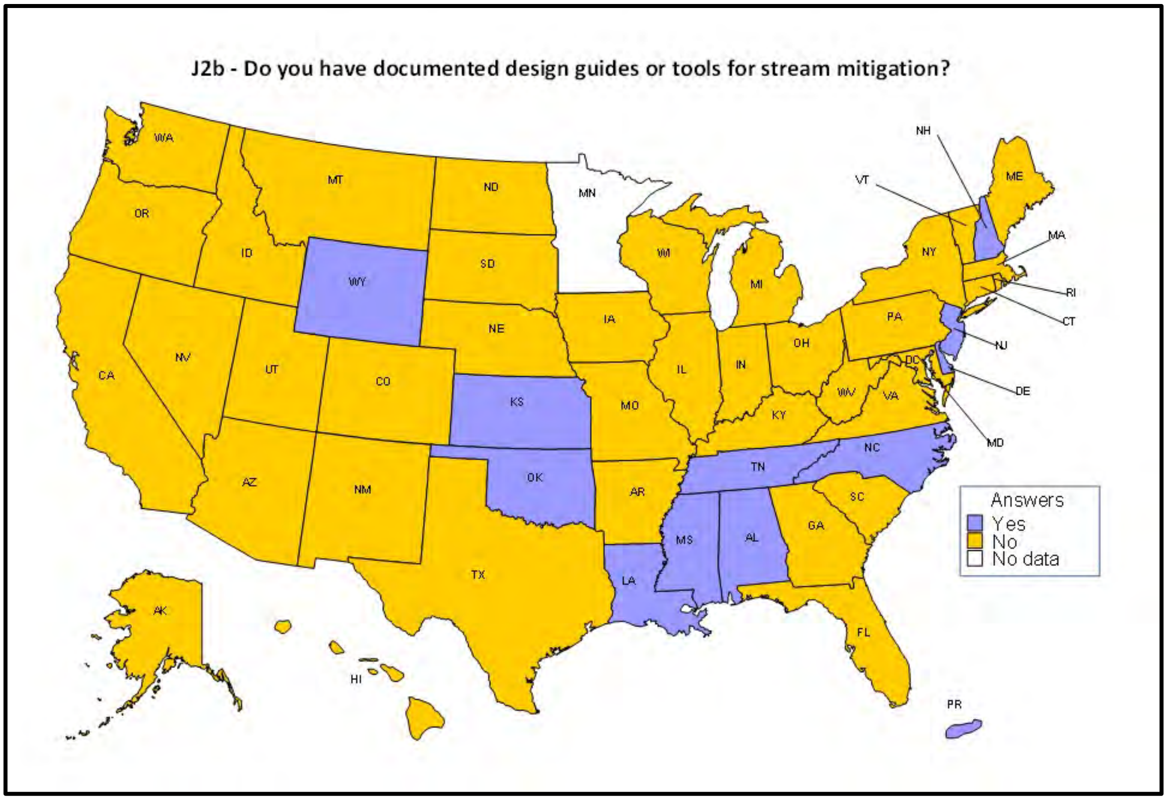


Figure 10.2.2 Eleven states and Puerto Rico that have design guidance for stream mitigation.

Question J.2.c

c. Do you monitor or provide maintenance to stream mitigation projects?

Yes	No
○	○

Response:

The responses show that only twenty one (21) states and Puerto Rico monitor and provide maintenance to stream mitigation projects. A national perspective of the responses is shown in Figure 10.2.3.

States' Maintenance for Stream Mitigation Projects:

- Alaska - Monitoring Stream Mitigation projects - a regulatory requirements.
- Pennsylvania - Yes, ECMTS database (as described in Design Manual 1 A).

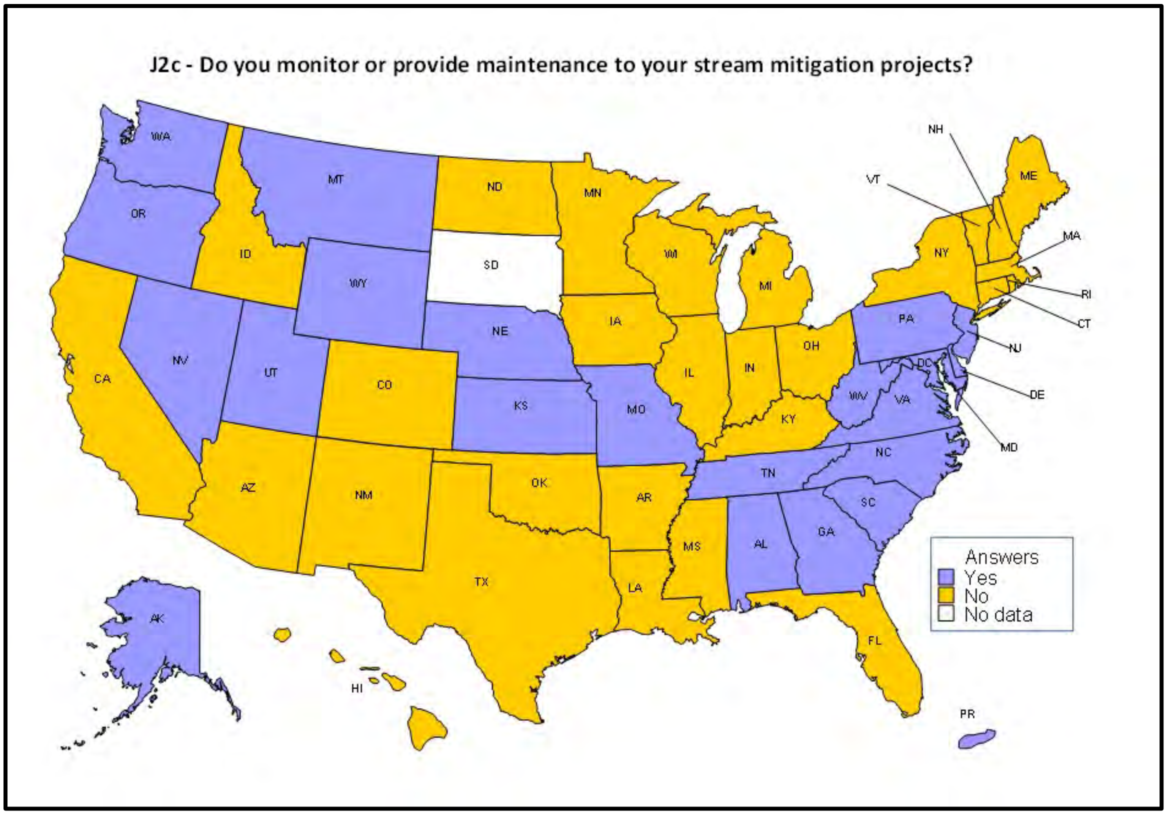


Figure 10.2.3 States and Puerto Rico that monitor and maintain stream mitigation projects.

10.3 Aquatic Organism Passage

This section presents three questions on states' practices in aquatic organism passage that includes how frequently aquatic organism passage is considered, the effects on project scheduling and whether documented design guides or tools are available.

Question J.3.a

3. Aquatic Organism Passage/Fish Passage Design
   a. How often is passage considered when designing projects?

Every Time	Routinely	Occasionally	Never
○	○	○	○

Response:

The results show that nine (9) states and Puerto Rico consider aquatic organism passage every time, sixteen (16) states routinely, seventeen (17) states occasionally, and eight (8) states never consider it. Figure 10.3.1 shows the individual response of each state.

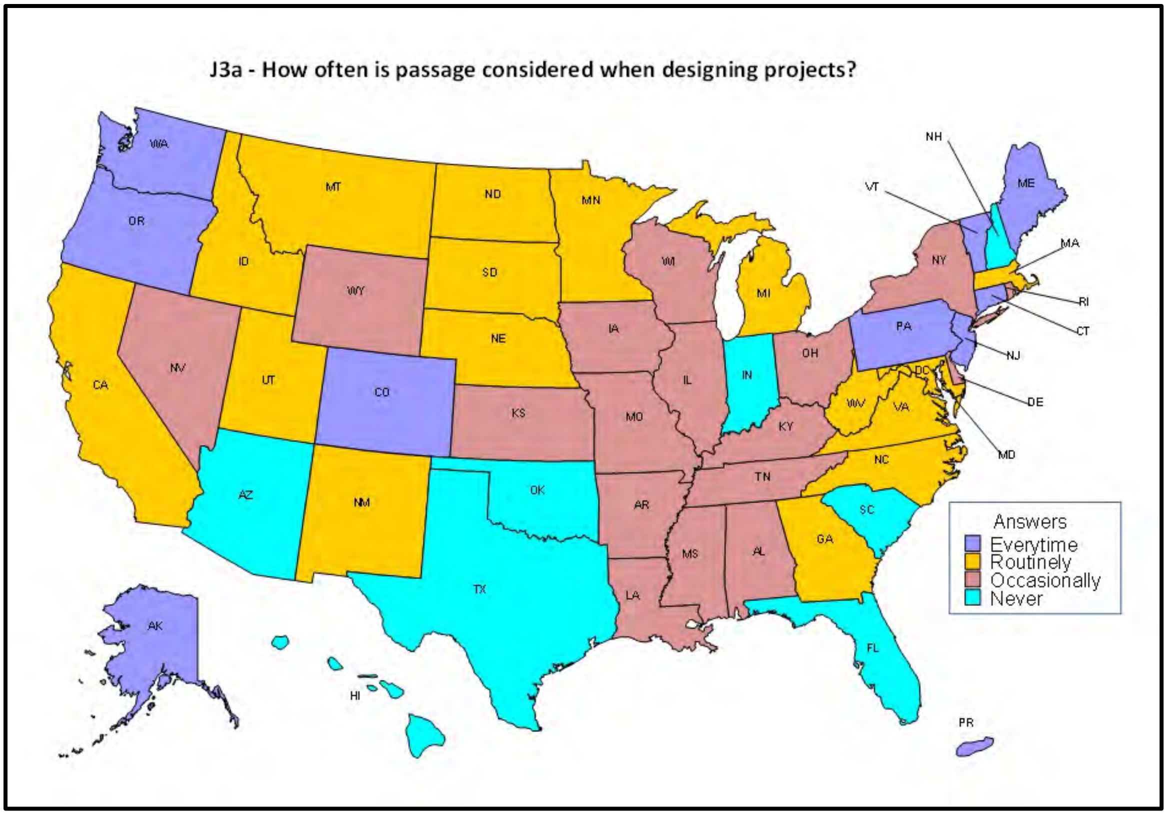


Figure 10.3.1 Frequency that individual states consider aquatic organism passage in stream crossing design.

Question J.3.b

b. Does incorporation of aquatic organism or fish passage design considerations cause significant project delays?

Yes	No
○	○

Response:

The response shows that eighteen (18) states and Puerto Rico experience project delays when incorporating aquatic organism design. Figure 10.3.2 provides the individual response of each state.

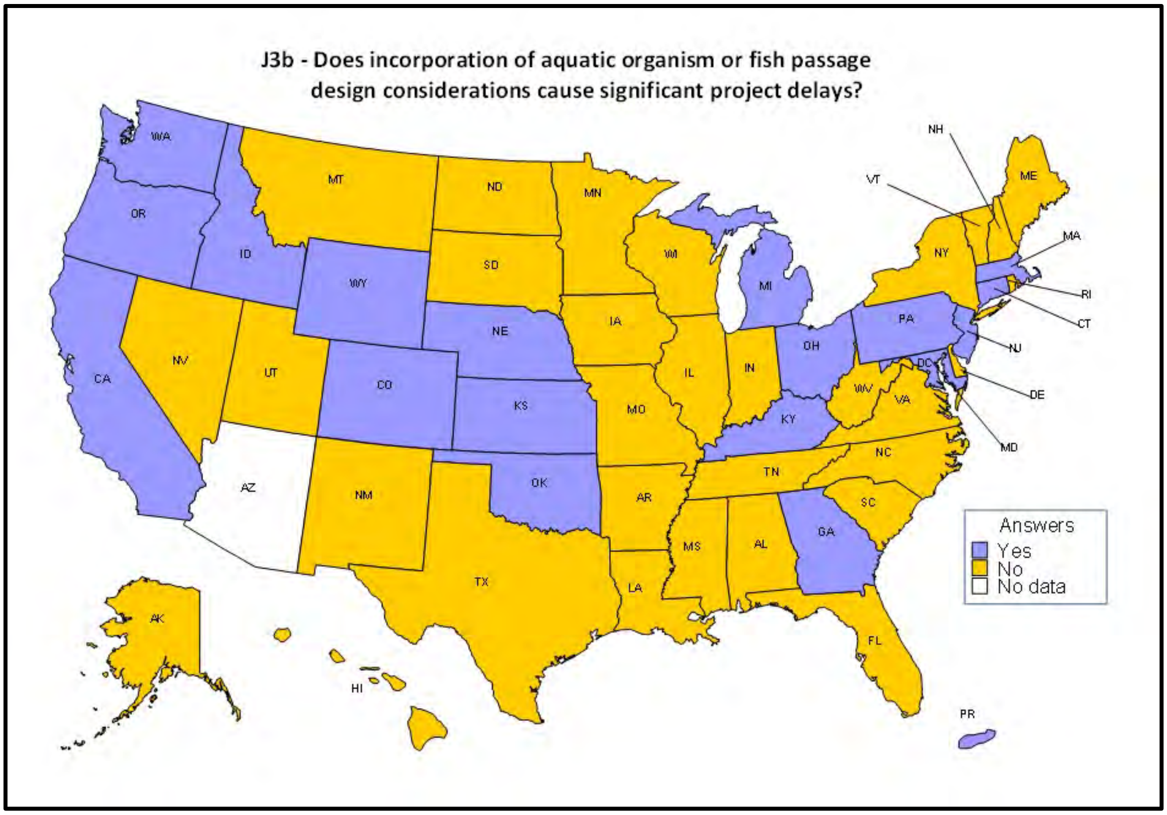


Figure 10.3.2 States that experience project delays with aquatic organism design.

Question J.3.c

c. Do you have documented design guides or tools for passage?

Yes	No
○	○

If these guides or tools are available online, please provide a link:

Response:

Fifteen states responded that they had documented design guides and the web link to the respective states is provided below:

- Alaska:
  http://www.habitat.adfg.alaska.gov/tech_reports/standards_techniques/dot_adfg_fishpass080301.pdf / /
  http://www.dot.state.ak.us/stwddes/desenviron/assets/pdf/procedures/agmt_safepsg.pdf
- California:
  http://www.dot.ca.gov/hq/oppd/fishPassage/index.htm
- Georgia:
  http://www.dot.ga.gov/doingbusiness/PoliciesManuals/roads/Pages/DesignPolicies.aspx
- Maine:
  http://www.maine.gov/mdot/environmental-office-homepage/fishpassage/3rd%20edition%20-%20merged%20final%20version%207-01-08a1.pdf
- Massachusetts:
  Wildlife Accommodation Guidelines are presented in Chapter 14 of the 2006 MassDOT PDDG
- New Jersey:
  http://www.state.nj.us/transportation/eng/documents/drainage/drainage.shtm
  Chapter 8.8 is about fish passage design, and it refers you to this link
  http://www.nj.gov/dep/landuse/announce/fhamanual20081201.pdf , which covers fish passages in chapter 5.
- North Carolina:
  http://www.ncdot.org/doh/preconstruct/highway/hydro/gl0399web/default.html
- Pennsylvania:
  Do you have documented design guides or tools for passage? Yes, BD 632 M. It was developed in conjunction with our PA Department of Environmental Protection and also PA Fish and Boat Commission.
  http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/H&HHomepage?OpenFrameset
- Utah:
  http://www.udot.utah.gov/main/uconowner.gf?n=3579663616055573662
- Vermont:
  "Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont"
  http://www.vtfishandwildlife.com/library/Reports_and_Documents/Aquatic%20Organism%20Passage%20at%20Stream%20Crossings/_Guidelines%20for%20the%20Design%20of%20Stream_Road%20Crossings%20for%20Passage%20of%20Aquatic%20Organisms%20in%20Vermont.pdf

- Washington:
  www.wdfw.wa.gov/hab/engineer/cm/
- West Virginia:
  http://www.wvdot.com/engineering/TOC_engineering.htm / Drainage Manual section 8.7.14

Additional Comments:

- Florida - we develop artificial reefs from demolished bridges - the grouper are happy :)

10.4 Resource Agency Requirements

The section on resource agency requirements focuses on the impact of requirements on project schedules.

Question J.4.a

4. Resource Agency Requirements
   a. Do resource agency requirements/comments cause significant project delays?

Yes	No
○	○

Are these delays due to:

			Yes	No
Hydraulic Revisions			○	○
Environmental Review Backlog			○	○
Inconsistent/insufficient Guidance on Requirements			○	○
Other			○	○

If you do not have delays, could you explain if you have implemented processes that reduce or eliminate the delays?

Additional Comments:

Response:

Table 10.4.1 provides the number of states that experience significant project delays because of resource agency requirements. Table 10.4.2 displays the individual responses of states and Puerto Rico.

Table 10.4.1 Number of states indicating significant delays and the cause of delays when meeting resource agency requirements.

Resource Agency Requirements/Comments That Cause Delays?	*Number States*
Delays	38
Reasons for Delays:	
Hydraulic Revisions	19
Environmental Review Backlog	26
Inconsistent/insufficient Guidance on Requirements	31
Other	9

Other Reasons for Delays:

- Alaska - Water quality related regulations create significant delays. Onerous requirements occasionally specific individuals, standard time for review is long.
- California – Engineer vs. Planner Conflict.
- Delaware - Lack of foresight and predesign coordination.
- Illinois - Delays are primarily Corp\404 permit due to backlog and unfamiliarity with permit regs. DNR permits can be delayed by hydraulic revisions, but DNR not the issue that Corps is. EPA can also be in the mix, particularly with countermeasures on sensitive streams. EPA input can impact bridge scour countermeasure type selection and ultimately effectiveness. This is certainly an area where one agency has overstepped rational bounds.
- Maryland - Inconsistencies are due to variations in interpretations of the guidelines or lack thereof.
- Montana - It is difficult to say that delays are common place but they certainly do occur. Some times there are differences of opinions between general engineering principles and resource agency wants.
- New York - Resource agency requirements do not significantly cause delays, but do add to costs. In NY, the Corps of Engineers Nationwide Permit Regional Conditions require all stream crossings (except for documented cases where not feasible) to have 2 ft. native stream bed material in culvert bottom (requiring either depressed culvert or 3 sided structure for additional cost) and to span the bankfull channel width (increasing span and cost over what may be needed to satisfy hydraulic criteria). Since most NYSDOT (and local agency) culvert projects are replacement of existing structures, and the COE permits apply to all

replacement structures on fish-bearing streams, new culverts are now routinely being upsized compared to existing. This may well be beneficial for an aquatic organism passage, but does increase construction cost compared to previous design criteria.
- Pennsylvania – Hydraulic Revisions rarely cause delays. Environmental Review Backlog does cause delays (PFBC, Game Com, DCNR). Inconsistent/insufficient Guidance on Requirements occasionally causes delays.
- Rhode Island - Superfluous Comments.
- Texas - finding suitable mitigation acceptable to USACE.
- West Virginia - Our resistance to spending additional time and money to meet continually changing requirements.

States' Processes That Reduce or Eliminate Delays:

- Alaska - Training and experience helps all phases of the project.
- Arkansas - Environmental Division is involved in design process at about 40% plan development stage, and any issues are worked out concurrently with design. No significant migratory fish populations in state.
- Iowa - All environmental issues are dealt with at the concept stage so that when design is initiated, any wetlands or stream mitigation is already determined for the project and incorporated into the design.
- Maine - Monthly interagency meeting; batch permits; MOAs, MOUs.
- Minnesota - We have a DNR liaison, DNR employee paid by Mn/DOT to keep projects moving forward and to identify problems early in the process. We also changed the process to get DNR input much earlier in preliminary design.
- Montana - We tend to work through the differences but it takes significant time, effort, and meetings sometimes resulting in numerous revisions to details, plans, special provisions. We do have processes in place for permit review times and escalation processes.
- New Hampshire - The NHDOT Bureau of Environment coordinates monthly Natural Resource Meetings where Resource Agency requirements are addressed with stakeholders.
- North Dakota - Through our SOV process, we receive adequate input from agencies, and generally have adequate time to include any necessary requirements in our projects during the concept phase.
- Pennsylvania - PennDOT has dedicated staff (via funded positions) at resource agencies. These staff only do PennDOT work. This has helped considerably.
- Wisconsin - WisDOT has a Cooperative Agreement with our Department of Natural Resources (WDNR), this agreement allows WisDOT (and our contractors) to do work on DOT projects without getting most permits, state issued and those delegated to the state to administer. WDNR is involved in our projects at multiple times from planning through design and into construction where they have several opportunities to review and comment and can inspect projects at any time. This ability to comment throughout the project development process allows input from WDNR to be reviewed multiple times which in turn gives a confidence that WDNRs concerns have been addressed.

Table 10.4.2 States' responses on project delays due to resource agency requirements.

J4a - Do resource agency requirements/comments cause significant project delays?					
		Delays Due To:			
State	Delays	Hydraulic Revisions	Environmental Review Backlog	Inconsistent/ insufficient Guidance on Requirements	Other
AL					
AK	■		■	■	■
AZ	■	■		■	
AR					
CA	■	■	■	■	■
CO	■	■		■	■
CT	■	■	■	■	
DE	■		■		■
FL	■	■			
GA	■	■	■	■	
HI	■		■		
ID	■	■	■	■	
IL	■	■	■	■	
IN	■		■	■	
IA					
KS	■		■	■	
KY	■		■	■	
LA					
ME					
MD	■			■	
MA	■	■		■	
MI	■		■	■	
MN					
MS	■				
MO					
MT					
NE	■	■	■	■	
NV	■		■		
NH	■		■	■	
NJ	■	■	■	■	■
NM	■		■	■	■
NY					
NC	■	■		■	
ND					
OH					
OK	■		■	■	
OR					
PA	■		■	■	
PR	■	■	■	■	
RI	■		■	■	■
SC	■	■	■	■	
SD	■				
TN	■			■	
TX	■	■	■		■
UT	■	■	■	■	
VT	■	■		■	
VA	■			■	
WA	■	■		■	
WV	■		■	■	■
WI					
WY	■	■	■	■	

11.0 Training

The chapter on training contains four sections addressing agencies' training programs including training subjects, sources, and training methods such as instructor-led, webinar, and conferences.

11.1 Non-NHI Training

The first section contains two questions on staff hydraulic training from sources other than the National Highway Institute (NHI).

Question K.1.a

K. Training
  1. Training (Non NHI)
    a. Do you provide or sponsor training on:

			Training Developed By	
	Yes	No	DOT Staff	Other Organization
Hydrology	○	○	☐	☐
Bridge Hydraulics	○	○	☐	☐
Culvert Hydraulics	○	○	☐	☐
Storm Drain Design	○	○	☐	☐
Roadside Ditch Design	○	○	☐	☐
Scour and Stream Stability	○	○	☐	☐
Erosion and Sediment Control	○	○	☐	☐

Response:

Figure 11.1.1 provides a bar chart showing the number of states that provide staff with non-NHI training on each of the seven hydraulic subject areas listed. Table 11.1.1 shows which states provide non-NHI hydraulic training in each of the hydraulic subject areas.

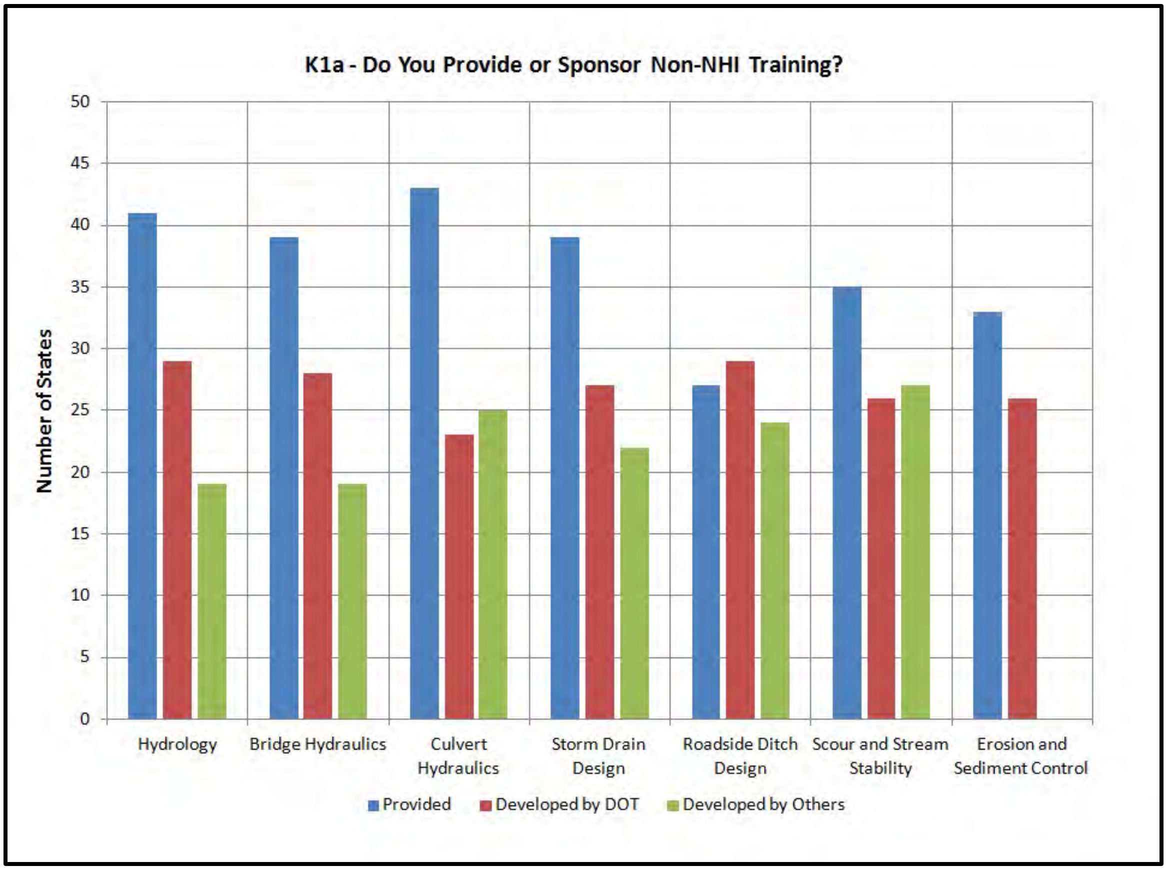


Figure 11.1.1 Number of states providing non-NHI training on hydraulic subjects.

Table 11.1.1 Hydraulic subjects taught with non-NHI sources in the respective states and Puerto Rico.

K1a - Do you provide or sponsor training on:	Hydrology			Bridge Hydraulics			Culvert Hydraulics			Storm Drain Design			Roadside Ditch Design			Scour and Stream Stability			Erosion and Sediment Control		
		Devel-oped by:			Devel-oped by:			Devel-oped by::			Devel-oped by:			Devel-oped by:			Devel-oped by:			Devel-oped by:	
State	Provided	DOT Staff	Other Organization	Provided	DOT Staff	Other Organization	Provided	DOT Staff	Other Organization	Provided	DOT Staff	Other Organization	Provided	DOT Staff	Other Organization	Provided	DOT Staff	Other Organization	Provided	DOT Staff	Other Organization
AL	X	X	X				X	X					X	X					X		X
AK	X		X	X		X	X		X	X		X	X	X	X	X		X	X	X	
AZ	X	X	X	X	X	X	X	X	X	X	X	X			X			X			X
AR	X	X		X	X		X	X		X	X										
CA	X	X	X				X	X	X	X	X	X	X	X	X	X		X		X	
CO	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CT										X	X	X							X	X	
DE	X	X		X	X		X	X		X	X	X	X	X					X		X
FL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GA	X		X	X		X	X		X	X		X	X		X	X		X	X		X
HI																			X	X	X
ID	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
IL	X	X					X	X		X	X		X	X					X	X	
IN	X	X	X	X	X	X	X	X		X	X					X	X				
IA	X		X	X		X	X		X	X		X				X		X	X		X
KS	X	X		X	X	X	X	X								X	X				
KY										X	X	X									
LA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
ME	X	X		X	X		X			X	X					X	X		X	X	
MD	X	X	X	X	X	X	X	X		X	X					X	X	X		X	
MA	X		X	X		X	X		X	X		X	X		X	X		X	X		X
MI	X	X		X	X		X	X		X	X		X	X					X	X	
MN				X	X		X	X		X	X					X	X		X		X
MS																					
MO	X	X	X	X	X		X	X	X	X						X					
MT		X			X			X			X			X			X			X	
NE	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X
NV	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NH	X		X	X		X	X		X	X		X	X		X	X		X	X		X
NJ	X		X	X		X	X		X	X		X	X		X	X		X	X		X
NM	X	X	X	X		X	X		X	X		X	X		X	X		X	X	X	X
NY	X	X		X	X		X	X								X	X				
NC	X	X		X	X		X	X		X	X		X	X		X	X				
ND																					
OH				X	X		X	X								X	X	X			
OK	X	X	X				X	X	X	X	X	X	X	X	X						
OR	X		X	X		X	X		X	X		X	X		X	X		X	X		X
PA	X		X	X		X	X		X	X		X	X		X	X		X	X		X
PR	X		X	X		X	X			X			X			X			X		
RI				X		X	X		X									X			
SC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SD	X		X	X		X	X		X							X		X	X		X
TN	X		X	X		X	X		X	X		X	X		X	X		X	X		X
TX	X		X	X		X	X		X	X		X				X		X	X		X
UT	X	X	X	X		X	X	X	X	X	X	X				X	X	X			
VT	X		X	X		X	X		X										X	X	
VA	X	X		X		X	X	X		X	X		X	X		X		X	X		X
WA	X	X					X	X		X	X		X	X		X	X			X	
WV	X	X		X	X		X	X		X	X		X	X		X	X		X	X	
WI																			X	X	
WY	X	X		X	X			X		X						X	X		X	X	

Question K.1.b

b. Do you present hydraulic related topics at state-wide training conferences or web meetings?

Yes	No
○	○

Response:

The responses show that 27 states provide hydraulic training at state-wide meetings or webinars. The responses of individual states and Puerto Rico are shown in Figure 11.1.2.

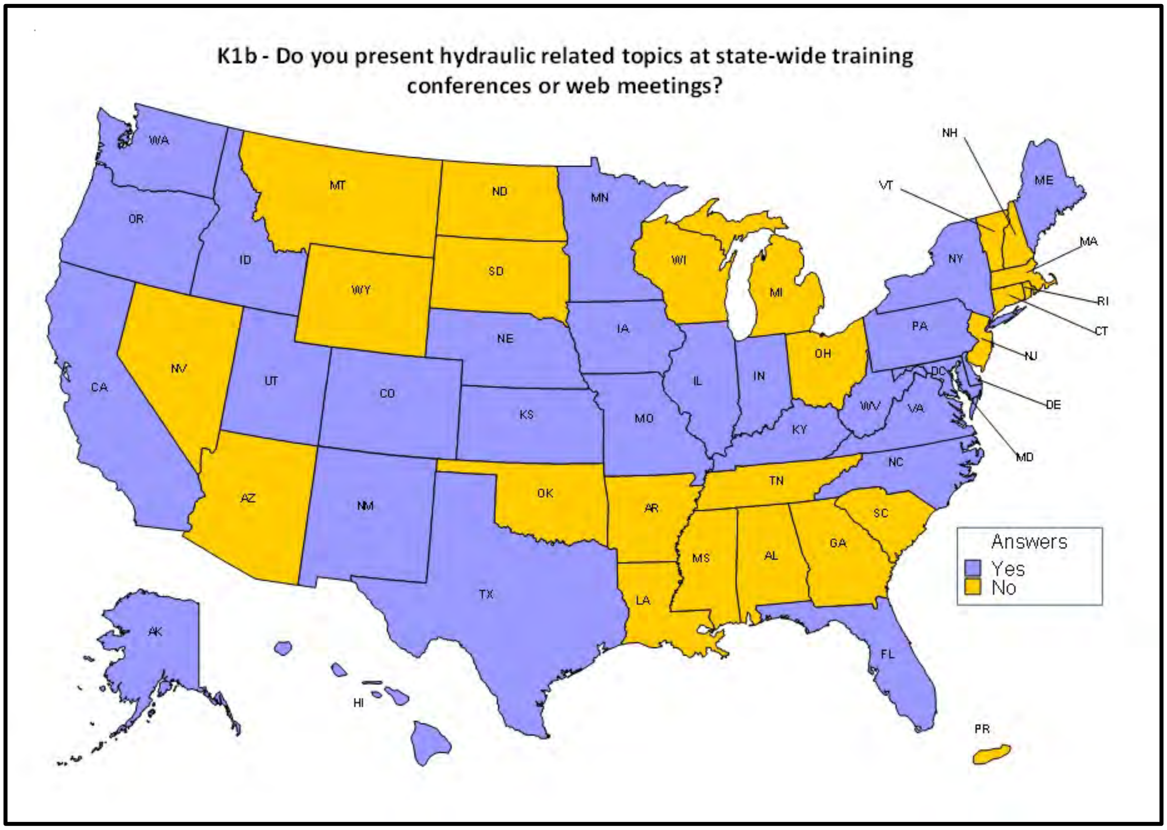


Figure 11.1.2 States that provide training through state-wide meetings or webinars.

11.2 NHI Training

This section contains three questions on the states use of NHI training including which hydraulic courses they have hosted, reasons for not hosting some classes, and whether they would be interested in instructor lead web based training.

<u>Question K.2.a</u>

2. Training (NHI)
    a. Have you, will you, or would you like to host an NHI Course?

	In the Last 5 Years	Scheduled	Would Like
135027 Urban Drainage Design	○	○	○
135028 Storm Water Pump Station Design	○	○	○
135041 HEC-RAS	○	○	○
135046 Stream Stability and Scour	○	○	○
135047 Stream Stability and Scour for Bridge Inspectors	○	○	○
135048 Countermeasure Design	○	○	○
135056 Culvert Design	○	○	○
135065 Introduction to Highway Hydraulics	○	○	○
135067 Practical Highway Hydrology	○	○	○
135071 Surface Water Modeling System (SMS)	○	○	○
135080 Hydrologic Analysis and Modeling (WMS)	○	○	○
135081 Introduction to Highway Hydraulics Software	○	○	○
135082 Highways in a Coastal Environment	○	○	○
135085 Plans of Action for Scour Critical Bridges	○	○	○

Response:

Figure 11.2.1 provides a bar chart of the number of states responding to each of the NHI hydraulic courses listed.

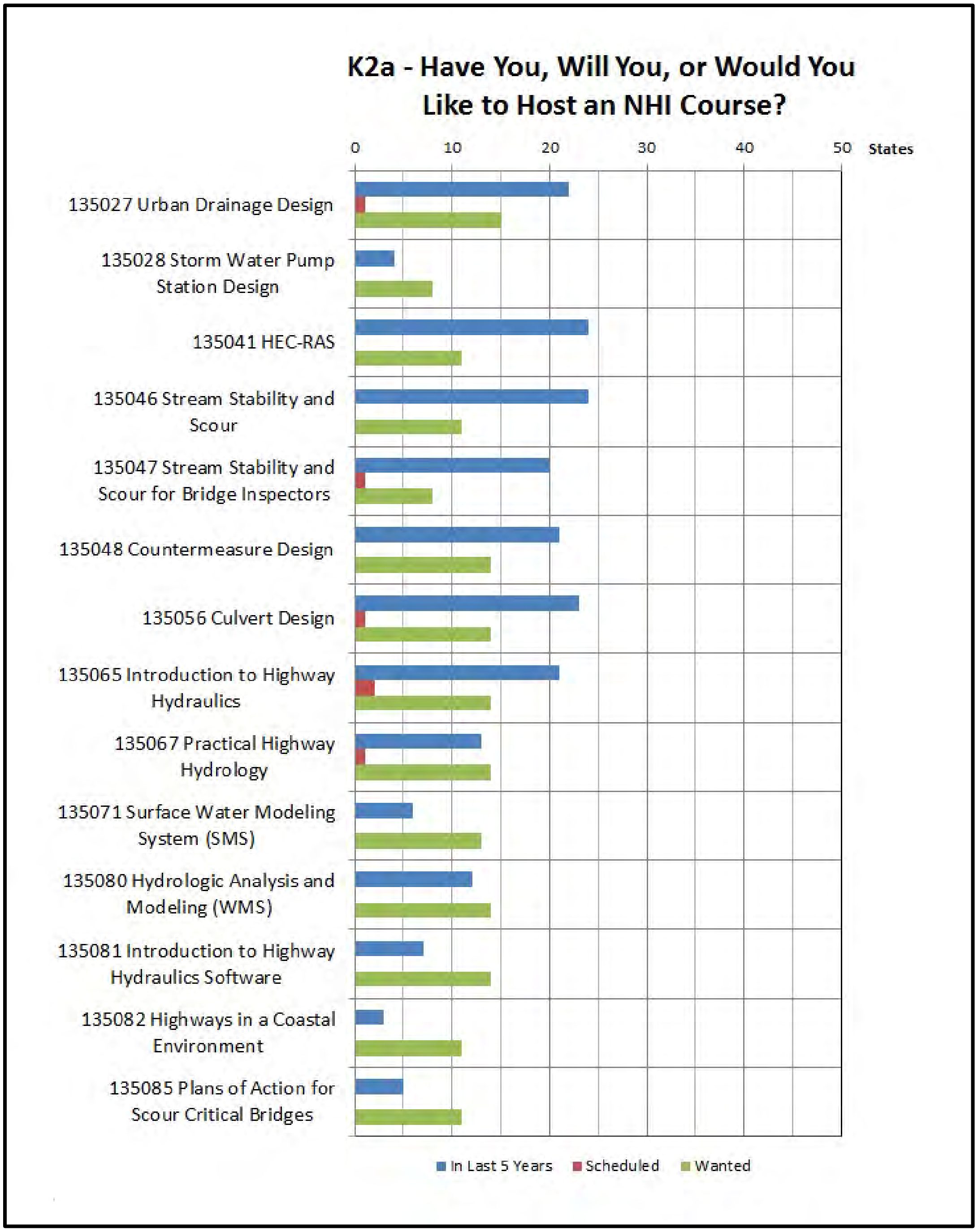


Figure 11.2.1 Number of states that have hosted, scheduled, or desire to host the respective NHI hydraulic courses.

Question K.2.b

b. Please check the reasons you have for not hosting NHI courses:

	Yes	No
Low Budget	○	○
Insufficient Staff Numbers to Fill Class	○	○
Workload Too Great	○	○
Do Not Like Course Materials	○	○
Not Interested	○	○
Other	○	○

Response:

Table 11.2.1 shows that thirty-seven (37) states and Puerto Rico indicated that their low budget was the reason for not hosting courses. Insufficient staff to fill a class and heavy workload are the next most checked reasons for not hosting courses with twenty (20) and nineteen (19) responses respectively.

Table 11.2.1 Reasons provided by states for not hosting NHI courses.

Reasons for not hosting NHI Course?	*Number States*
Low Budget	38
Insufficient Staff Numbers to Fill Class	20
Workload Too Great	19
Do Not Like Course Materials	0
Not Interested	2
Other	5

Other Reasons for Not Hosting NHI Courses:

- Kansas - Too expensive.
- Nevada - Have had similar classes.
- New York - Management doesn't like to invest in NHI Hydraulic courses for a small number of engineers.
- Pennsylvania - PennDOT has funded the development of customized in-house courses for H&H and Drainage Course including topics on WMS, HEC-RAS, Stormwater, Permitting, E&S, etc. These courses are focused on PennDOT requirements and also our state permitting and Federal requirements and our customized to our states hydrologic and hydraulic issues and our Design

Manuals. PennDOT has developed numerous courses and offers them multiple times a year.

- West Virginia - Scour Equations need to be updated.
- Wisconsin - Would like to be more WisDOT specific.

Question K.2.c

c. Would you be interested in taking a course via web conference training (web based with live instructor)?

Yes	No
○	○

Response:

Forty-two states and Puerto Rico responded that they would be interested in web based training opportunities.

11.3 Training Needs

This section consists of only one question that asked states to describe other hydraulic training needs they would like to receive that were not addressed in the questionnaire.

Question K.3

3. Please describe any other training needs you might want but have not already been identified in this survey?

Response:

Seventeen states responded with additional training needs they would like to receive that were not identified in the survey.

Specific State Training Needs:

- Alaska - Stormwater management (permanent BMP) design, focusing on use of data sources available in Alaska, current guides would include detention design, water quality treatment, etc. Use of atypical FEMA programs like fan for alluvial fans and the application of FEMA guidelines to coastal flood zones. River ice engineering. Bridge Deck Drainage Design in cold regions, including stormwater management BMPs.

- Arizona - We are working on receiving training on HEC-HMS, which we are going to fully adopt to replace HEC-1 on all new projects.
- Delaware - Water Quality.
- Florida - Transport and Fate of Pollutants; Pipe soil/structure analysis.
- Georgia - Would like NHI erosion control class and a water quality class,
- Illinois - Hydrograph model such as HMS. I believe HMS is embedded in WMS, but the WMS NHI class doesn't go into HMS in depth.
- Iowa – FESWMS.
- Maryland - Stream Morphology focused to science rather than engineering, long term degradation.
- Montana - We will continue to utilize NHI courses and supplement with courses that may be offered in our area by other entities as they become available.
- Nevada - Practical sediment transport; Detention basin design.
- New Mexico - Culvert Management and Inventory System.
- New York - Our biggest training need is NHI training to maintain proficiency for hydraulic engineers, and to train new regional hydraulic engineers and their assistants. Over the last 8-10 years, NYSDOT has gone from two NHI hydraulic courses per year, to one or none. With NYS current budget problems, all NHI training has been cancelled. How long this will remain in effect is anyone's guess.
- North Carolina - Flume Demonstration.
- South Dakota - I see a need for training is the design of highways in FEMA NFIP floodplains.
- Vermont - Advanced HEC-RAS / DOT specific NFIP training.
- Wisconsin - Design for storm water BMPs for both quantity control and TSS removal.
- Wyoming - DVD courses.

11.4 Regional Network Training

This section consists of two questions to determine if states have participated in regional web conferences or attended a National Hydraulic Engineering Conference.

Questions K.4.a and K.4.b

1. Regional Networks (conferences, web-meetings, teleconferences, etc.)
   a. Have you attended a FHWA hydraulics regional webconference?

Yes	No
○	○

b. Have you attended a National Hydraulic Engineering Conference?

Yes	No
○	○

Additional Comments:

Response:

The response shows that forty (40) states and Puerto Rico have participated in an FHWA hydraulics regional web-conference and that thirty-four (34) states and Puerto Rico have attended a National Hydraulic Engineering Conference. Figure 11.4.1 identifies the response of individual states and Puerto Rico.

Specific State Comments to Clarify Responses:

- Kansas - Online training would be very helpful. Unless hosted on-site, travel costs are too expensive. As of 2009, KDOT out-of-state travel budget is zero. In-state travel budget is severely reduced. FHWA National Hydraulics Conference, and other related conferences, should be offered via the internet (real-time) in 2010 due to recession.
- Maryland - Availability of conference material as training for wider use of engineers via web. Much material can be used for on-line training. Power point with some audio or talking points will be necessary.
- New York - NYSDOT does not let staff attend National Hydraulic Engineer Conference due to prohibition on out of state travel.
- South Carolina - Lack of funding all but precludes trips out of state for training.
- Wisconsin - Need to develop a mechanism so state hydraulic engineers can attend this conference. Out of state travel is highly scrutinized and often times not approved.
- Wyoming - Used to always attend the regional HEC conferences prior to national. Would attend if budget allows.

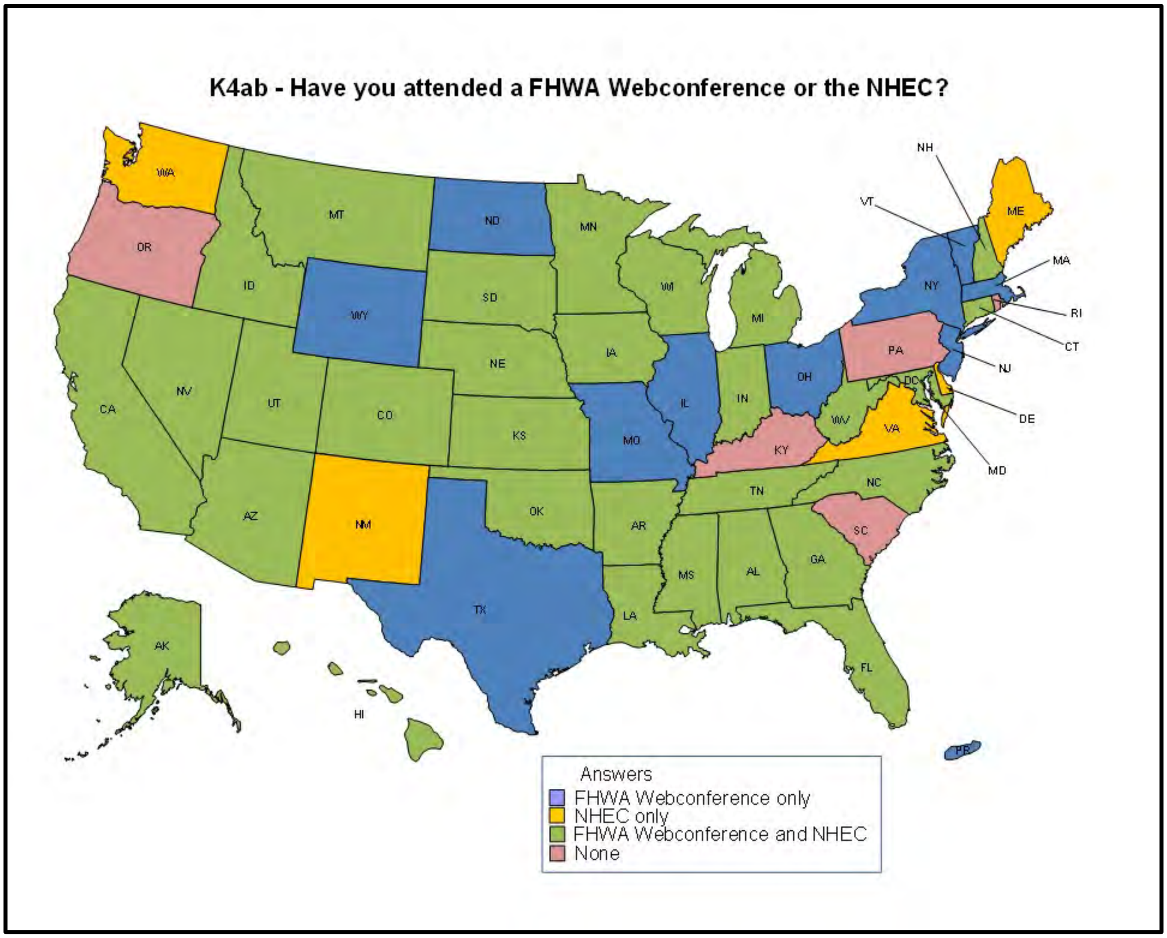


Figure 11.4.1 States that have participated in either an FHWA web-conference or the NHEC.

12.0 Research

12.1 Hydraulic Research Topics

Research categories are described in general hydraulic functional areas of Hydrology, Culverts, Bridges, and Pavement Drainage. Each functional area is further broken down into specific hydraulic topics in order to determine research areas that have been completed or are on-going, as well as those that are planned or that are not planned, but the state would like to see conducted.

<u>Question L.1</u>

L. Research
   1. Please explain what research you have conducted or would like to see conducted for the following categories:

Hydrology

		Recently Completed	Year Completed	On-Going	Planned	Would Like
USGS Regression Equations		☐		☐	☐	☐
Precipitation Frequency Map Updates		☐		☐	☐	☐
Other		☐		☐	☐	☐

Culverts

		Recently Completed	Year Completed	On-Going	Planned	Would Like
Loss Coefficients, Composite, Roughness, etc.		☐		☐	☐	☐
Trenchless Technology		☐		☐	☐	☐
Aquatic Organism Passage Design		☐		☐	☐	☐
Inspection Techniques		☐		☐	☐	☐
Other		☐		☐	☐	☐

Bridges

		Recently Completed	Year Completed	On-Going	Planned	Would Like
Scour		☐		☐	☐	☐
Stream Stability		☐		☐	☐	☐
Debris Accumulation		☐		☐	☐	☐
Countermeasures		☐		☐	☐	☐
Tidal Hydraulics		☐		☐	☐	☐
Tidal Scour		☐		☐	☐	☐
Other		☐		☐	☐	☐

Pavement Drainage

		Recently Completed	Year Completed	On-Going	Planned	Would Like
Hydroplaning		☐		☐	☐	☐
Erosion Control Products		☐		☐	☐	☐
Other		☐		☐	☐	☐

Additional Comments:

Response:

Figure 12.1.1 provides a bar chart that displays the number of states that responded to each of the topical areas of hydraulic research. The responses of the states and Puerto Rico on each individual research topic are shown in Table 12.1.1 to 12.1.4.

Other Hydrology Research Listed by States:

- California – Desert Hydrology completed in 2007.
- Colorado – Peak Flow.
- Florida – Hurricane Rainfall.
- Georgia – Updating Urban Regression Equations.
- Maryland – Regression Equations by Thomas completed in 2005.
- Montana -IDF curves completed in 1998. REM completed in 1996. Evaluation of pier scour eq for coarse bed streams completed in 2004. Determination of channel morphology characteristics, bankfull discharge and various design peak discharges completed in 2004.
- New Hampshire - Problem statement anticipated for impervious area in small watersheds (<2 sq. miles).
- New York - Flows at confluences – NCHRP.
- South Dakota - Paleoflood in Black Hills by USGS.

Year Regression Equations Completed:

- Alabama – 2004 and 2007.
- Alaska – 2003.
- Arkansas – 2007.
- Colorado – 2009.
- Connecticut – 2004.
- Georgia – 2009.
- Illinois – 2004.
- Kansas – 2000.
- Louisiana – 2003.

- Maine – 1999.
- Minnesota – 2009.
- Montana – 2003.
- New Hampshire – 2009.
- New York – 2006.
- North Carolina – 2009.
- Ohio – 2006.
- Oklahoma – 1977.
- South Dakota – 1998.
- Tennessee – 2003.
- Vermont – 2003.
- Washington – 1997.
- West Virginia – 2010.
- Wyoming – 2003.

Year Precipitation Maps Updated:

- Arkansas – 2007.
- Louisiana - 1998.
- Oklahoma – 1999.
- Pennsylvania – 2008.
- South Carolina – 2008.
- South Dakota – In progress with NOAA.
- Washington – 2002.

Other Culvert Research Listed by States:

- Alabama - Effects of Culverts on Natural Conditions of Streams in the Coastal Plain Physiographic Province of Alabama.
- California - Baffle impacts to flow, abrasion.
- Maryland - Low flow culvert hydraulics -pool fund study.
- South Dakota - Box culverts by FHWA Turner Fairbanks.

Year Aquatic Organism Passage Design Research Completed:

- Idaho – 2006.
- Washington – 2008.

Other Bridge Research Listed by States:

- Maryland - Long term degradation study.
- South Dakota – Evaluate SRICOS.

Year Scour Research Completed:

- Alabama – 2007.

- Georgia – 2009.
- Illinois – 2009.
- Massachusetts – 1995.
- Missouri – 2009.

Year Bridge Countermeasure Research Completed:

- Louisiana – 2005.

Year Bridge Tidal Hydraulics Research Completed:

- Louisiana – 2009.
- Maryland – 2004.
- Massachusetts – 1993.

Other Pavement Drainage Research Listed by States:

- Delaware – Inlet Grate Efficiency.
- Florida – Groundwater Effects on RM.
- Maryland - Stormwater Management Performance of Underground Facility, Failed infiltration basins.

Other Research Conducting or Would Like:

- Alaska - Would like research on loss coefficients, composite roughness, etc. depending upon the scope, objective, goals, etc. Would like research on aquatic organism passage design depending upon the scope, objective, goals, etc. With respect to trenchless technology, have projects that could be researched. Scour research with USGS. Tidal hydraulics - USGS is using Delft S-D at an Alaska Bridge. Depending on scope, objective, and goals, would like research on stream stability, debris accumulation, and countermeasures, and hydroplaning.
- Georgia - Currently funding research on pavement stormwater runoff water quality. Also, currently funding research on improving scour prediction formulas by studying simultaneous local and contraction scour and studying pressure scour to determine the interaction of pier scour, local scour and abutment scour at overtopping.
- Illinois - Scour research done by USGS Illinois office in Urbana on EFA-SRICOS scour testing\estimating, the Texas A&M methodology. Also fiber-optic scour monitoring project underway. Would like update of Urban regression equations and update of statewide rainfall data used for hydrologic applications.
- Missouri - Erosion Control on going through new products evaluation. No research per se.
- New Mexico - NMDOT is funding a research study to develop a risk index for watercourse aggradation and degradation.
- Ohio - Fixed Scour Monitoring.

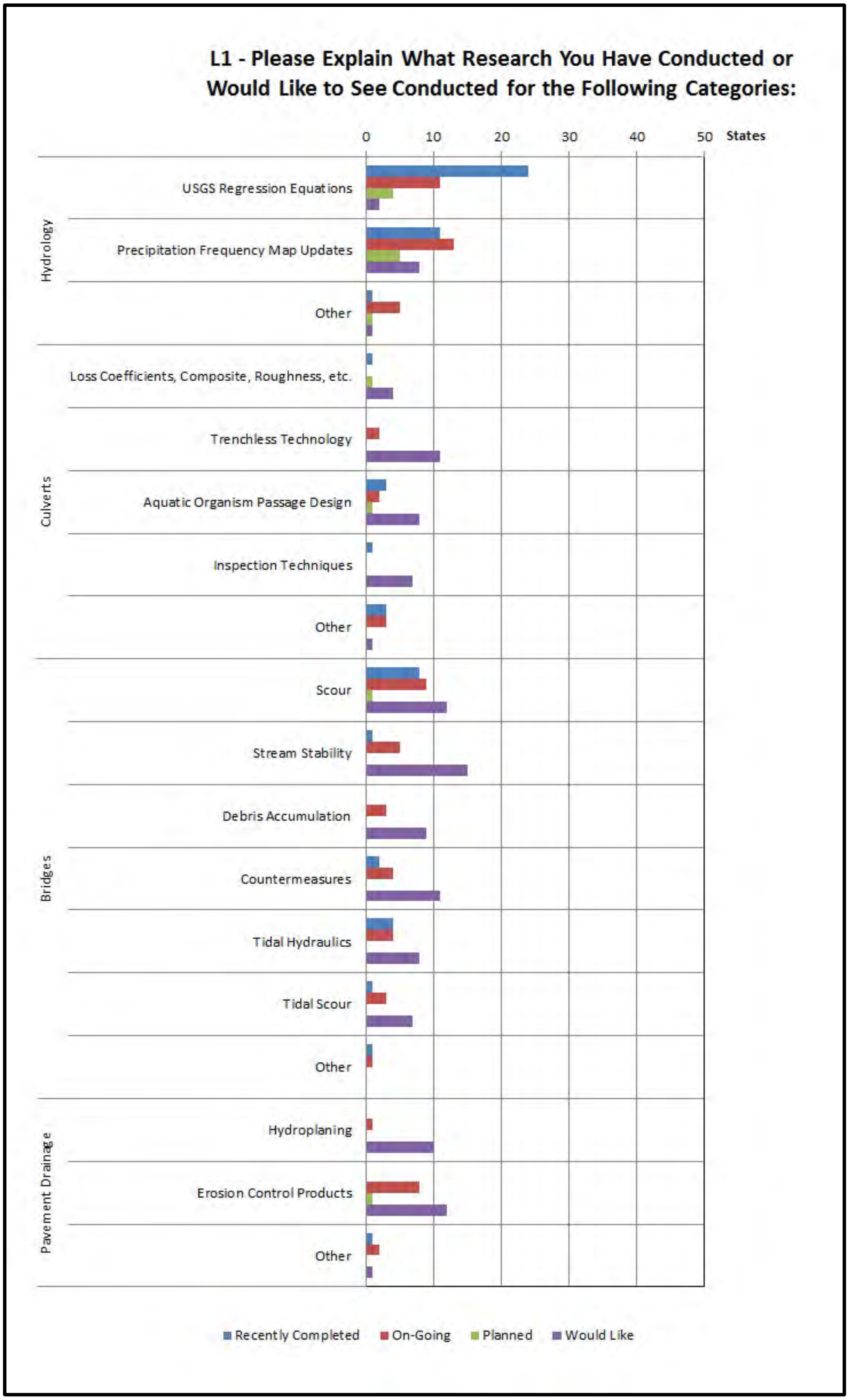


Figure 12.1.1 Number of states responding to each of the research categories listed in question L.1.

Table 12.1.1 Individual state responses regarding hydrology research.

L1 - Please Explain What Research You Have Conducted or Would Like to See Conducted for Hydrology												
	Recently Completed			On-Going			Planned			Would Like		
State	USGS Regression Equations	Precipitation Frequency Map Updates	Other	USGS Regression Equations	Precipitation Frequency Map Updates	Other	USGS Regression Equations	Precipitation Frequency Map Updates	Other	USGS Regression Equations	Precipitation Frequency Map Updates	Other
AL	■			■				■				
AK					■		■					
AZ							■					
AR	■	■										
CA				■	■							
CO	■				■				■			
CT	■										■	
DE	■	■										
FL	■			■								■
GA	■				■	■						
HI				■							■	
ID												
IL	■										■	
IN												
IA				■	■							
KS	■										■	
KY	■	■										
LA	■	■		■	■							
ME	■							■				
MD			■			■						
MA							■	■				
MI												
MN	■				■							
MS				■	■							
MO					■							
MT				■		■						
NE					■							
NV										■	■	
NH	■										■	
NJ												
NM												
NY	■					■		■				
NC	■											
ND				■								
OH	■											
OK	■	■										
OR		■								■		
PA		■										
PR												
RI												
SC		■										
SD					■	■	■					
TN	■	■										
TX	■	■										
UT	■										■	
VT	■				■			■				
VA												
WA	■	■										
WV				■								
WI				■	■							
WY	■										■	

Table 12.1.2 Individual state responses regarding culvert research.

State	L1 - Please Explain What Research You Have Conducted or Would Like to See Conducted for Culverts: Recently Completed					On-Going					Planned					Would Like				
	Loss Coefficients, Composite, Roughness, etc	Trenchless Technology	Aquatic Organism Passage Design	Inspection Techniques	Other	Loss Coefficients, Composite, Roughness, etc	Trenchless Technology	Aquatic Organism Passage Design	Inspection Techniques	Other	Loss Coefficients, Composite, Roughness, etc	Trenchless Technology	Aquatic Organism Passage Design	Inspection Techniques	Other	Loss Coefficients, Composite, Roughness, etc	Trenchless Technology	Aquatic Organism Passage Design	Inspection Techniques	Other
AL					■					■								■		
AK							■										■		■	
AZ																				
AR																				
CA					■												■			
CO																				■
CT																				
DE																		■		
FL							■													
GA								■								■	■		■	
HI																				
ID			■																	
IL																				
IN																				
IA											■									
KS								■												
KY																		■	■	
LA																				
ME																				
MD										■										
MA																		■		
MI																■				
MN													■							
MS																				
MO																				
MT																				
NE																				
NV																				
NH																	■		■	
NJ																				
NM					■					■										
NY																■	■	■	■	
NC																				
ND																				
OH																				
OK																				
OR																■	■	■	■	
PA																		■		
PR																	■			
RI																			■	
SC																				
SD	■																			
TN																				
TX																				
UT			■	■																
VT																	■			
VA																				
WA			■														■			
WV																				
WI																	■	■		
WY																				

Table 12.1.3 Individual state responses regarding bridge research.

L1 - Please Explain What Research You Have Conducted or Would Like to See Conducted for Bridges																												
State	Recently Completed							On-Going							Planned							Would Like						
	Scour	Stream Stability	Debris Accumulation	Countermeasures	Tidal Hydraulics	Tidal Scour	Other	Scour	Stream Stability	Debris Accumulation	Countermeasures	Tidal Hydraulics	Tidal Scour	Other	Scour	Stream Stability	Debris Accumulation	Countermeasures	Tidal Hydraulics	Tidal Scour	Other	Scour	Stream Stability	Debris Accumulation	Countermeasures	Tidal Hydraulics	Tidal Scour	Other
AL	■																					■						
AK								■				■														■	■	
AZ																												
AR																							■		■			
CA																							■					
CO																						■	■	■	■			
CT																												
DE												■	■										■					
FL	■			■	■	■																						
GA	■							■																				
HI																												
ID																												
IL	■																											
IN																												
IA								■																				
KS								■	■	■															■			
KY																						■	■		■			
LA				■	■			■	■	■	■	■	■															
ME																												
MD					■		■							■														
MA	■				■																		■	■	■		■	
MI																						■		■	■			
MN											■																	
MS																						■	■	■	■	■	■	
MO	■																											
MT																												
NE																												
NV																						■	■					
NH	■																						■	■				
NJ																												
NM																												
NY																						■	■	■	■	■	■	
NC																										■	■	
ND																												
OH								■																				
OK																												
OR								■	■	■	■	■	■															
PA																						■	■					
PR																						■	■		■	■	■	
RI																						■				■	■	
SC																												
SD								■	■																			
TN																												
TX	■	■																					■			■		
UT								■	■		■													■				
VT																							■					
VA																												
WA																								■	■	■		
WV															■							■	■	■	■			
WI																						■						
WY																												

Table 12.1.4 Individual state responses regarding pavement drainage research.

L1 - Please Explain What Research You Have Conducted or Would Like to See Conducted for Pavement Drainage												
	Recently Completed			On-Going			Planned			Would Like		
State	Hydroplaning	Erosion Control Products	Other	Hydroplaning	Erosion Control Products	Other	Hydroplaning	Erosion Control Products	Other	Hydroplaning	Erosion Control Products	Other
AL								■				
AK											■	
AZ												
AR												
CA										■	■	
CO										■	■	
CT												
DE											■	■
FL			■		■					■		
GA					■	■				■		
HI												
ID												
IL												
IN												
IA												
KS												
KY											■	
LA					■							
ME												
MD					■	■						
MA										■	■	
MI												
MN					■							
MS				■								
MO					■							
MT												
NE												
NV											■	
NH											■	
NJ												
NM												
NY											■	
NC										■		
ND												
OH												
OK										■		
OR					■					■		
PA											■	
PR											■	
RI												
SC												
SD												
TN												
TX					■							
UT												
VT												
VA												
WA										■		
WV										■	■	
WI												
WY												

13.0 Software Design Aids

This question asks states to identify which hydrologic software they use for highway design.

13.1 Hydrologic Software

Question M.1

M. Software Design Aids
1. Hydrologic Software
   (check all that you use)

☐	PEAKFQ (USGS Flood Frequency Analyses)		
☐	HEC-1 (USACE Flood Hydrograph Package)		
☐	HEC-HMS (USACE Flood Hydrologic Modeling System)		
☐	HEC-SSF (USACE Statistical Software Package)		
☐	TR-55 (National Resources Conversation Service Release Number 55)		
☐	WIN TR-20 (National Resources Conversation Service Release Number 20)		
☐	NFF (National Flood Frequency Program)		
☐	NSS (National Streamflow Statistics Program)		
☐	WMS (Watershed Modeling System)		
☐	Other		
☐	Other		

Response:

Figure 13.1.1 provides a bar chart displaying the number of states that use each of the hydrologic software programs listed. TR-55 is the most commonly used software as indicated by 35 states and Puerto Rico closely followed by HEC-HMS with thirty-three (33) states and Puerto Rico using it. The responses of individual states and Puerto Rico is shown in Table 13.1.1.

Other Hydrologic Software Design Aids Used:

- California – IDF2000; NWS Atlas 14.
- Connecticut – USGS Stream Stats.
- Illinois – Illinois Stream Stats.
- Iowa – FESWMS.
- Maine - HydroCAD (like TR20).
- Maryland - GISHydro 2000.
- Minnesota – HydroCAD; XPSWMM.

- Missouri - In-house runoff software w/ various methods. In-house log pearson routine.
- Montana – Fish X-ing; Storm Cadd/Pond Pack.
- Nebraska – ARCVIEW Regression Equations.
- New Hampshire - HydroCAD, (TR-20 surrogate, uses polynomials).
- New York - USGS StreamStats (beta for NY); NYS Flood Frequency Tool (developed by NY office USGS.
- Pennsylvania - EFH2; WRC.
- Puerto Rico – ICPR.
- South Carolina – ICPR; XP-SWMM.
- Washington – MGS Flood; Stormshed.
- Wisconsin - Hydro CADD, StormCAD.
- Wyoming - SCS, SWMM,KinematicWaVE. In house programs; Regional regression, SBUH,Stanford,Chicago Kinematic wave rainfall runoff model,CHUP.

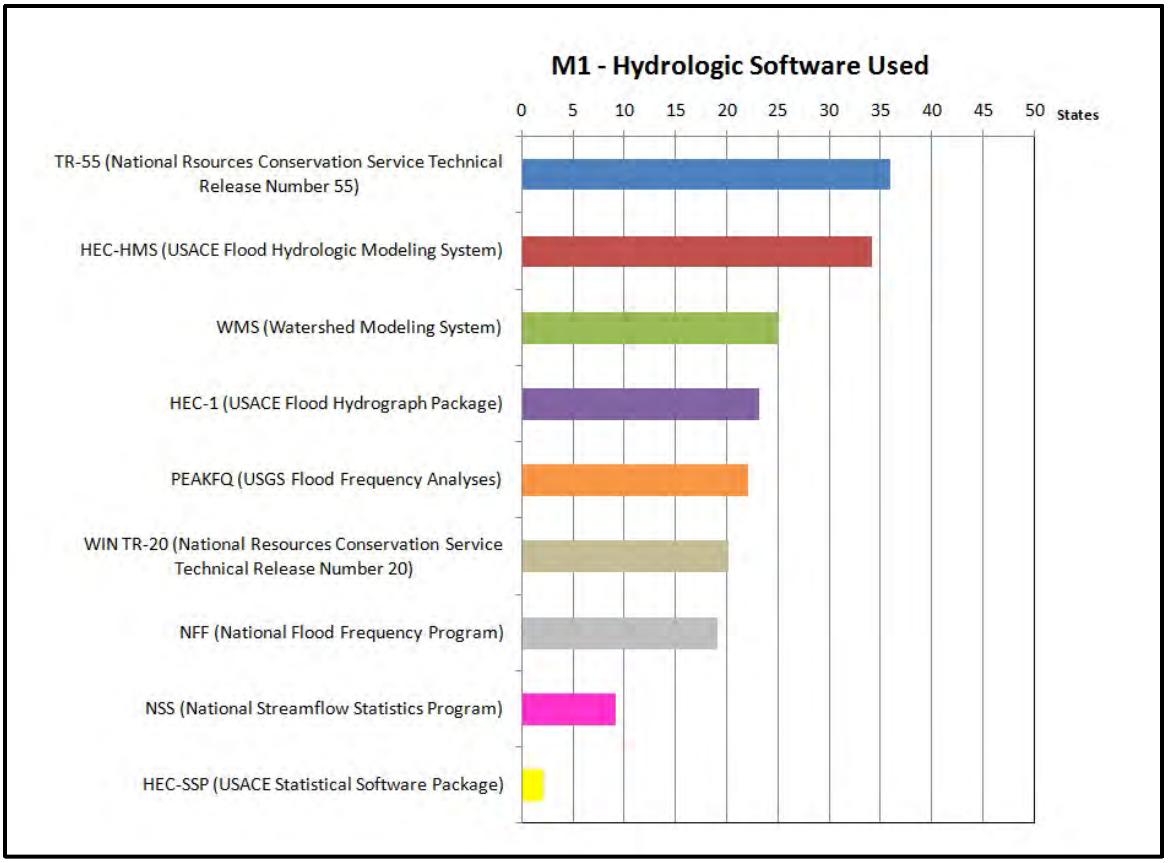


Figure 13.1.1 Number of states using the hydrology software listed.

Table 13.1.1 States' use of hydrologic software.

State	M1 - Software Design Aids - Hydrologic Software Used									
	PEAKFQ	HEC-1	HEC-HMS	HEC-SSF	TR-55	WIN TR-20	NFF	NSS	WMS	Other
AL			X		X					
AK	X				X				X	
AZ		X	X						X	
AR		X	X		X		X			
CA		X	X		X	X	X		X	X
CO	X	X	X		X	X	X		X	
CT			X		X	X			X	X
DE			X		X	X	X	X		
FL	X				X					
GA		X	X		X	X	X		X	X
HI					X	X				
ID	X	X			X		X			
IL		X	X		X	X	X			X
IN	X		X		X	X				
IA			X		X					X
KS			X		X					
KY			X				X		X	
LA	X	X	X		X					X
ME			X			X				X
MD	X				X	X				X
MA	X	X	X	X	X	X	X	X	X	
MI					X	X				
MN	X						X		X	X
MS										
MO			X							X
MT			X						X	X
NE					X	X				X
NV	X	X			X				X	
NH			X		X	X	X	X	X	X
NJ		X	X		X	X		X	X	
NM	X	X	X		X		X	X	X	
NY		X			X				X	X
NC		X						X		
ND			X					X		
OH	X									
OK	X	X	X		X		X		X	
OR	X		X	X	X				X	
PA	X	X	X		X	X	X	X	X	X
PR	X	X	X						X	X
RI			X		X					
SC	X	X			X	X			X	X
SD	X		X				X		X	
TN			X		X					
TX	X	X	X		X	X				
UT		X	X				X	X	X	
VT							X		X	
VA	X	X	X		X	X	X		X	
WA					X					X
WV					X					
WI	X	X	X		X	X	X			X
WY	X	X	X						X	X

13.2 Hydraulic Design Software

This question lists hydraulic design software provided by FHWA and the Corps of Engineers and asks each state and Puerto Rico to identify which ones that they use.

Question M.2

2. Hydraulic Design Software
   (check all that you use)

☐	HEC-RAS (USACE River Analyses System)		
☐	HY-8 (FHWA Culvert Analyses Program) DOS version		
☐	HY-8 (FHWA Culvert Analyses Program) Windows Version		
☐	SMS (Surface Water Modeling Software)		
☐	HEC-2 (USACE Water Surface Profiles)		
☐	WSPRO (USGS Water Surface Profiles)		
☐	V-Urban (Urban Drainage Design Program)		
☐	Hydraulic Toolbox (FHWA Design Program)		
☐	FST2DH (Two Dimensional Finite Element Surface Water Model)		
☐	RMA-2 (USACE Two Dimensional Finite Element Hydrodynamic Numerical Model)		
☐	Other		
☐	Other		

Additional Comments:

Response:

Figure 13.2.1 provides a bar chart displaying the number of states that use the hydraulic design software programs listed. All fifty states and Puerto Rico indicated their usage of HEC-RAS and forty-nine states and Puerto Rico indicate their usage of the HY-8 Windows Version. Table 13.2.1shows the individual states and Puerto Rico's response to question M.2.

Other Hydraulic Design Software Used:

- Alabama - Stormcad, Culvert Master, Hychl, Hydra.
- Alaska - WMS use varies across ADOT&PF.
- Arizona - Various in-house culvert design programs. Broken Back Culvert.
- Delaware - Storm and sanitary.
- Florida – ADCIRC; WAM / SWAN.

- Georgia – StormCAD; Culvertmaster.
- Illinois - WSP-2.
- Kansas - In-house; ManningSolver; USACE software (RAS, HMS) very good. Use TR-20 DOS version since Windows version 1.11 seems buggy, not up to expected standards. Would use 2D modeling software if less expensive NHI training were offered. NHI courses are usually well done and useful.
- Maryland – ABSCOUR.
- Minnesota - Geopak Drainage; XP-SWMM.
- Missouri - FST2DH not currently performed in-house, rather by consultants, etc.
- Nebraska – BECAP.
- New Mexico - Bentley Storm Cadd; Pond Pack Flow Master StormCAD V8i Culvertmaster.
- Pennsylvania - TUFLOW within SMS; WSPRO? Yes, but allowed but only to recreate a FEMA study that was original developed in WSPRO.
- Puerto Rico – ICPR.
- South Dakota - Nebraska broken back culvert.
- Tennessee - Geopak Drainage; Haested Methods.
- Wisconsin – HydroCAD; StormCAD, Flow Master, Culvert Master.
- Wyoming - CDS culverts, WSP sediment, scour and bridge contraction, junction loss, momentum, water surface profile in round and square pipes, storm drain pressure line analysis. Rarely use HY-8, rarely use WSPRO, rarely use HEC-2. Usually import to HEC-RAS. In house energy dissipator and outlet protection, in house improved inlet for Box culverts, in house WSP sediment transport, bridge scour and bridge contraction (USGS Bradley method) mixed flow regime.

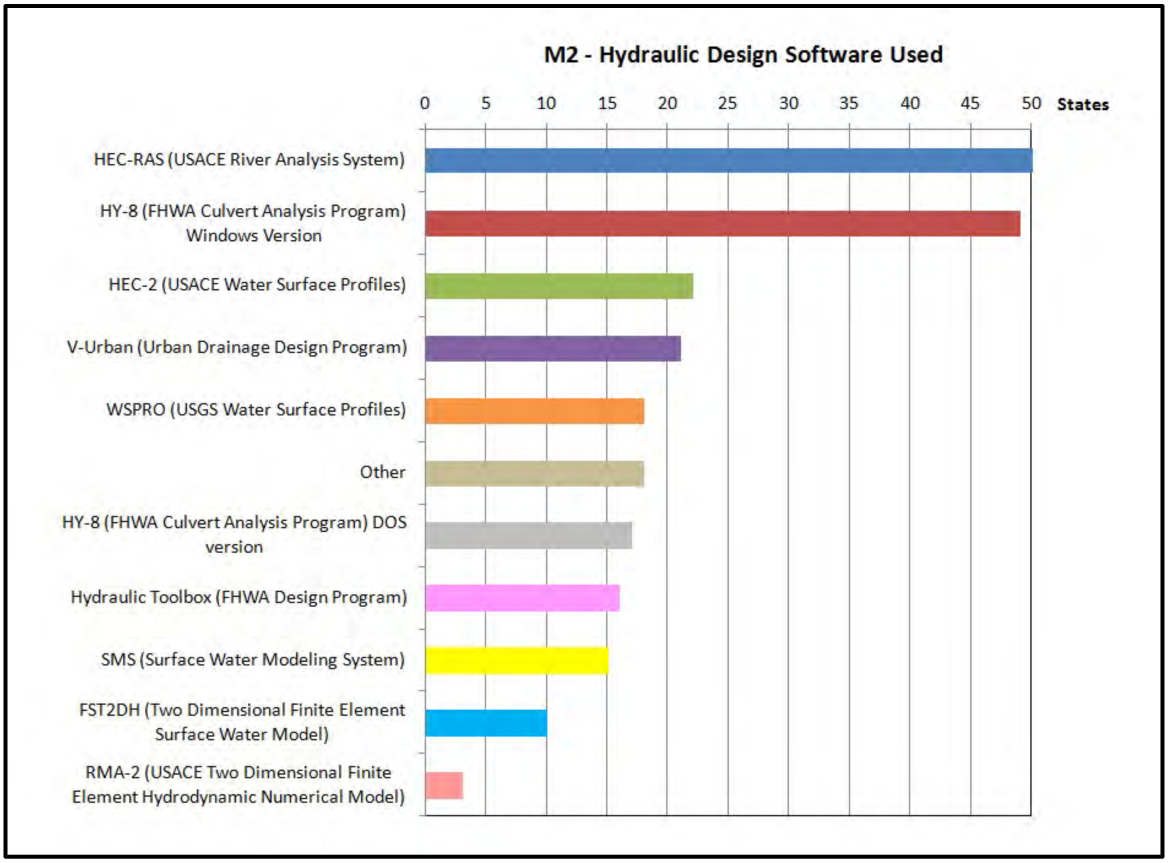


Figure 13.2.1 Number of states using the hydraulic design software listed.

Table 13.2.1 States' use of hydraulic software programs.

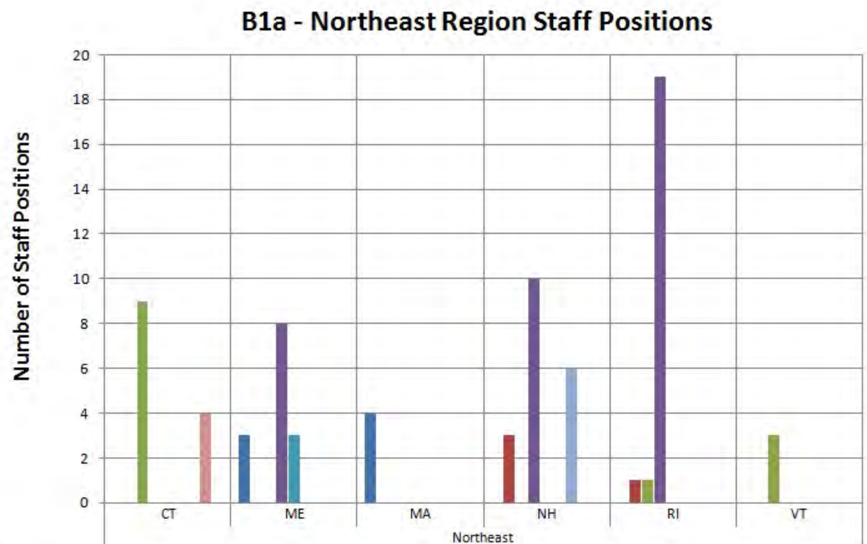
M2 - Software Design Aids – Hydraulic Design Software Used											
State	HEC-RAS	HY-8 DOS version	HY-8 Windows Version	SMS	HEC-2	WSPRO	V-Urban	Hydraulic Toolbox	FST2DH	RMA-2	Other
AL	■	■	■			■	■				■
AK	■	■	■	■				■			
AZ	■		■		■		■				■
AR	■		■		■		■	■			
CA	■		■	■	■	■		■	■		
CO	■	■	■	■			■				
CT	■	■	■	■	■	■	■	■	■		
DE	■		■			■	■	■			■
FL	■		■							■	■
GA	■		■		■	■	■				■
HI	■		■								
ID	■		■					■			
IL	■		■		■	■		■			■
IN	■	■	■			■					
IA	■		■	■					■		
KS	■	■	■								■
KY	■	■	■				■	■			
LA	■	■	■		■	■		■			■
ME	■		■				■				
MD	■		■	■			■	■	■	■	■
MA	■		■	■	■		■			■	
MI	■		■		■						
MN	■		■	■	■		■				■
MS	■		■		■	■					
MO	■	■	■						■		
MT	■	■	■					■			
NE	■		■		■						■
NV	■		■		■	■	■	■			
NH	■		■				■				
NJ	■		■		■	■	■				
NM	■	■	■	■					■		■
NY	■		■	■							
NC	■		■		■						
ND	■		■				■	■			
OH	■		■								
OK	■	■	■		■	■	■	■	■		
OR	■		■			■	■				
PA	■	■	■	■	■	■	■				■
PR	■	■	■	■	■	■					■
RI	■										
SC	■		■	■	■	■	■				
SD	■		■								■
TN	■		■								■
TX	■		■		■						
UT	■	■	■	■					■		
VT	■	■	■					■			
VA	■		■		■		■				
WA	■		■					■	■		
WV	■		■								
WI	■	■	■		■	■					■
WY	■			■		■			■		■

Appendix

A – Hydraulic Staff Positions

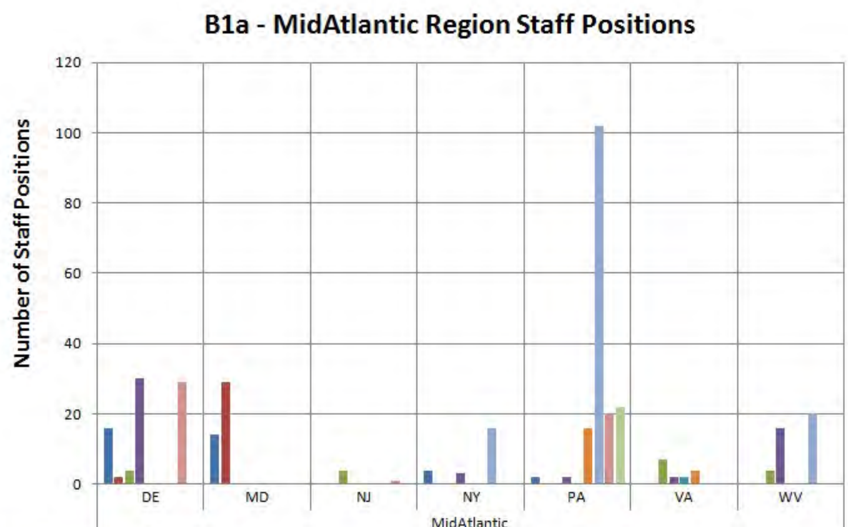
B – Hydraulic Section Responsibilities

Hydraulic Staff Positions



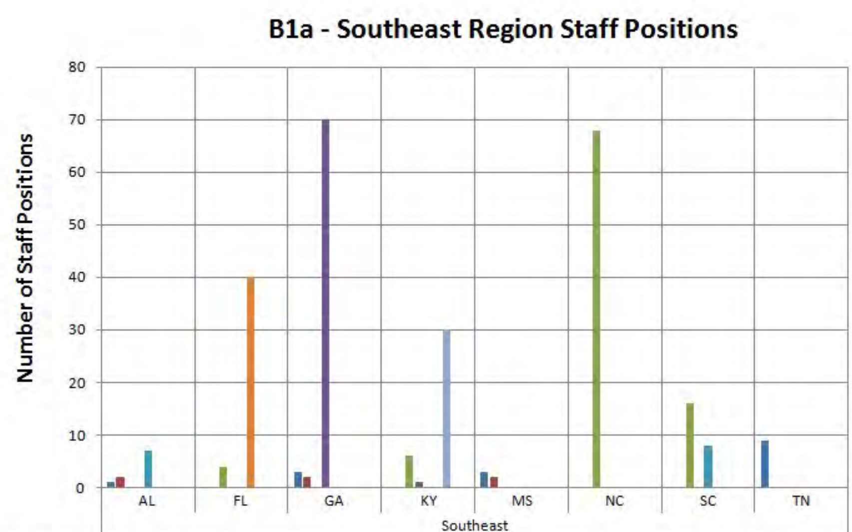
	CT	ME	MA	NH	RI	VT
Central Office Bridge Hydraulic Section		3	4		0	
Central Office Roadway Hydraulic Section			0	3	1	
Central Office Combined Hydraulic Section	9		0		1	3
Central Office Design Section (collateral)		8	0	10	19	
Central Office Other		3	0			
District Office Hydraulic Section			0			
District Office Design Section (collateral)			0	6		
District Office Maintenance Section (collateral)	4		0			
District Office Other			0			

Figure A - 2.1.1 Northeast Region Staff Positions.



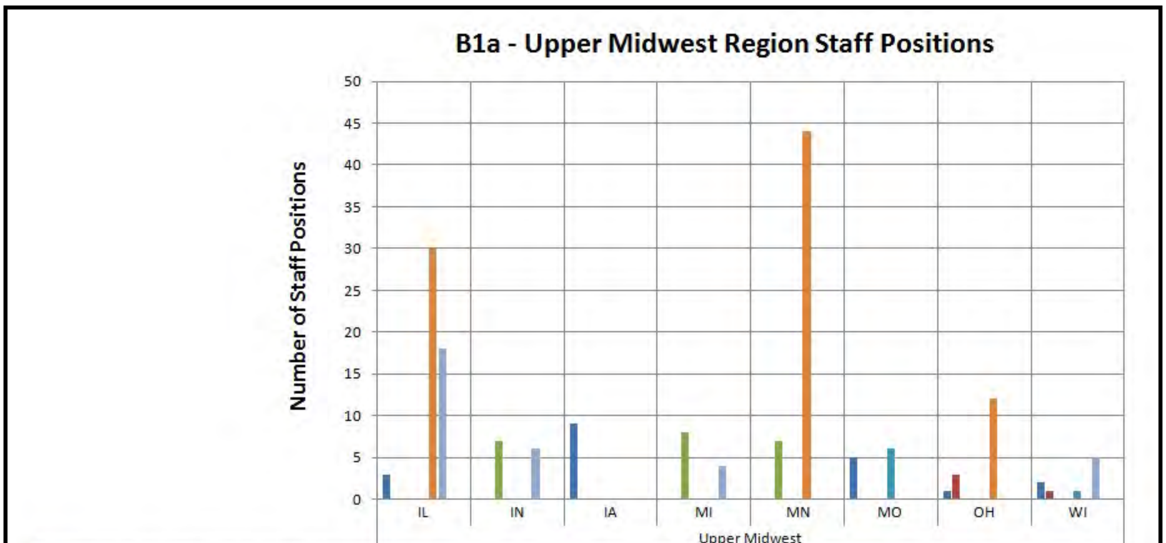
	DE	MD	NJ	NY	PA	VA	WV
Central Office Bridge Hydraulic Section	16	14		4	2		
Central Office Roadway Hydraulic Section	2	29					
Central Office Combined Hydraulic Section	4		4			7	4
Central Office Design Section (collateral)	30			3	2	2	16
Central Office Other						2	
District Office Hydraulic Section					16	4	
District Office Design Section (collateral)				16	102		20
District Office Maintenance Section (collateral)	29		1		20		
District Office Other					22		

Figure A - 2.1.2 Mid Atlantic Region Staff Positions.



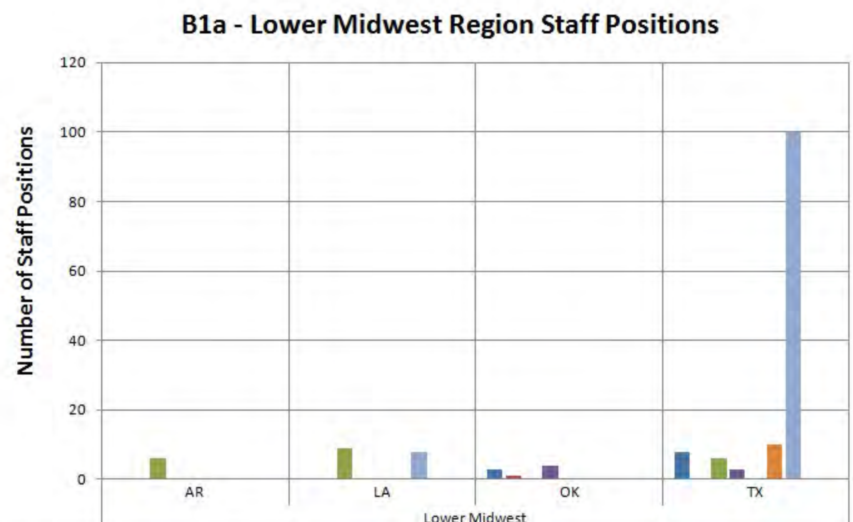
	AL	FL	GA	KY	MS	NC	SC	TN
Central Office Bridge Hydraulic Section	1		3		3			9
Central Office Roadway Hydraulic Section	2		2		2			
Central Office Combined Hydraulic Section		4		6		68	16	
Central Office Design Section (collateral)			70	1				
Central Office Other	7						8	
District Office Hydraulic Section		40			0	0		
District Office Design Section (collateral)				30		0		
District Office Maintenance Section (collateral)						0		
District Office Other								

Figure A - 2.1.3 Southeast Region Staff Positions.



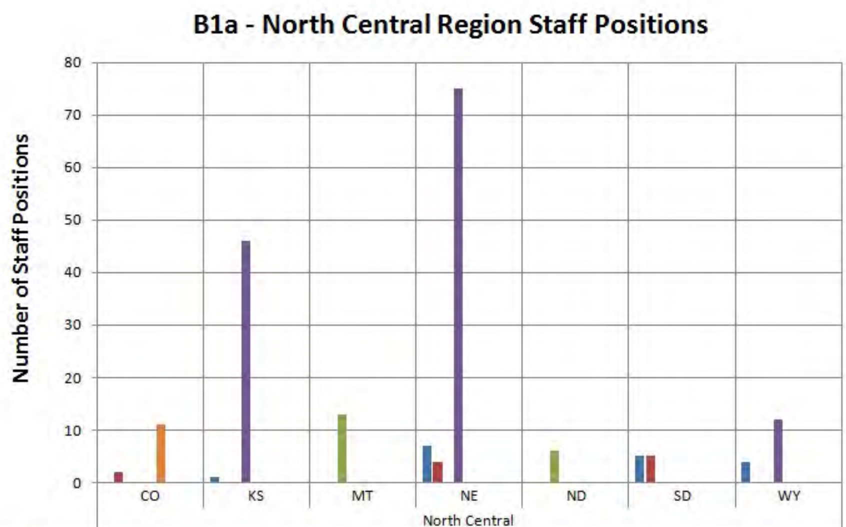
	IL	IN	IA	MI	MN	MO	OH	WI
Central Office Bridge Hydraulic Section	3		9			5	1	2
Central Office Roadway Hydraulic Section							3	1
Central Office Combined Hydraulic Section		7		8	7			
Central Office Design Section (collateral)								
Central Office Other						6		1
District Office Hydraulic Section	30				44		12	
District Office Design Section (collateral)	18	6		4				5
District Office Maintenance Section (collateral)								
District Office Other								

Figure A - 2.1.4 Upper Midwest Region Staff Positions.



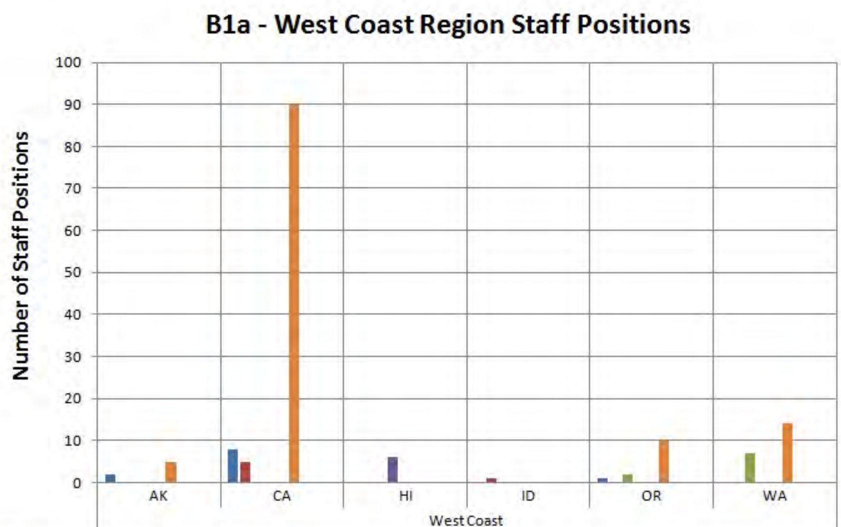
	AR	LA	OK	TX
Central Office Bridge Hydraulic Section			3	8
Central Office Roadway Hydraulic Section			1	
Central Office Combined Hydraulic Section	6	9	0	6
Central Office Design Section (collateral)			4	3
Central Office Other				0
District Office Hydraulic Section			0	10
District Office Design Section (collateral)		8	0	100
District Office Maintenance Section (collateral)			0	0
District Office Other				0

Figure A - 2.1.5 Lower Midwest Region Staff Positions.



	CO	KS	MT	NE	ND	SD	WY
Central Office Bridge Hydraulic Section	0	1		7		5	4
Central Office Roadway Hydraulic Section	2	0		4		5	
Central Office Combined Hydraulic Section	0	0	13		6	0	
Central Office Design Section (collateral)	0	46		75		0	12
Central Office Other	0	0				0	
District Office Hydraulic Section	11	0	0			0	
District Office Design Section (collateral)	0	0	0			0	
District Office Maintenance Section (collateral)	0	0	0			0	
District Office Other	0	0				0	

Figure A - 2.1.6 North Central Region Staff Positions.



	AK	CA	HI	ID	OR	WA
Central Office Bridge Hydraulic Section	2	8			1	
Central Office Roadway Hydraulic Section		5		1		
Central Office Combined Hydraulic Section					2	7
Central Office Design Section (collateral)			6			
Central Office Other						
District Office Hydraulic Section	5	90			10	14
District Office Design Section (collateral)						
District Office Maintenance Section (collateral)						0
District Office Other						

Figure A - 2.1.7 West Coast Region Staff Positions.

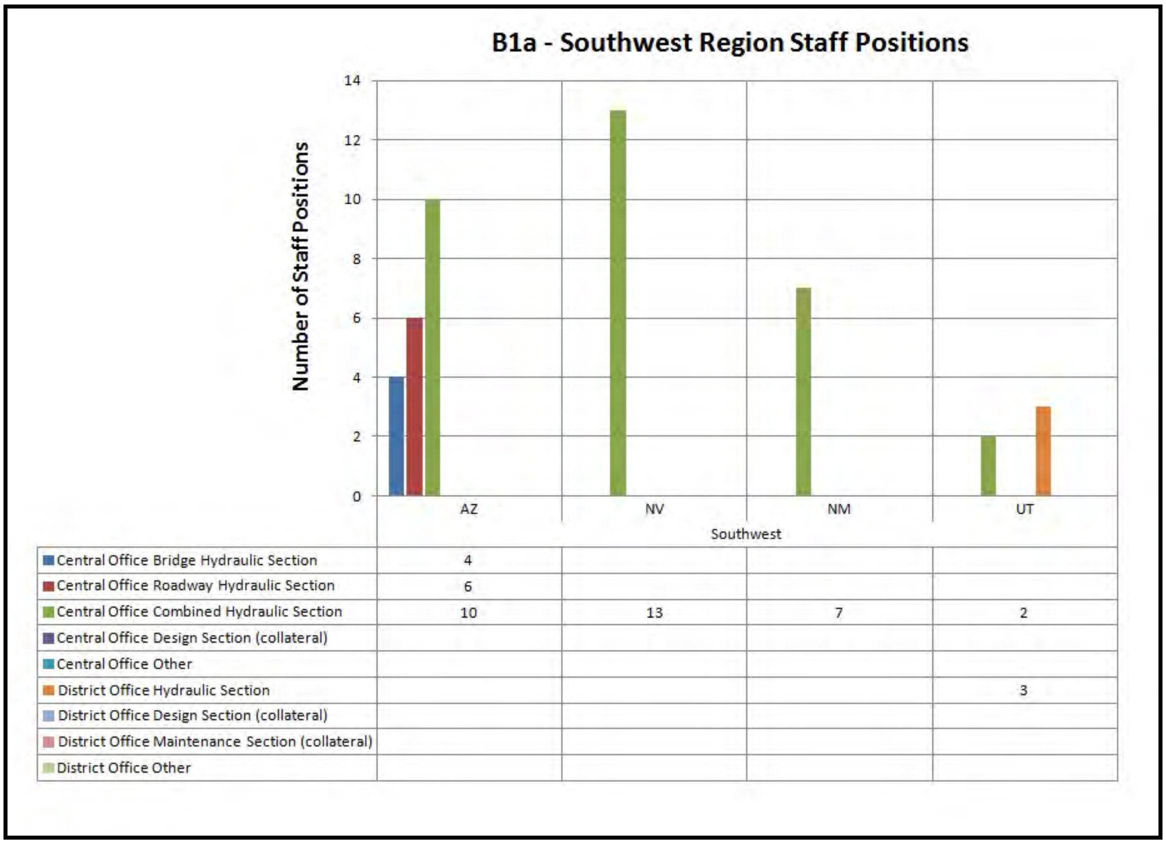


Figure A - 2.1.8 Southwest Region Staff Positions.

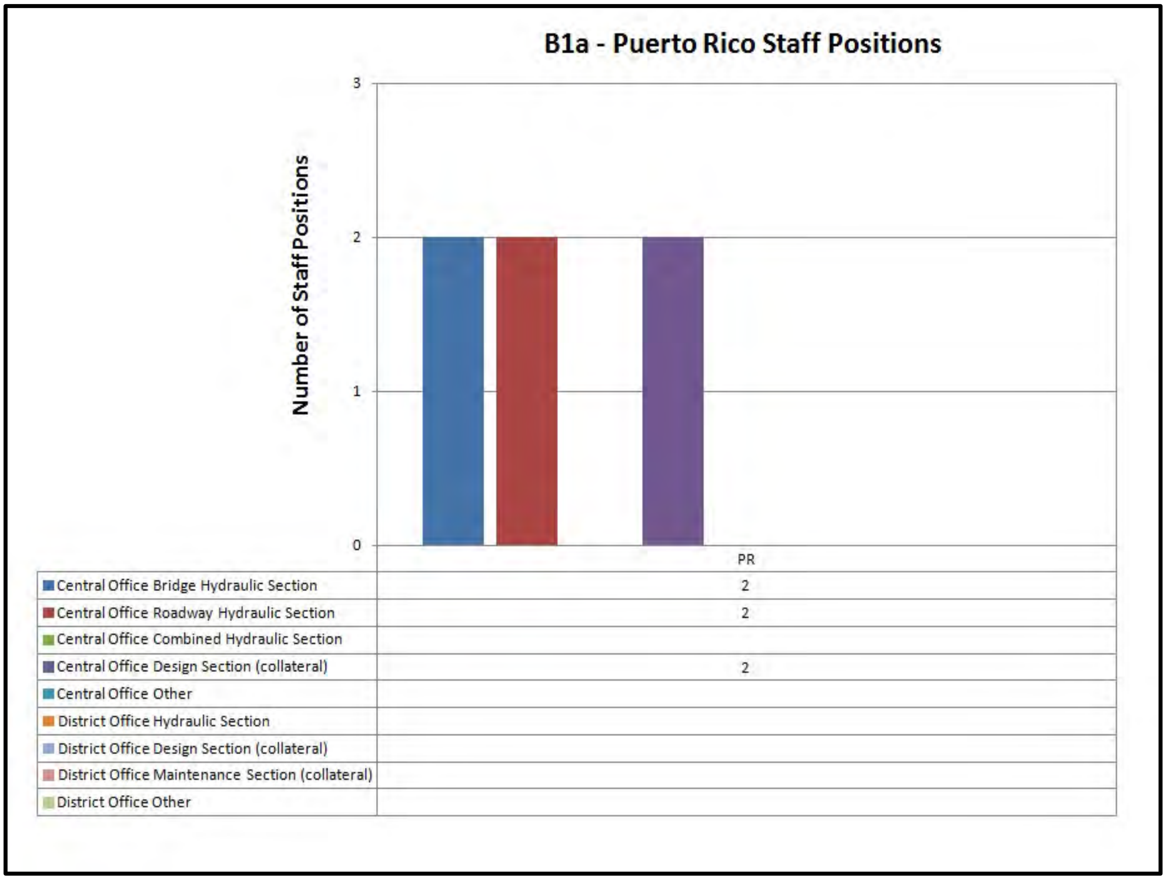
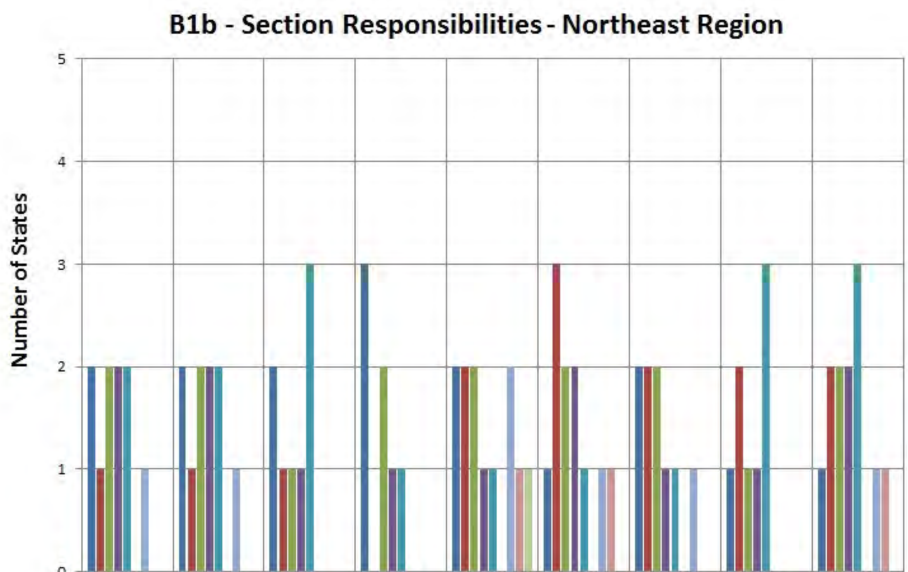


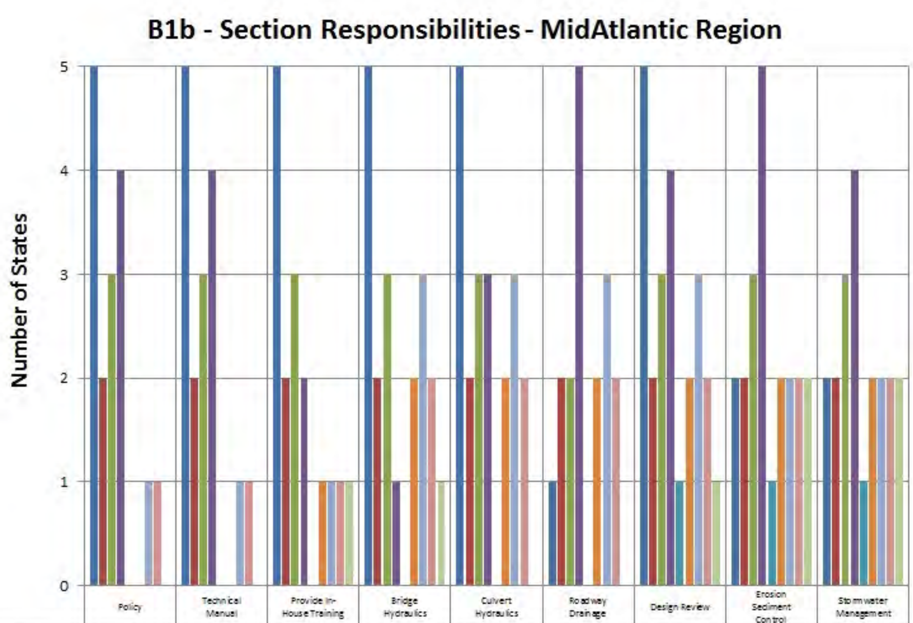
Figure A - 2.1.9 Puerto Rico Staff Positions.

Hydraulic Section Responsibilities



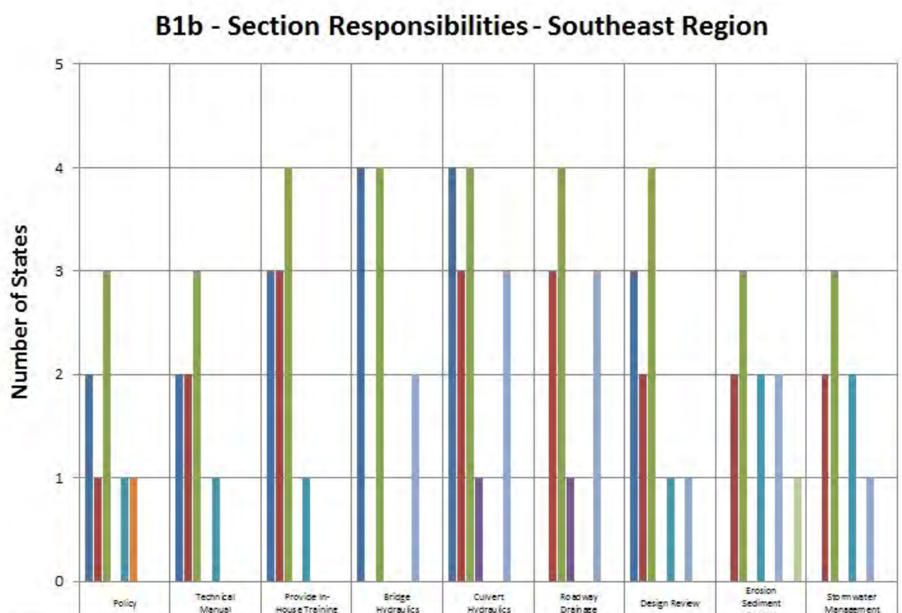
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	2	2	2	3	2	1	2	1	1
Central Office Roadway Hydraulic Section	1	1	1	0	2	3	2	2	2
Central Office Combined Hydraulic Section	2	2	1	2	2	2	2	1	2
Central Office Design Section (collateral)	2	2	1	1	1	2	1	1	2
Central Office Other	2	2	3	1	1	1	1	3	3
Distict Office Hydraulic Section	0	0	0	0	0	0	0	0	0
Distict Office Design Section (collateral)	1	1	0	0	2	1	1	0	1
Distict Office Maintenance Section (collateral)	0	0	0	0	1	1	0	0	1
Distict Office Other	0	0	0	0	1	0	0	0	0

Figure B – 2.1.1 Northeast Region Hydraulic Section Responsibilities.



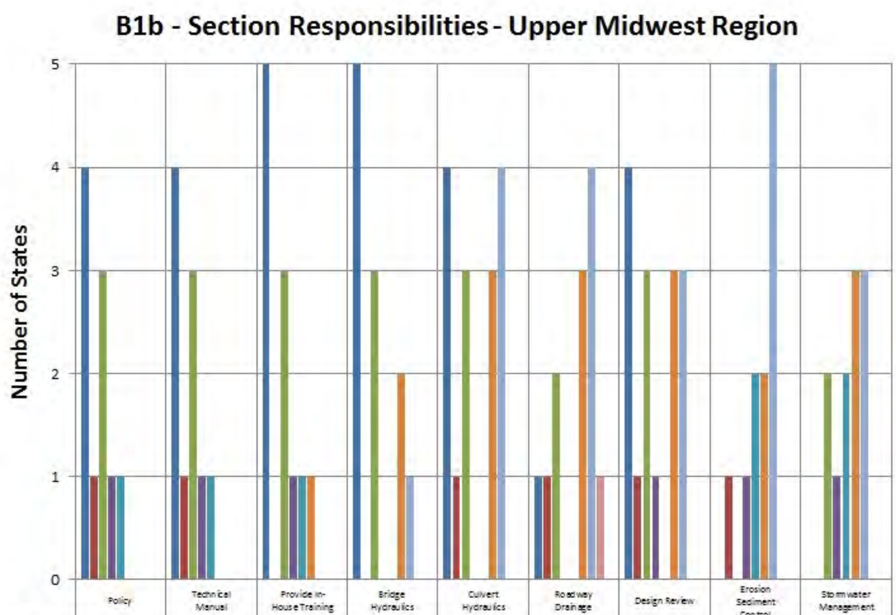
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	5	5	5	5	5	1	5	2	2
Central Office Roadway Hydraulic Section	2	2	2	2	2	2	2	2	2
Central Office Combined Hydraulic Section	3	3	3	3	3	2	3	3	3
Central Office Design Section (collateral)	4	4	2	1	3	5	4	5	4
Central Office Other	0	0	0	0	0	0	1	1	1
Distict Office Hydraulic Section	0	0	1	2	2	2	2	2	2
Distict Office Design Section (collateral)	1	1	1	3	3	3	3	2	2
Distict Office Maintenance Section (collateral)	1	1	1	2	2	2	2	2	2
Distict Office Other	0	0	1	1	0	0	1	2	2

Figure B – 2.1.2 Mid Atlantic Region Hydraulic Section Responsibilities.



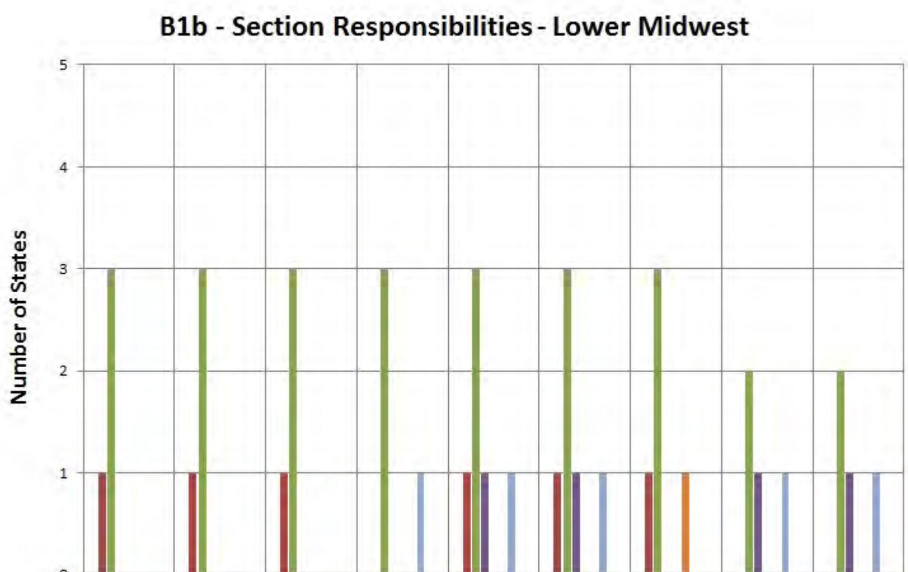
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	2	2	3	4	4	0	3	0	0
Central Office Roadway Hydraulic Section	1	2	3	0	3	3	2	2	2
Central Office Combined Hydraulic Section	3	3	4	4	4	4	4	3	3
Central Office Design Section (collateral)	0	0	0	0	1	1	0	0	0
Central Office Other	1	1	1	0	0	0	1	2	2
Distict Office Hydraulic Section	1	0	0	0	0	0	0	0	0
Distict Office Design Section (collateral)	0	0	0	2	3	3	1	2	1
Distict Office Maintenance Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Other	0	0	0	0	0	0	0	1	0

Figure B – 2.1.3 Southeast Region Hydraulic Section Responsibilities.



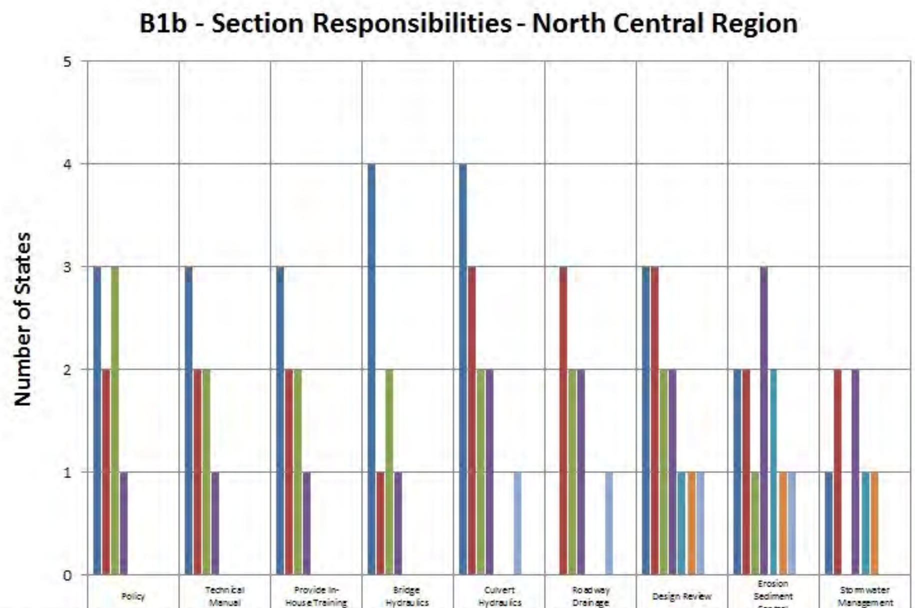
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	4	4	5	5	4	1	4	0	0
Central Office Roadway Hydraulic Section	1	1	0	0	1	1	1	1	0
Central Office Combined Hydraulic Section	3	3	3	3	3	2	3	0	2
Central Office Design Section (collateral)	1	1	1	0	0	0	1	1	1
Central Office Other	1	1	1	0	0	0	0	2	2
Distict Office Hydraulic Section	0	0	1	2	3	3	3	2	3
Distict Office Design Section (collateral)	0	0	0	1	4	4	3	5	3
Distict Office Maintenance Section (collateral)	0	0	0	0	0	1	0	0	0
Distict Office Other	0	0	0	0	0	0	0	0	0

Figure B – 2.1.4 Upper Midwest Region Hydraulic Section Responsibilities.



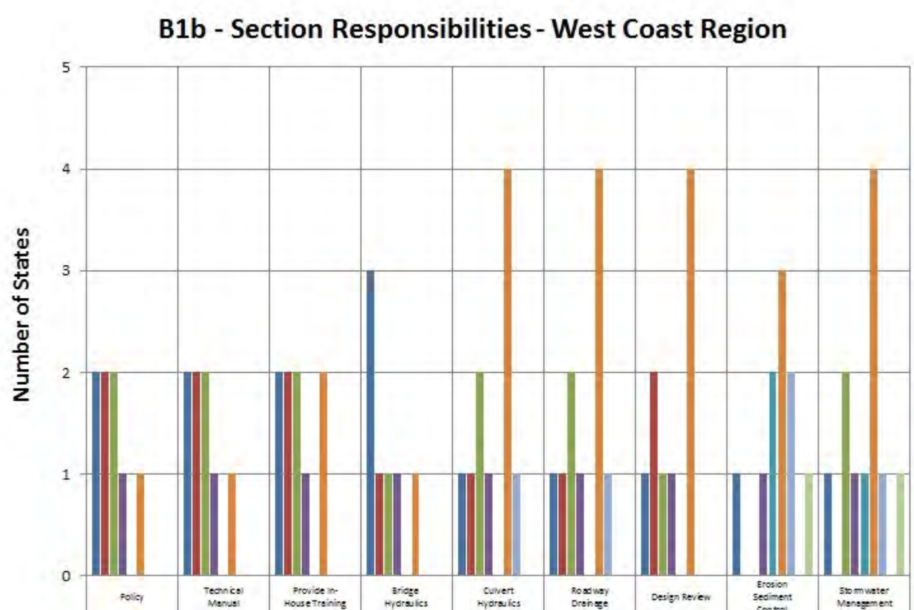
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	0	0	0	0	0	0	0	0	0
Central Office Roadway Hydraulic Section	1	1	1	0	1	1	1	0	0
Central Office Combined Hydraulic Section	3	3	3	3	3	3	3	2	2
Central Office Design Section (collateral)	0	0	0	0	1	1	0	1	1
Central Office Other	0	0	0	0	0	0	0	0	0
Distict Office Hydraulic Section	0	0	0	0	0	0	1	0	0
Distict Office Design Section (collateral)	0	0	0	1	1	1	0	1	1
Distict Office Maintenance Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Other	0	0	0	0	0	0	0	0	0

Figure B – 2.1.5 Lower Midwest Region Hydraulic Section Responsibilities.



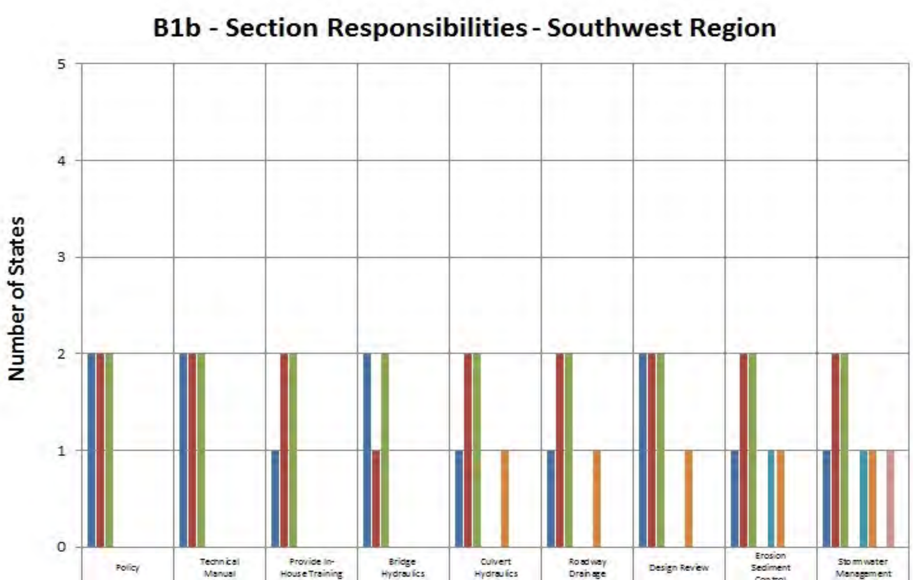
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	3	3	3	4	4	0	3	2	1
Central Office Roadway Hydraulic Section	2	2	2	1	3	3	3	2	2
Central Office Combined Hydraulic Section	3	2	2	2	2	2	2	1	0
Central Office Design Section (collateral)	1	1	1	1	2	2	2	3	2
Central Office Other	0	0	0	0	0	0	1	2	1
Distict Office Hydraulic Section	0	0	0	0	0	0	1	1	1
Distict Office Design Section (collateral)	0	0	0	0	1	1	1	1	0
Distict Office Maintenance Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Other	0	0	0	0	0	0	0	0	0

Figure B – 2.1.6 North Central Region Hydraulic Section Responsibilities.



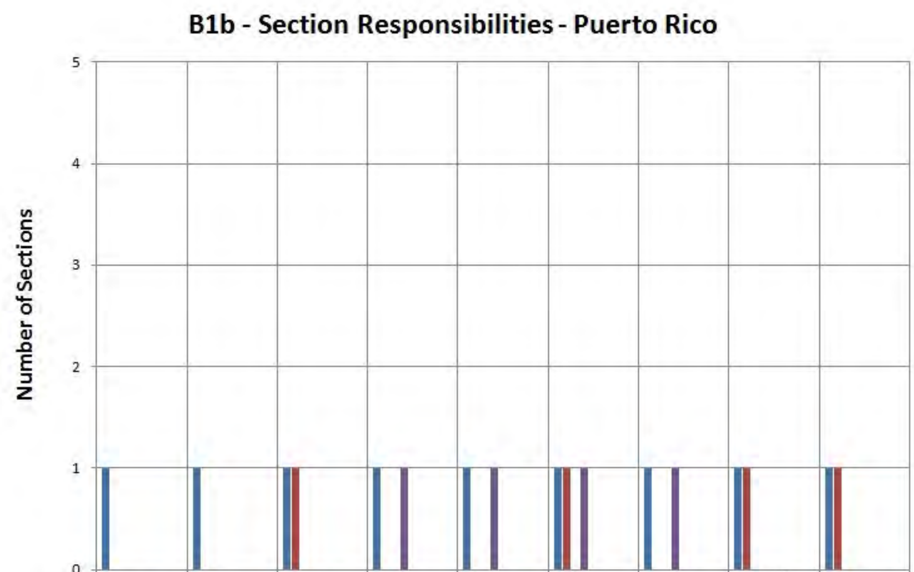
	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	2	2	2	3	1	1	1	1	1
Central Office Roadway Hydraulic Section	2	2	2	1	1	1	2	0	0
Central Office Combined Hydraulic Section	2	2	2	1	2	2	1	0	2
Central Office Design Section (collateral)	1	1	1	1	1	1	1	1	1
Central Office Other	0	0	0	0	0	0	0	2	1
Distict Office Hydraulic Section	1	1	2	1	4	4	4	3	4
Distict Office Design Section (collateral)	0	0	0	0	1	1	0	2	1
Distict Office Maintenance Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Other	0	0	0	0	0	0	0	1	1

Figure B – 2.1.7 West Coast Region Hydraulic Section Responsibilities.



	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	2	2	1	2	1	1	2	1	1
Central Office Roadway Hydraulic Section	2	2	2	1	2	2	2	2	2
Central Office Combined Hydraulic Section	2	2	2	2	2	2	2	2	2
Central Office Design Section (collateral)	0	0	0	0	0	0	0	0	0
Central Office Other	0	0	0	0	0	0	0	1	1
Distict Office Hydraulic Section	0	0	0	0	1	1	1	1	1
Distict Office Design Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Maintenance Section (collateral)	0	0	0	0	0	0	0	0	1
Distict Office Other	0	0	0	0	0	0	0	0	0

Figure B – 2.1.8 Southwest Region Hydraulic Section Responsibilities.



	Policy	Technical Manual	Provide In-House Training	Bridge Hydraulics	Culvert Hydraulics	Roadway Drainage	Design Review	Erosion Sediment Control	Stormwater Management
Central Office Bridge Hydraulic Section	1	1	1	1	1	1	1	1	1
Central Office Roadway Hydraulic Section	0	0	1	0	0	1	0	1	1
Central Office Combined Hydraulic Section	0	0	0	0	0	0	0	0	0
Central Office Design Section (collateral)	0	0	0	1	1	1	1	0	0
Central Office Other	0	0	0	0	0	0	0	0	0
Distict Office Hydraulic Section	0	0	0	0	0	0	0	0	0
Distict Office Design Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Maintenance Section (collateral)	0	0	0	0	0	0	0	0	0
Distict Office Other	0	0	0	0	0	0	0	0	0

Figure B – 2.1.9 Puerto Rico Hydraulic Section Responsibilities.