

R-02-03

**CANAL-LINING DEMONSTRATION PROJECT
YEAR 10 FINAL REPORT**



November 2002

**U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation**

**Pacific Northwest Region
Water Conservation Center**

**Technical Service Center
Civil Engineering Services
Materials Engineering Research Laboratory**

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suit 1204, Arlington VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Report (0704-0188), Washington DC 20503.

1. AGENCY USE ONLY (Leave Blank)		2. REPORT DATE November 2002	3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE Canal-Lining Demonstration Project Year 10 Final Report			5. FUNDING NUMBERS	
6. AUTHOR(S) Jay Swihart and Jack Haynes				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Bureau of Reclamation Technical Service Center Civil Engineering Service Materials Engineering Research Laboratory Denver, Colorado			8. PERFORMING ORGANIZATION REPORT NUMBER R-02-03	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Same			10. SPONSORING/MONITORING AGENCY REPORT NUMBER DIBR	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Available from the National Technical Information Service, Operations Division, 5285 Port Royal Road, Springfield, Virginia 22161			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The Deschutes Canal-Lining demonstration Project is a cooperative effort among the Bureau of Reclamation, several irrigation districts, and several geosynthetic lining manufactures. The purpose of this study is to develop low-cost canal-lining technologies to reduce seepage over severe rocky subgrade conditions. The 34 test sections include combinations of geosynthetics, soil, concrete grout, Shotcrete, roller compacted concrete, elastomeric coatings, and sprayed-in-place foam. This report assesses the performance of test sections after 1 to 10 years of service. This report also documents the construction of five of the newest tests sections . At this time, seven of the test sections have failed, while the remaining test sections are in fair to excellent conditions. Each test section covers about 30,000 square feet, and unit construction costs ranged from less than \$1.00 to more than \$4.00 per ft ² . The test sections are divided into four generic types: exposed geomembranes, fluid-applied membranes, geomembranes with concrete cover, and concrete alone. Preconstruction and postconstruction ponding test have shown effectiveness at reducing seepage between 70 and 95 percent. The most promising lining alternative demonstrate benefit/cost ratios between 3 and 4.				
14. SUBJECT TERMS geosynthetic/water conservation/geotextile/geocomposite/geomembrane/ponding tests/Benefit/Cost Analysis/life-cycle costs			15. NUMBER OF PAGES 230	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UL	18. SECURITY CLASSIFICATION OF THIS PAGE UL	19. SECURITY CLASSIFICATION OF ABSTRACT UL	20. LIMITATION OF ABSTRACT UL	

R-02-03

**CANAL-LINING DEMONSTRATION PROJECT
YEAR 10 FINAL REPORT**

by

**Jay Swihart
Jack Haynes**

**Denver Technical Service Center Civil Engineering Services
Materials Engineering Research Laboratory Denver, Colorado**

**Pacific Northwest Region
Water Conservation Center
Boise, Idaho**

November 2002

Mission Statements

U.S. Department of the Interior

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Federal Disclaimer

The information contained in this report regarding commercial products or firms may not be used for advertising or promotional purposes and is not to be construed as an endorsement of any product or firm by the Bureau of Reclamation.

ACKNOWLEDGMENTS

The authors wish to thank the irrigation districts whose support was essential to the planning and implementation of this project. Reclamation particularly appreciates the support from the boards of directors of the Arnold, North Unit, Tumalo, Ochoco, Juniper Flat, Frenchtown, Lugert-Altus, Bitter Root, Buffalo Rapids, and Lewiston Orchards Irrigation Districts. Reclamation also wants to thank Mr. Rick Stone, a private landowner on the Twin Falls Irrigation District, for participating in the installation of a test section on his property. Water user support consisted of both a financial commitment and the acceptance of the risks involved with using unfamiliar technologies.

The authors wish to acknowledge the various material suppliers and contractors who were willing to participate in the project. In addition to making financial contributions, the participating companies provided invaluable technical support. These companies have also assumed risks by placing their products adjacent to those of their competitors under adverse conditions and often in new applications.

CONTENTS

Page

EXECUTIVE SUMMARY	ES-1
CHAPTER 1 - INTRODUCTION	1
Environmental Assessment of Canal Lining	2
Value of Conserved Water	2
CHAPTER 2 - NEW TEST SECTIONS	7
Test Section TF-1.—	8
Test Section LO-1.—	23
Test Section O-5.—	37
Test Section BU-1.—	51
Test Section BI-I.—	67
CHAPTER 3 - CONDITION ASSESSMENT	83
Visual Inspections	83
Maintenance	86
Durability	92
Arnold Irrigation District—Main Canal	92
Test Section A-1—	92
Test Section A-2—	97
Test Section A-3—	100
Test Section A-4—	104
Test Section A-5—	108
Test Section A-6—	116
Test Section A-7—	120
Test Section A-8—	123
Test Section A-9 and A-10—	127
North Unit Irrigation District—Main Canal	128
Test Section NU-1 and NU-2—	128
Test Sections NU-3 and NU-4—	130
Test Section N-5—	131
Test Sections NU-6 through NU-9—	132
Test Section NU-6—	135
Test Section NU-7—	138
Test Section NU-8—	140
Test Section NU-9—	142
Tumalo Irrigation District—Bend Feed Canal	144
Test Section T-1—	144
Test Section T-2—	145
Test Section T-3—	150
Ochoco Irrigation District—Main Canal	151
Test Section O-1 and O-2—	151
Test Section O-3a and O-3b—	156
Test Section O-4—	159
Test Section O-5—	163

CONTENTS - continued

	<i>Page</i>
Lugert-Altus Irrigation District	166
Test Section L-1—	166
Juniper Flat Improvement Company	169
Test Section J-1—	169
Frenchtown Irrigation District	175
Test Section F-1—	175
Twin Falls—Rick Stone Ranch, Farm Lateral	178
Test Section TF-1—	178
Lewiston Orchards Irrigation District	185
Test Section L-1—	185
Buffalo Rapids Irrigation District	186
Test Section BU-1a and 1b—	186
Bitter Root Irrigation District	189
Test Section BI-1—	189
Coupon Testing	191
CHAPTER 4 - SEEPAGE ANALYSIS	193
Preconstruction Ponding Tests	193
Arnold	193
North Unit	193
Ochoco	193
Postconstruction Ponding Tests	194
Arnold Ponding Tests	194
North Unit Ponding Test	194
Ochoco Ponding Tests	194
Effectiveness	200
CHAPTER 5 - BENEFIT/COST ANALYSIS	203
CHAPTER 6 - CONCLUSIONS	209
CHAPTER 7 - FUTURE STUDIES	211
Tulelake Irrigation District - The Firs	212
BIBLIOGRAPHY	217

APPENDICES

Appendix A
Appendix B
Appendix C
Appendix D
Appendix E
Appendix F

CONTENTS - continued

Tables

<i>Table</i>		<i>Page</i>
1	Irrigation Districts that have participated in the Canal Lining Demonstration Project	3
2	Canal Lining Costs - Arnold and North Unit Test Sections	4
3	Canal Lining Costs - Tumalo and Ochoco Test Sections	5
4	Canal Lining Costs - Lugert-Altus, Juniper Flat, Frenchtown, Twin Falls, Lewiston, Buffalo Rapids and Bitter Root Irrigation District Test Sections	6
5	10-Year Condition Assessment - Arnold Test Sections	83
6	10-Year Condition Assessment - North Unit Test Sections	84
7	Condition Assessment - Tumalo, Lugert-Altus, and Juniper Flat Test Sections	85
8	Categories of the test sections	86
9	Maintenance Assessment for the Arnold Test Sections	88
10	Maintenance Assessment for the North Unit Test Sections	89
11	Maintenance Assessment for the Tumalo Main Canal and the Ochoco Main Canal - Tumalo Irrigation District and Ochoco Irrigation District	90
12	Maintenance Assessment for the Lugert-Altus, Juniper Flat, Frenchtown, Rick Stone Ranch, Lewiston Orchards, Buffalo Rapids, and the Bitter Root Test Sections	91
13	Coupon Testing of Exposed Geomembrane test sections	191
14	Arnold Canal Ponding Tests	195
15	North Unit Canal Ponding Test	197
16	North Unit Canal Ponding Test - Invert only	198
17	Ochoco Canal Ponding Tests	199
18	Test section results	200
19	Effectiveness, durability, and maintenance requirements of generic types of canal linings	203
20	Benefit/Cost Analysis	204
21	Benefit/Cost ratios of four types of canal linings	209

Figures

<i>Figure</i>		<i>Page</i>
1	Location map, Rick Stone Ranch Canal Lining Installation	9
2	Location map, Lewiston Orchards Irrigation District Canal Lining Project	24
3	Location map, Ochoco Main Canal	38
4	Location map, Buffalo Rapids Main Canal	52
5	Location map, Bitter Root Irrigation District Main Canal	68
6	Location map, Arnold Canal	93
7	Location map, North Unit Main Canal	129
8	Location map, North Unit Main Canal 1998 Ponding Tests	196

GLOSSARY

CSPE	=	Chlorosulfanated polyethylene
CSPE-R	=	Reinforced chlorosulfanated polyethylene
EPDM	=	Ethylene Propylene Diene Monomer
EVA	=	Ethylene vinyl acetate
GCL	=	Geosynthetic clay liner
HDPE	=	High density polyethylene
LLDPE	=	Linear low density polyethylene
mPE	=	metallized polyethylene
PE	=	Polyethylene
PP	=	Polypropylene
PVC	=	Polyvinyl chloride
RCC	=	Roller compacted concrete
UV	=	Ultraviolet
VLDPE	=	Very low density polyethylene

EXECUTIVE SUMMARY

Reclamation has constructed 34 canal-lining test sections in 11 irrigation districts in four States to assess durability and effectiveness (seepage reduction) over severe rocky subgrades. The lining materials include combinations of geosynthetics, shotcrete, roller compacted concrete, grout mattresses, soil, elastomeric coatings, and sprayed-in-place foam. Twenty-eight test sections are located in central Oregon, three are in Montana, two are in Idaho, and one is in Oklahoma. Each test section typically covers 15,000 to 30,000 square feet. The test sections now range in age from 1 to 10 years. Preliminary benefit/cost (B/C) ratios have been calculated based on initial construction costs, maintenance costs, durability (service life), and effectiveness (determined by preconstruction and postconstruction ponding tests). The 34 test sections are divided into 4 generic categories as shown in the table below.

Table ES-1.—Test results for the 34 test sections

Type of Lining	Construction Cost (\$/ft ²)	Durability (years)	Maintenance Cost (\$/ft ² -yr)	Effectiveness at Seepage Reduction (percent)	B/C Ratio
Fluid-applied Membrane	\$1.40 - \$4.33	10 - 15 yrs	\$0.010	90 %	0.2 - 1.5
Concrete alone	\$1.92 - \$2.33	40 - 60 yrs	\$0.005	70 %	3.0 - 3.5
Exposed Geomembrane	\$0.78 - \$1.53	10 - 25 yrs	\$0.010	90 %	1.9 - 3.2
Geomembrane with Concrete Cover	\$2.43 - \$2.54	40 - 60 yrs	\$0.005	95 %	3.5 - 3.7

Each of the lining alternatives offers advantages and disadvantages. The geomembrane with concrete cover seems to offer the best long-term performance.

Fluid-applied membrane – Many of these test sections have failed and have been removed from the study. Most of the problems were related to poor quality control because of adverse weather common to field construction in late fall and early spring. These types of linings may have potential for special niche applications such as lining existing steel flumes or existing concrete channels.

Concrete – Excellent durability, but long-term effectiveness was only 70 percent because of random cracking. Irrigation districts are familiar with concrete, and they can easily perform required maintenance.

Exposed Geomembrane – The effectiveness is excellent (90 percent), but exposed geomembranes are susceptible to mechanical damage from animal traffic, construction equipment, and vandalism. Although exposed geomembranes have the lowest initial construction costs, they have a limited service life (typically 15 to 20 years). Also, exposed geomembranes are often poorly maintained because irrigation districts are unfamiliar with the geomembrane material, and sometimes need special equipment and training to perform even minor repairs.

Concrete with Geomembrane Underliner – The geomembrane underliner provides the water barrier, and the concrete cover protects the geomembrane from mechanical damage and weathering. System effectiveness is estimated at 95 percent. Districts can readily maintain the concrete cover, but they do not have to maintain the geomembrane underliner.

Effectiveness – Ponding tests showed a typical preconstruction seepage rate of about 1.0 foot per day. Postconstruction ponding tests showed effectiveness of 70 to 95 percent for the various lining alternatives.

Maintenance – Over the course of 10 years, maintenance costs have been relatively low for all the lining alternatives. Generally, exposed geomembranes require about twice the maintenance of concrete linings. For all lining alternatives, benefit/cost analysis shows that every \$1 spent on maintenance returns \$10 in conserved water by increasing effectiveness and design life. Therefore, more emphasis should be placed on maintenance, especially for exposed geomembrane linings.

New Test Sections

The newest test sections have been in service for only 1 to 2 years. While some of these test sections look promising, more time is needed to evaluate them before estimating service lives and benefit-cost ratios. These test sections include:

- Wet-applied polyurethane geocomposite
- Exposed reinforced metallized polyethylene
- Exposed bituminous geomembrane
- Exposed white textured HDPE
- Exposed EVA geocomposite

Coupon Testing

Six of the exposed geomembrane test sections were sampled for laboratory evaluation. Although many of the exposed geomembranes visually appear to be in excellent condition, the changes in physical properties suggest that many are beginning to degrade. Service life predictions are included in table ES-2.

Table ES-2—Coupon Testing of Exposed Geomembrane test sections

Test Section	Material	Age	Visual Assessment	Physical Property Testing	Service Life Prediction
A-3	80-mil Textured HDPE	10 years	Excellent	Elongation down 90% OIT down 30%	20-25 years
A-4	30-mil PVC with Bonded Geotextile	10 years	Very Good	Tensile up 30% Modulus up 140% Elongation down 70%	10-15 years
A-5	45-mil Hypalon	10 years	Fair to Poor	Tear strength down 60%	10-15 years
A-6	36-mil Hypalon	10 years	Fair	Tear strength down 60%	10-15 years
O-3	45-mil EPDM	2 years	Excellent	Elongation down 30% Tear strength down 50%	15-20 years
O-4	30-mil LLDPE	2 years	Excellent	Tensile down 10% Tear Strength down 10%	10-15 years