CHAPTER 4–SURVEY RESULTS

GENERAL INFORMATION RESULTS

Completed surveys were collected and compiled for analysis (refer to Appendix B for the informational survey format). Out of the one hundred (100) State and Federal agency personnel contacted to participate in the informational survey, thirty (30) responded. Agencies who responded are listed in Appendix C and summaries of their responses are presented in Appendix D. Analysis of the thirty (30) returned surveys showed that two-thirds (20 respondents) had previously been involved with the design or installation of culvert pipe liners, while one-third (10 respondents) indicated that they had no previous experience with culvert pipe liners. Agencies that had previously been involved with the design and installation of culvert pipe liners were asked to provide the year they became familiar with using lining techniques for rehabilitation purposes. Survey results indicated that the average year agencies became familiar with lining techniques was around 1990, with 1980 being the earliest year. This indicates that the majority of surveyed agencies have been utilizing lining techniques for at least the past decade. Table 44 presents a summary of the State and Federal agencies that responded to the informational survey, as well as those who had previous knowledge or experience with pipe liners.

Table 44. Summary of Personnel Responding to Informational Survey.

General Survey Analysis	
Number of Personnel Contacted	100
Number of Personnel Responded	30
Percent Responded	30%

Analysis of Respondents			
Agency[1]	**Respondents With Prior Design or Installation Experience**	**Respondents With No Prior Design or Installation Experience**	**Total Number of Respondents Per Agency**
BLM	0	1	1
BOR	1	0	1
CORP	0	1	1
DOT	14	6	20
USFS	4	1	5
NPS	1	1	2
Column Totals	**20**	**10**	**30**

[1] BOR – Bureau of Reclamation, CORP – Corporation, NPS – National Park Service

Responses were compiled from the specific data provided by the agencies that had previously been involved with the design and installation of culvert pipe liners. Agencies were asked to identify which types of liners (refer to Appendix B for the lining methods as defined in the informational survey) they had previously designed or installed, as well as the total approximate length of pipe lined with each liner. Total approximate lengths obtained from each agency were categorized according to lining method and combined with the lengths provided from all other agencies in corresponding categories. Results indicated that sliplining was by far the most used method (80.5%) of those responding to the survey. However, several agencies indicated that sliplining was the only lining method they were familiar with or had previously used. Spray-on lining was the second most used method (13.0%), while methods not defined in the survey (Other) and the cured-in-place pipe lining method were the third (4.0%) and fourth (1.6%) most used methods, respectively. Agencies who provided information for the “Other” category were most often referring to paving the culvert invert as an alternative rehabilitation method. Close-fit lining and spirally wound lining were the methods used the least to rehabilitate deteriorated pipes (0.7% and 0.2%, respectively). Since some agencies provided information for more than one lining method, the total number of respondents providing data for each method was also computed. Table 45 provides a categorized summary of total approximate lengths of pipe lined by all agencies and the number of respondents used to compute the total lengths.

Table 45. Categorized Summary of Total Approximate Lengths of Pipe Lined by All Agencies.

Number of Respondents	19

Lining Method	**Approximate Total Length**	**Percent of Total**	**Number of Respondents**
Sliplining	45.4 kilometers (149,025 feet)	80.5%	14
Spray-on lining	7.4 kilometers (24,120 feet)	13.0%	3
Other[1]	2.2 kilometers (7,300 feet)	4.0%	4
Cured-in-place lining	908 meters (2,980 feet)	1.6%	6
Close-fit lining	380 meters (1245 feet)	0.7%	4
Spirally wound lining	137 meters (450 feet)	0.2%	2
Column Totals	**56.4 kilometers (185,120 feet)**	**100%**	**33**

[1]Indicates a method that does not fall into the predefined categories

Respondents were asked to provide any standards, specifications, and guidelines used in the design and installation of pipe liners. Standards, specifications, and guidelines were categorized into the following: ASTM, Government/State, Manufacturers, Owner Agencies, and Other Organizations. Sources of information gathered regarding standards, specifications, and guidelines were compiled and are presented in Table 46. Table 46 indicates that several ASTM and manufacturer standards are used during the design and installation process. Additionally, Table 46 suggests that several State DOTs have developed their own standards, which demonstrates the need for the development of a national standard for use by Federal and State agencies.

Table 46. Summary of Sources of Information for Standards, Specifications, and Guidelines for Culvert Liners.

Category	Standard/Specification/Guideline
ASTM	ASTM A 615 – Standard Specification for Deformed and Plain Billet Steel Bars for Concrete Reinforcement(86)
	ASTM C 94 – Standard Specification for Ready-Mixed Concrete(87)
	ASTM C 150 – Standard Specification for Portland Cement
	ASTM C 260 – Air Entraining Admixtures for Concrete(88)
	ASTM C 494 – Standard Specification for Chemical Admixture for Concrete(89)
	ASTM C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete
	ASTM C 796 – Standard Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam(90)
	ASTM C 869 –Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete(91)
	ASTM D 256 – Test Method for Determining the Pendulum Impact Resistance of Notched Specimens of Plastics(92)
	ASTM D 638[1] – Test Method for Tensile Properties of Plastics
	ASTM D 790[1] – Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
	ASTM D 1248 – Specification for Polyethylene Plastic Molding and Extrusion Material(93)
	ASTM D 1784[1] – Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
	ASTM D 2122[1] – Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings
	ASTM D 2152[1] – Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion
	ASTM D 2321 – Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications(94)
	ASTM D 2412[1] –Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading
	ASTM D 2417 – Specification for Perforated, Laminated Wall Bituminized Fiber Pipe for General Drainage(95)
	ASTM D 2444[1] – Test Method for Impact Resistance of Thermoplastic Pipe and Fittings be Means of a Tup (Falling Weight)
	ASTM D 2584 – Standard Test Method for Ignition Loss of Cured Reinforced Resins(96)
	ASTM D 2657[1] –Practice for Heat-Joining of Polyolefin Pipe and Fittings
	ASTM D 3212[1] – Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
	ASTM D 3350[1] – Specification for Polyethylene Plastics Pipe and Fittings Materials

Table 46 (cont.). Summary of Sources of Information for Standards, Specifications, and Guidelines for Culvert Liners.

Category	Standard/Specification/Guideline
ASTM (cont.)	ASTM D 5260 – Standard Classification for Chemical Resistance of Poly(Vinyl Chloride) (PVC) Homopolymer and Copolymer Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds(97)
	ASTM D 5813[1] – Standard Specification for Cured-In-Place Thermosetting Resin Sewer Pipe
	ASTM F 585[1] – Standard Practice for Insertion of Flexible Polyethylene Pipe Into Existing Sewers
	ASTM F 714[1] – Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter
	ASTM F 894[1] – Specification for Polyethylene (PE) Large Diameter Profile Wall Sewer and Drain Pipe
	ASTM F 949 – Standard Specification for Poly(Vinyl Chloride) (PVC) Corrugated Sewer Pipe With a Smooth Interior and Fittings(98)
	ASTM F 1216[1] – Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube
	ASTM F 1504[1] – Standard Specification for Folded Poly(Vinyl Chloride) (PVC) Pipe for Existing Sewer and Conduit Rehabilitation
	ASTM F 1697[1] – Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Strip for Machine Spiral-Wound Liner Pipe Rehabilitation of Existing Sewers and Conduit
	ASTM F 1698[1] – Standard Practice for Installation of Poly(Vinyl Chloride) (PVC) Profile Strip Liner and Cementitious Grout for Rehabilitation of Existing Man-Entry Sewers and Conduits
	ASTM F 1743 – Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe
	ASTM F 1803 – Standard Specification for Poly (Vinyl Chloride) (PVC) Closed Profile Gravity Pipe and Fittings Based on Controlled Inside Diameter(99)
Government	FHWA Culvert Repair Practices Manual (1995) [1]
	FHWA FP-96 Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects[1]
	BOR Specification Paragraphs
Manufacturer	Advanced Drainage Systems, Inc. (ADS)
	Broad Cove Associates
	CPChem™ Performance Pipe (Plexco®, Spirolite™, and DriscoPlex™)[1]
	Contech Construction Products, Inc.
	Danby™ of North America[1]
	Environmental Pipeliners, Inc.[1]
	Fusion Seal Corporation
	Hancor
	Hawkeye Tile
	Hobas Pipe USA, Inc.[1]
	Insituform® Technologies, Inc.[1]
	ISCO Industries, LLC (Snap-Tite®)[1]

Table 46 (cont.). Summary of Sources of Information for Standards, Specifications, and Guidelines for Culvert Liners.

Category	Standard/Specification/Guideline
Manufacturer (cont.)	KHW Pipe (Sclairpipe® and Weholite)
	Lane Enterprises, Inc.
	Lanzo Lining Services[1]
	Metal Culverts, Inc.
	National Envirotech Group, LLC[1]
	Phillips
	Pipe Liners, Inc. (U-Liner®)[1]
	Pipelining Products, Inc. (Sure-Line Pipe® and Cure-Line Pipe®)[1]
	Plexco
	Poly Profiles Technology, Inc. [1]
	PSI
	Rib Loc® Group Limited[1]
	S.O.S. Construction[1]
	Spiniello Companies[1]
	Tompson Culverts
	Ultraliner™ Inc. [1]
Owner Agencies (cont.)	Caltrans[2] Culvert Restoration Techniques Insituform
	Caltrans Design Information Bulletin No. 76 - Culvert Rehabilitation Using Plastic Liners[1]
	Caltrans Study #F90Tl15 - Culvert Restoration Techniques
	Colorado DOT Specifications
	U.S. Forest Service Specifications
	Maryland DOT Specifications
	Michigan DOT Specifications
	Missouri DOT Specifications
	Montana DOT Specifications
	New Hampshire DOT Specifications
	Ohio DOT Specifications
	Southern California Greenbook
	Vermont DOT Specifications
Other Organizations	AWWA M11 Steel Pipe – A Guide for Design and Installation
	WRc Sewerage Rehabilitation Manual 4th Edition
	PPI Guidance and Recommendations on the Use of Polyethylene Pipe for the Sliplining of Sewers[1]

[1]Designates those Standards/Specifications/Guidelines obtained by CSU personnel prior to distribution of informational survey,
[2]California Department of Transportation

A series of questions was also presented for respondents to provide personal opinions and information regarding pipelining techniques. Questions that were asked included: “Which types of pipe liners have proven to be easiest to install, most successful, most unsuccessful, most expensive, and least expensive?” Responses showed that sliplining was overwhelmingly the respondents’ choice for easiest to install, most successful, and least expensive. Survey results also suggested that the most expensive lining technique was cured-in-place lining. Table 47 presents the results of the subjective questions asked in the survey. It should be noted that not all respondents provided answers for each question, while other respondents provided multiple answers for some questions.

Table 47. Results of Subjective Questions.

Question: "Which Liners Were Easiest to Install?"	
Number of Personnel Responding to Question: 18	
Lining Method	**Total Number of Answers Received**
Sliplining	14
Other	2
Spirally wound lining	1
Cured-in-place lining	1
Spray-on lining	1
All	1
Close-fit lining	0
Column Total	**20**

Question: "Which Liners Were Most Successful?"	
Number of Personnel Responding to Question: 18	
Lining Method	**Total Number of Answers Received**
Sliplining	15
Cured-in-place lining	2
Spray-on lining	2
Close-fit lining	1
Other	1
All	1
Spirally wound lining	0
Column Total	**22**

Table 47 (cont.). Results of Subjective Questions.

Question: "Which Liners Were Most Unsuccessful?"	
Number of Personnel Responding to Question: 9	
Lining Method	**Total Number of Answers Received**
Sliplining	3
Spirally wound lining	2
Other	2
None	2
Close-fit lining	1
Cured-in-place lining	1
Spray-on lining	0
Column Total	**11**

Question: "Which Liners Were Most Expensive?"	
Number of Personnel Responding to Question: 13	
Lining Method	**Total Number of Answers Received**
Cured-in-place lining	7
Sliplining	3
Other	2
Spray-on lining	1
Close-fit lining	0
Spirally wound lining	0
Column Total	**13**

Question: "Which Liners Were Least Expensive?"	
Number of Personnel Responding to Question: 12	
Lining Method	**Total Number of Answers Received**
Sliplining	8
Other	4
Spray-on lining	1
Close-fit lining	0
Spirally wound lining	0
Cured-in-place lining	0
Column Total	**13**

Agency personnel were finally asked if they could provide the project team with average costs, design life criteria, maintenance procedures, and environmental issues associated with each of the lining methods. Responses indicated that average costs can vary widely and are dependent upon the size of liner and type of material used. Sliplining and close-fit lining had similar average price ranges. Spirally wound lining and cured-in-place lining were also similar in cost and had the highest average cost of all lining methods. Costs for spray-on lining and “Other” (specifically paving the invert) were reported in dollars per square foot. The average price ranges for each lining method are presented in Table 48.

Table 48. Average Price Range for Each Lining Method.

Number of Respondents	8

Lining Method	Average Price Range			
	Per Linear Meter	Per Square Meter	Per Linear Foot	Per Square Foot
Sliplining	$82 to $656		$25 to $200	
Close-fit lining	$164 to $394		$50 to $120	
Spirally wound lining	$984		$300	
Cured-in-place lining	$984		$300	
Spray-on lining		$108 to $269		$10 to $25
Other		$161 to $323		$15 to $30

Additionally, four (4) respondents provided information regarding the design life of the lining techniques. Generally, design life of all lining methods was determined to be within the range of 10 to 50 years. Agencies who responded, commented that design life was dependent upon may factors, such as but not limited to, water quality, environmental conditions, corrosion resistance, and liner thickness.

Only three (3) respondents indicated that their agency has or uses standard maintenance procedures for culvert pipe liners. This demonstrates the need to develop standard maintenance procedures once a pipe has been lined.

Two environmental issues were provided by several respondents to the survey. The first issue was associated with the cured-in-place lining technique. In this method, water or steam is used to heat and cure the liner to create a strong bond between the host pipe and the liner. Due to the chemicals and resins used in this process, this installation method may be hazardous to an environmentally sensitive area. Fish passage through newly lined pipes was mentioned as the second environmental issue. Often times, the velocities in a newly lined pipe will increase due to the smooth surface of the liner, thereby inhibiting fish passage.

PROJECT SPECIFIC RESULTS

In addition to the results obtained from the general information section of the survey, as previously discussed, respondents were asked if they could provide any project-specific information associated with documented case studies. In total, eight (8) project-specific case studies were provided by the respondents and are listed in Table 49.

Table 49. Summary of Eight Project-specific Case Studies Provided by the Respondents.

	Case Study Provided by:							
	Maryland State Highway Administration	**Michigan DOT**	**Oregon DOT**	**Vermont Agency of Transportation, Maintenance & Aviation Division**	**USFS in Cass Lake, Minnesota**	**USFS (Ottawa National Forest) in Ironwood, Michigan**	**USFS in Cleveland, Tennessee**	**NPS (Pacific West Region) in Oakland, California**
Project name	Not submitted	I-96	Foster Reservoir Culvert	Brighton Culvert Relining (VT 105, BR 90)	Forest Road 2171 Third River Road	Paulding Creek Dam Repair	Peavine-Sheeds Creek Road	Point Reyes National Seashore
Project description	Paving the invert of 52 small structures	Lining of 61 meters (200 feet) of 107-centimeter (42-inch) deteriorated corrugated metal pipe	Lining of 85.4 meters (280 feet) of 76-centimeter (30-inch) deteriorated corrugated metal pipe	Lining 25 meters (82 feet) of 213-centimeter (84-inch) deteriorated corrugated metal pipe	Bituminous overlay and culvert rehabilitation	Lining existing 1.2-meter (48-inch) corrugated metal spillway pipe	Lining two existing 45.7-centimeter (18-inch) deteriorated corrugated metal pipe	Lining existing 30.5- to 45.7-centimeter (12-to18-inch) deteriorated corrugated metal pipe
Type of liner used	Spray-on lining	Cured-in-place lining	Continuous sliplining utilizing 12-meter (40-foot) segments fusion welded together	Sliplining	Sliplining	Sliplining	Sliplining	Close-fit lining
Time to complete installation	1 year	Not submitted	5 days	25 days	10 days	16 to 24 hours	2 days	5 days
Year project was completed	2002	1998	2002	2002	2002	2002	2000	2001
Cost of project	$2,000,000	approximately $100,000	$45,000	$70,460	$350,000	approximately $25,000	$2,700	$30,000
Length of pipe lined	3.5 kilometers (11,500 feet)	61 meters (200 feet)	85.4 meters (280 feet)	25 meters (82 feet)	236.3 meters (775 feet)	14.6 meters (48 feet)	27 meters (90 feet)	152 meters (500 feet)

Table 49 (cont.). Summary of Eight Project-specific Case Studies Provided by the Respondents.

	Case Study Provided by:							
	Maryland State Highway Administration	**Michigan DOT**	**Oregon DOT**	**Vermont Agency of Transportation, Maintenance & Aviation Division**	**USFS in Cass Lake, Minnesota**	**USFS (Ottawa National Forest) in Ironwood, Michigan**	**USFS in Cleveland, Tennessee**	**NPS (Pacific West Region) in Oakland, California**
Original size of pipe lined	Not submitted	107-centimeter (42-inch)	76-centimeter (30-inch)	213-centimeter (84-inch)	38-centimeter (15-inch)	1.2-meter (48-inch)	45.7-centimeter (18-inch)	30.5 to 45.7-centimeter (12- to 18-inch)
Material of pipe lined	Concrete	Corrugated metal pipe	Corrugated metal pipe	Corrugated metal pipe	Corrugated metal pipe	Corrugated metal pipe	Corrugated metal pipe	Corrugated metal pipe
Other lining methods proposed	Sliplining, spirally wound lining, and other	None	Spirally wound lining and cured-in-place lining	None	None	Not submitted	None	Sliplining, spirally wound lining, and cured-in-place lining
Deciding factor for choosing the liner used in project	Cost	Not applicable	Cost: Sliplining was the most cost effective and grouting was necessary to fill the voids surrounding the deteriorated pipe	Not applicable	Availability, cost, and the contractors ability to install it	Not submitted	Availability and type of installation	Amount of diameter reduction and cost
How the liner has performed	So far so good	Not submitted	As expected	Liner has only been in service a few months	So far, so good	Liner has only been in service for a little under a year	Good	So far, fine

SUMMARY

In December of 2002, CSU sent e-mail to approximately one-hundred (100) State and Federal agency personnel to inform them about the informational survey intended to provide CSU and the FHWA Federal Lands Highway (FLH) with information pertaining to current methodologies used in culvert pipe liner design and installation. Out of the approximate one-hundred (100) State and Federal agency personnel contacted, thirty (30) responded to the survey. Analysis of the thirty (30) returned surveys showed that two-thirds (20 respondents) had previously been involved with the design or installation of culvert pipe liners, while one-third (10 respondents) indicated that they had no previous experience with culvert pipe liners. From the collected responses of those with previous experience in the design or installation of culvert pipe liners, it was determined that sliplining was the technique most often used by Federal and State agency personnel (80.5%). In fact, many agencies indicated that sliplining was the only lining method their agency had previously used. Additionally, survey results indicated that the average year agencies became familiar with lining techniques was around 1990, with 1980 being the earliest year, indicating that the majority of agencies surveyed have been utilizing lining techniques for over a decade.

Respondents to the survey also indicated that numerous standards, specifications, and guidelines have been used in the design and installation of culvert pipe liners. Several of the agencies who responded stated that their agency had developed its own specifications for culvert pipe liners, which demonstrates the need for the development of a national standard for use by Federal and State agencies. A series of subjective questions showed that the respondents overwhelmingly choose the method of sliplining as the easiest liner to install, the most successful, and the least expensive.

Average general costs of liner methods varied widely and were dependent upon the size of liner and type of material used. Responses showed that sliplining and close-fit lining had similar average price ranges ($20 to $200 per linear foot and $50 to $120 per linear foot, respectively). Spirally wound lining and cured-in-place lining were also similar in cost (both at $300 per linear foot) and had the highest average cost of all lining methods. Design life estimates provided by the respondents ranged from ten (10) to fifty (50) years for all lining methods. Only three (3) respondents reported that their agency has or uses standard maintenance procedures for culvert pipe liners, indicating the need to develop standard maintenance procedures once a pipe has been lined. Lastly, two environmental issues were provided by respondents and are of concern when using liners to rehabilitate deteriorated culverts. First, a concern was expressed associated with the cured-in-place lining technique. Due to the chemicals and resins used in the cured-in-place lining method, the installation process may be hazardous to an environmentally sensitive area. Secondly, fish passage through newly lined pipes may become an issue if velocities are increased enough that fish cannot swim upstream.