Deschutes Canal Lining Demonstration - Construction Report

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ABSTRACT: Canals in central Oregon typically lose up to 50 percent of their water through seepage. The area's volcanic geology accounts for the high seepage rates, as canals are typically unlined with fractured basalt bottoms and sides of highly permeable soil and rock. The Bureau of Reclamation (Reclamation) constructed 18 canal lining test sections to assess effectiveness in reducing seepage. Lining materials included combinations of geosynthetics, soil, concrete, elastomeric coatings, and sprayed-in-place foam. Each test section is 100 to 300 meters long, and covers between 1,500 and 3,000 m^2. This paper summarizes the construction phase including construction materials, construction techniques, unit construction costs, and initial water savings. Construction costs ranged from US $11 to $47 per m^2. Initial ponding tests indicate that seepage rates have been reduced by one to two orders of magnitude. These 18 test sections will be monitored over the next 10 years to ascertain durability (life-cycle costs) and effectiveness (long-term seepage rates).

1 INTRODUCTION

New canals are typically lined with compacted clay, concrete, or geomembranes to reduce seepage losses. Older canals are often unlined, and can have high seepage rates depending on the permeability of the native soils. Canals in the northwestern United States have extremely high seepage rates because of the volcanic geologic conditions. Typical subgrade conditions (see Fig 1) include fractured basalt, loose rock, and volcanic cinders (Gilbert and Carter, 1991).

Figure 1 - Typical existing canals consist of fractured basalt bottoms with sides of loose volcanic rock.

These volcanic soils are highly angular and can easily damage geomembrane liners (Morrison and Starbuck, 1984). Removal and replacement would require extensive blasting which is cost prohibitive.

In some canal reaches, up to 50 % of the irrigation water is lost to seepage. Reclamation estimates that unlined irrigation canals in the Upper Deschutes River Basin (central Oregon) lose 300 x 10^6 m^3 of water per year through seepage (Reclamation 1972). To put that loss in perspective, that's enough water for an additional 250,000 to 500,000 households (at 300 to 600 m^3 of water per household per year).

This paper describes the construction phase of a 10-year canal lining demonstration project to evaluate the durability and effectiveness of different lining materials for reducing seepage from canals with high rates of water loss and severe angular subgrade conditions. Water saved through lining can enhance and stabilize river flows, reduce irrigation water shortages, and benefit recreation, fish, and wildlife. This paper details the construction materials (geosynthetics, soil, concrete, shotcete, elastomeric coatings, and sprayed-in-place foam), their installation, construction costs, and initial water savings. Durability, life-cycle costs, long-term water savings, and the costs of conserved water will be the subjects of future papers.

2 CONSTRUCTION

Prospective material suppliers were asked to submit proposals for new materials and installation techniques that could accommodate severe subgrades, form a watertight membrane, resist weathering, and resist animal damage and vandalism. Eighteen test sections have been installed to date (10 on the Arnold Canal and 8 on the North Unit Canal). To simulate full-scale construction, each test section ranged from 100 to 300 meters in length and 1,500 to 3,000 m^2 in area. Tables 1 and 2 describe the test sections and include unit construction costs. The unit costs are Reclamation estimates including labor, equipment, materials, overhead, and profit. Costs not included are design costs and unlisted items, as well as allowances for remote job sites, cold weather, and limited access. Figures 2-8 show typical construction activities for the 18 test sections. More detailed construction, seepage, and cost information can be found in Reclamation Research Report (Swihart, Haynes and Comer, 1994).

Table 1 - Arnold Canal Test Sections

No	Lining Material	Cost ($/$m^2$)
1	0.1-mm Petromat geocomposite with 75-mm shotcrete cover	$22.20
2	0.75-mm VLDPE* with 75-mm Shotcrete cover and 540 g/m^2 geotextile cushion	$23.00
3	Exposed 2.0-mm HDPE*	$14.85
4	Exposed PVC*/geotextile geocomposite with 200 g/m^2 geotextile cushion	$11.30
5	Exposed 1.1-mm Hypalon with 540 g/m^2 geotextile cushion	$11.90
6	Exposed 0.9-mm Hypalon/ Geotextile geocomposite	$11.10
7	1.0-mm PVC with 75-mm grout-filled mattress	$25.40
8	75-mm grout-filled mattress	$20.00
9-10	Exposed 1.5-mm VLDPE or HDPE with 400-g/m^2 geotextile cushion and 75-mm grout-filled mattress on side slopes only	$19.30

*VLDPE = Very Low Density Polyethylene
HDPE = High Density Polyethylene
PVC = Polyvinyl Chloride

Figure 2 - Arnold Canal test sections 1 and 2. Application of shotcrete cover over geomembrane.

Figure 3 - Arnold Canal test sections 3 through 6. Installation of exposed geomembrane liner.

Figure 4 - Arnold Canal test sections 7 through 10. Installation of grout-filled mattress.

Table 2 - North Unit Test Sections

No	Lining Material	Cost ($\$/m^2$)
1	Polyurethane foam with Futura 500/550 protective coatings	\$46.60
2	Polyurethane foam with Geothane 5020 protective coating	\$42.20
3	Exposed 200-g woven geotextile with Geothane 5020 protective coating	\$28.40
4	Exposed 200-g/m^2 nonwoven geotextile with Geothane 5020 protective coating	\$28.40
6	75-mm-thick, steel-fiber reinforced shotcrete	\$17.10
7-8	75-mm-thick, polyfiber reinforced shotcrete	\$15.80
9	75-mm-thick, unreinforced shotcrete	\$14.30

Figure 5 - North Unit Canal test sections 1 and 2. Spray application of polyurethane foam and coatings.

Figure 6 - North Unit Canal test sections 3 and 4. Application of protective coating to geotextile.

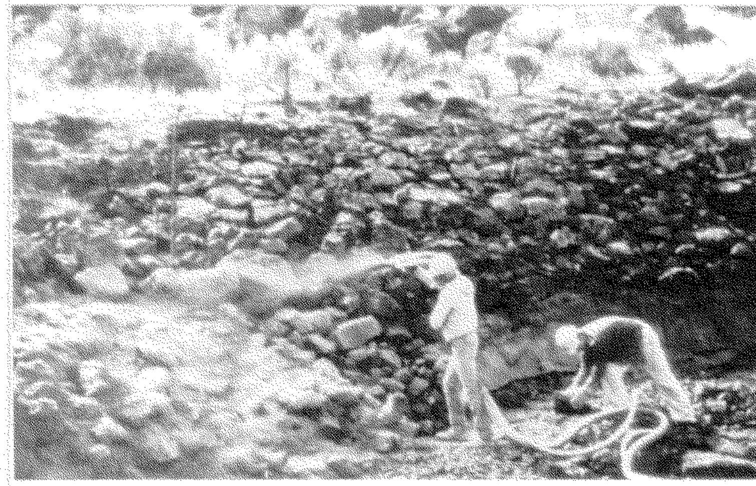

Figure 7 - North Unit Canal test sections 6 through 9. Application of 75-mm shotcrete lining.

Figure 8 - North Unit Canal test sections 6 through 9. Completed canal section with 75-mm shotcrete lining.

The 18 test sections were installed over a 17-month period, from November 1991 to March 1993. Some construction difficulties were encountered because of the short construction window. As these canals are in use from mid-Spring through mid-Fall, all construction activities (as well as routine operation and maintenance activities) must be performed in a few short weeks in early spring and late fall. The weather is often uncooperative during these times. While some test section installations had excellent weather, others experienced rain, snow, and freezing temperatures.

Note: Information in this paper concerning commercial products and firms may not be used for advertising purposes and is not an endorsement by Reclamation.

3 PONDING TESTS

Seepage rates were determined by ponding tests both before and after canal lining. Pre-construction seepage rates are shown in Table 3, while the anticipated seepage rates based on geologic conditions are shown in Table 4 (Bureau of Reclamation, 1948).

Table 3 - Pre-construction Seepage Rates

Test Pond	Seepage Rate (m^3/m^2-day)
Arnold Pond A	0.20
Arnold Pond B	0.43
North Unit Pond	1.28

Table 4- Seepage Rates Based on Geologic Conditions

Geologic Conditions	Seepage Rate (m^3/m^2-day)
Canal with concrete lining	0.02
Canal in clay and clay loam	0.12
Canal in volcanic ash	0.21
Canal in sand and volcanic ash	0.37
Canal in sand and gravelly sand	0.67

The seepage rates for both Arnold Canal test ponds falls within the expected range. However, the North Unit seepage rate is higher than expected, and suggests the presence of localized fissures or sinkholes.

Post-construction ponding tests were performed on each of the 10 Arnold Canal test sections (see fig 9). The average seepage rate was 0.02 m^3/m^2-day with minimal differences between the 10 test sections. This post-construction seepage rate is one to two orders of magnitude lower than the pre-construction seepage rates. Post-construction ponding tests on the North Unit test sections are scheduled for spring or fall 1994.

Figure 9 - Post-construction ponding tests.

4 CONCLUSIONS AND FUTURE STUDIES

At this point, the 18 alternative lining materials and installations can only be compared on the basis of initial construction costs (US \$11 to \$47 per square meter), and short-term seepage rates (essentially zero).

A truly meaningful comparison should be based on both effectiveness (long-term seepage rates) and life-cycle costs. Life-cycle costs will include initial construction costs, maintenance costs and design life (durability). The long-term effectiveness and durability of these 18 test sections will be addressed in a series of "Durability Reports" to be published over the next 10 years. The first durability report (after one to two years service) will likely be available by fall 1994.

5 REFERENCES

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