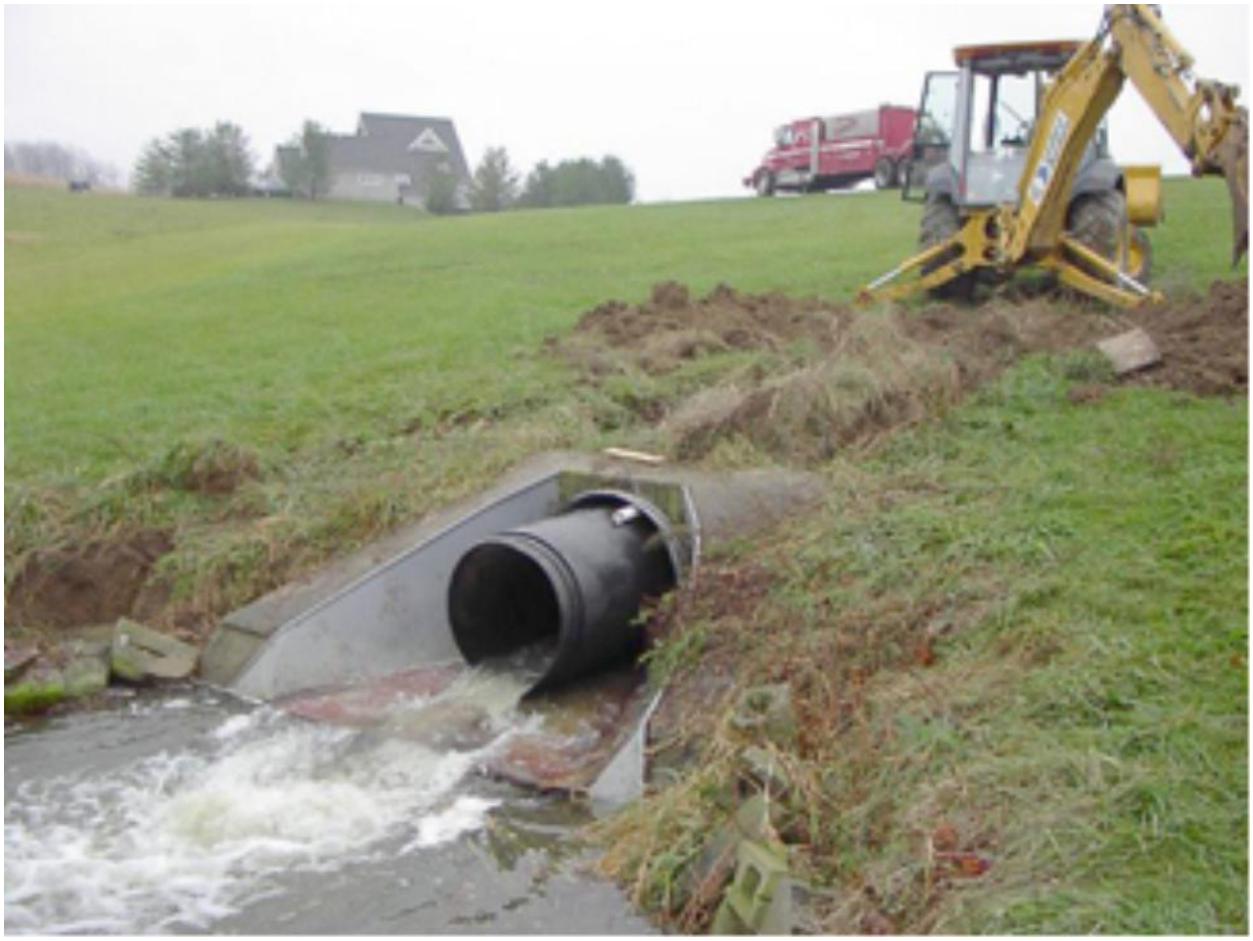
CULVERT PIPE LINER GUIDE AND SPECIFICATIONS

Publication No. FHWA-CFL/TD-05-003 **July 2005**



U.S. Department of Transportation
Federal Highway Administration

CTIP

Federal Lands Highway
Commitment to Excellence

Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228

FOREWORD

The Federal Lands Highway (FLH) of the Federal Highway Administration (FHWA) promotes development and deployment of applied research and technology applicable to solving transportation related issues on Federal Lands. s within the FHWA.

The objective of this study was to produce guidelines and specifications for the use of culvert liners. Drainage facilities, such as culverts, decay due to the processes of abrasion, corrosion, and erosion, shortening the anticipated service life of the facility. Many culverts have deteriorated and need repair or replacement. Until recently, most repair or replacement of culverts required open-cutting (trench digging). State Departments of Transportation (DOTs), the Federal Highway Administration (FHWA), and others have turned toward trenchless technology as a cost effective solution to culvert rehabilitation.

Trenchless technology can be used with a wide range of methods, materials, and equipment for rehabilitation or replacement. Rehabilitation of existing culverts through lining techniques has gained popularity in the United States. To date, several trenchless lining techniques have been used for the rehabilitation of existing culverts. However, choosing an optimum lining technique can be complicated considering the vast amount of organizations specializing in the manufacturing and installation of culvert liners, as well as the various materials, applications, and limitations associated with each lining technique. A user-friendly Microsoft® Excel-based Multi-criteria Decision Analysis (MCDA) tool that allows the user to customize the decision aid model was developed.

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Quality Assurance Statement

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-CFL/TD-05-003		

4. Title and Subtitle	5. Report Date
Culvert Pipe Liner Guide and Specifications	July 2005
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
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9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Colorado State University Engineering Research Center Fort Collins, CO 80523	11. Contract or Grant No. DTFH68-01-P-00321

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Federal Highway Administration Central Federal Lands Highway Division 12300 W. Dakota Avenue Lakewood, CO 80228	Final Report August 2002 – August 2004
	14. Sponsoring Agency Code HFTS-16.4

15. Supplementary Notes

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16. Abstract

Trenchless technology can be used with a wide range of methods, materials, and equipment for rehabilitation or replacement of damaged or deteriorated pipe culverts. To date, several trenchless lining techniques have been used for the rehabilitation of existing culverts. Colorado State University was contracted to establish guidelines and specifications for the use of culvert liners. Task 1 involved a thorough literature review to collect information describing the state-of-the-practice in culvert pipe lining. Task 2 involved the development of a decision-making methodology for choosing appropriate culvert liners based on various factors. Task 3 required CSU to prepare and submit a final report whereby providing guidance to both the Design and Construction Branches of the FHWA and to State DOTs.

17. Key Words	18. Distribution Statement
TRENCHLESS TECHNOLOGY, CULVERT REHABILITATION, CULVERT LININGS	No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	169	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS AND SYMBOLS

Actual	actual rating of alternative
AASHTO	American Association of State Highway and Transportation Officials
ADS	Advanced Drainage Systems, Inc.
AK	Alaska
AL	Alabama
ANSI	American National Standards Institute
AR	Arkansas
AZ	Arizona
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
Best	best rating of alternative for a specified criterion
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
C	Celsius
CA	California
Caltrans	California Department of Transportation
CFL	close-fit lining
CIPP	cured-in-place pipe
CIPPL	cured-in-place pipe lining
cm	centimeter
CMP	corrugated metal pipe
CO	Colorado
CORP	Corporation
CP	discrete compromise programming method
CPVC	chlorinated poly(vinyl chloride)
CSU	Colorado State University
CT	Connecticut
DC	District of Columbia
DE	Delaware
DE	does not enhance structural integrity
DOT	departments of transportation
EPDM	ethylene polypelene diene monomer
ESCR	environmental stress crack resistance
F	Fahrenheit
FHWA	Federal Highway Administration
FL	Florida
FLH	Federal Lands Highway
ft	feet
GA	Georgia
GRP	glass fiber reinforced polyester
H	height
H	horizontal

HI	Hawaii
HDPE	high-density polyethylene
in.	inches
IA	Iowa
ID	Idaho
IL	Illinois
IN	Indiana
ISO	International Organization for Standardization
kPa	kiloPascal
KS	Kansas
KY	Kentucky
LA	Louisiana
LLC	Limited Liability Company
m	meter
MA	Massachusetts
MCDA	Multi-criteria Decision Analysis
MD	Maryland
MDPE	medium density polyethylene
ME	Maine
MI	Michigan
MN	Minnesota
MO	Missouri
MS	Mississippi
MT	Montana
N/A	not available
N/S	not supplied
NA	not applicable
NE	Nebraska
NASSCO	National Association of Sewer Service Companies
NC	North Carolina
NCHRP	National Cooperative Highway Research Program
ND	North Dakota
NE	Nebraska
NH	New Hampshire
NJ	New Jersey
NM	New Mexico
NPS	National Park Service
NTIS	National Technical Information Service
NUCA	National Utility Contractors Association
NV	Nevada
NY	New York
NYC	New York City
OH	Ohio
OK	Oklahoma
OR	Oregon
p	exponent determining weight of rating

PA	Pennsylvania
PDF	portable document format
PE	polyethylene
PLF	price per linear foot
Prohibits	existence of prohibits the use
PSF	price per square foot
psig	pounds per square inch, gauge
PP	polypropylene
PPI	Plastics Pipe Institute
PVC	poly(vinyl chloride)
PVDF	poly-vinylidene chloride
R	relative importance of criterion i
RI	Rhode Island
RI	restores structural integrity
S	overall score for alternative j
SD	South Dakota
SC	South Carolina
Sliplining	sliplining
SOL	spray-on lining
STP	special technical report
SWL	spirally wound lining
T	waterway minimum wall
TN	Tennessee
TRB	Transportation Research Board
TV	television
TX	Texas
US	United States
USFS	U.S. Forest Service
UT	Utah
V	vertical
VA	Virginia
VT	Vermont
W	weight
WA	Washington
WAM	weighted average method
WI	Wisconsin
Worst	worst rating of alternative for a specified criterion
WV	West Virginia
www	World Wide Web
WY	Wyoming