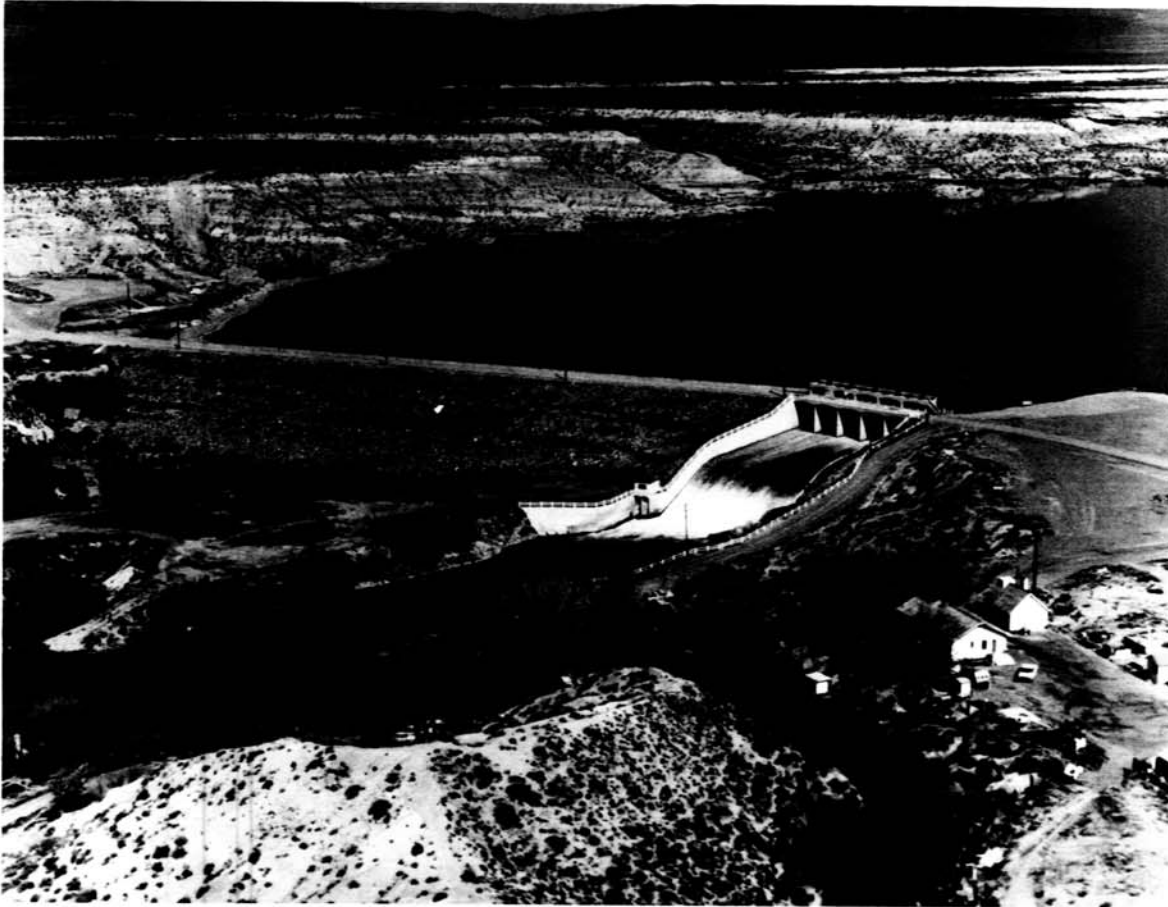


WATER OPERATION AND MAINTENANCE

BULLETIN NO. 156

June 1991



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Water Conservation: Tomorrow Has Arrived
U.S. Tackles Leaking Tanks
Retaining Forest Roads
The Denver Office Geosynthetic Team
Spotlight on Rye Patch Dam and Reservoir

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The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging information for use by Bureau personnel and water user groups for operating and maintaining project facilities.

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Ferne Studer, Managing Editor
Bill Bouley, Technical Editor
Facilities Engineering Branch
Engineering Division
Denver Office, Code D-5210
PO Box 25007, Denver CO 80225
Telephone: (303) 236-8087 (FTS 776-8087)



Cover photograph:

Rye Patch Dam and Reservoir,
Humboldt Project, Nevada. Aerial
view looking upstream on Humboldt
River about 26 miles northerly of
Lovelock, Nevada.

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PROTECT THOSE BULKHEAD GATE AND STOPLOG SEALS

by Bill Bouley¹

It is time to use your bulkhead gates or stoplogs to isolate and dewater your work area. If they are stored in the open, climatic conditions and the rays of the sun have probably dried out and cracked the rubber seals which will affect their watertightness. Otherwise, a farsighted maintenance foreman removed those seals to prevent such deterioration and stored them in a warehouse. Since this equipment is seldom used, the seals could be difficult to find in their storage location or could be in a deteriorated condition. After the seals have been located in the warehouse, they are taken to the field and attached correctly to the bulkhead gate or stoplog and adjusted to form a watertight seal.

The above scenarios are typical of what has been observed for bulkhead gate or stoplog storage. If the reason for the bulkhead gate or stoplog use is for an emergency shutdown of a penstock, stilling basin, canal, etc., time spent locating and replacing seals could be critical.

The Lahontan Basin Project Office has a partial solution to the weathering problem. Project personnel have covered the neoprene seals of the larger bulkhead gate for their Stampede Dam Powerplant with duct tape. Duct tape has protected the seals, but the tape has deteriorated in the sunlight causing a separation between the adhesive and outer layers of the tape. Project personnel recommend that a more ultraviolet resistant material be used for seal protection.

The Materials Science Section in the Denver Office Division of Research has the following suggestions for preserving the life of rubber seals. The most effective means of prolonging rubber is temperature control. Black rubber exposed to sunlight can easily reach a surface temperature of 160° or more. At this temperature, many rubber products, including neoprene, can harden considerably in a relatively short time. A white coating can reduce that 160° temperature to less than 120°. Reclamation experience has shown that black rubber can harden and crack in 5 years. Under the same conditions, but with a white coating, the rubber performed well for over 20 years.

The coating must be a latex (water-based) product. Solvents in oil-based paint could harm the rubber. A flat white outside latex paint works well as a protective coating. Minor problems such as discoloration, peeling, and cracking of the paint should be expected. At best this is a temporary coating because selection and application of a "permanent-type" coating would be difficult and expensive for an in-service product. The paint will need occasional touchup to provide a permanent solution, and may need recoating after water immersion, so choose an inexpensive product.

A further measure to protect the seals is storing the bulkhead gates or stoplogs off the ground or operating deck on blocks to prevent compressing the seals during non-use. Wooden planks, or other inexpensive material, are used to support the main sections of the bulkhead gate or stoplog and to provide the clearance for the seals.

¹ Bill Bouley is a Civil Engineer, Bureau of Reclamation, Facilities Engineering Branch, Denver, Colorado.



Bulkhead gate stored below gantry crane at Canyon Ferry.



Duct tape over neoprene seals on large bulkhead gate at Stampede Powerplant.

NONTRADITIONAL CANAL LINING ALTERNATIVES

by Thomas E. Mitchell¹

Introduction

Lining irrigation canals helps conserve water and conveys water more efficiently. First, lining reduces canal seepage which prevents the loss of water from the distribution system. The loss of water is not only economically undesirable, but the lost water could seep onto adjacent lands and have added detrimental effects. Secondly, a more hydraulically efficient canal cross section can be achieved. With lining, the friction of flowing water can be reduced, or a more efficient canal prism geometry can be used. A hydraulically efficient cross section allows higher flows through a smaller channel. For new canals, this will reduce the amount of right-of-way and the associated cost of purchasing the right-of-way. For existing unlined canal systems that are upgraded by lining, a more hydraulically efficient canal cross section means potentially more capacity for the same cross-sectional area. However, if the capacity is not increased, this leads to more flexibility and efficiency in operation. Lining can also reduce channel erosion which will reduce the cost of maintaining the canals or channel systems.

Traditionally, the most common types of lining to achieve these benefits have been earth linings, concrete linings, or PVC (polyvinyl chloride) linings used in trapezoidal-shaped sections. There has been a great deal of research and application of these types of linings on Reclamation distribution systems. Reclamation publications on these traditional linings are listed at the end of this article.

The purpose of this article is to present nontraditional alternative lining applications. The most common reason for not using these alternative linings is their higher cost. However, they have specialized engineered applications where they may be considered useful. These alternative linings, their specialized applications, and their potential benefits are discussed.

Semicircular Canals (Zero Slump Concrete)

Engineers in Spain have developed a method of constructing semicircular canals using zero slump concrete and have been using this method of construction successfully since 1961. Zero slump concrete is defined as concrete having a slump of less than 0.5 inch which, may be achieved with a high cement content. Semicircular canals have a more hydraulically efficient cross-sectional geometry. When first examined, this might mean reduced cost for construction; however, other factors must be considered. Reclamation's report titled "Evaluation of Semicircular Canals," 1984, summarizes these considerations.

Before a semicircular section is selected, a feasibility study should be done comparing it with a trapezoidal section. One of the major factors in choosing a design for a semicircular section is the central angle θ (see figure 1). Semicircular sections generally have steeper sides slopes than trapezoidal sections. This requires that the soil either have an adequate

¹ Thomas E. Mitchell is a Design Manager, Water Conveyance Branch, Bureau of Reclamation, PO Box 25007, Denver, Colorado 80225.

internal angle of friction, or that it is stabilized either by overexcavation and backfilling with select material or chemical treatment of the soil (see the chapter on Stabilizing Soils). The central angle θ may also be reduced, but this reduces the hydraulic efficiency of the section. If the angle θ is reduced enough, the section can be even less efficient than a trapezoidal section. Therefore, semicircular sections require at least moderately cohesive soils and they are not adaptable to cohesionless soils.

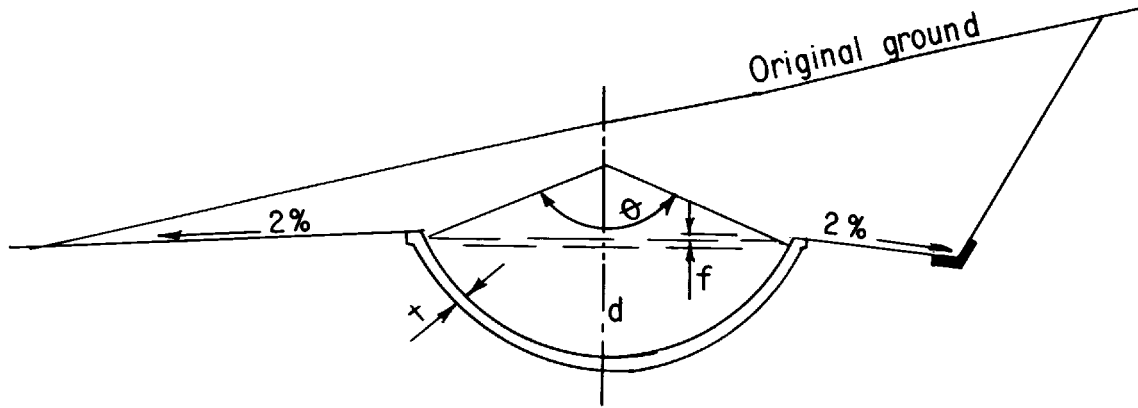
Other advantages to consider for semicircular sections are reduced right-of-way, possible reduction in excavation and concrete quantities, and a possible reduction in seepage area of the canal prism. Semicircular sections are stronger in uplift loads, and they may work better in areas with high ground water; however, this might be offset by a decrease in strength for lateral loads. These advantages must be compared with the disadvantages of a possible increase in the difficulty in construction and modification in structures required. For maintenance and safety, semicircular sections would probably be more difficult to repair, and their steeper side slopes would be more dangerous to animals trapped in the canal. In general, semicircular canals also seem to be best suited for canals with flow capacities less than 1,000 ft³/s.

Semicircular canals have some potential cost saving advantages, and they should be studied in more detail if the initial conditions seem favorable to this method of construction.

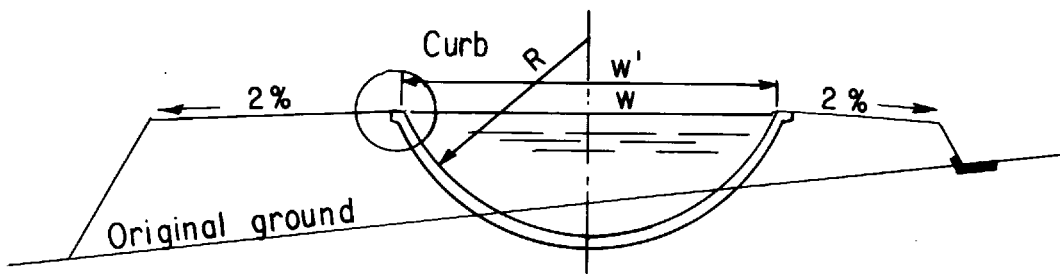
Shotcrete Over Geosynthetic

The Bureau of Reclamation has designed lining for approximately 1 mile of canal with shotcrete over a geosynthetic on the Towoac Canal for the Dolores Project in Colorado. This method of construction was chosen for several reasons. First, 1 mile is too short a reach of canal to economically use a custom-built lining machine. Second, this project was a canal rehabilitation where the canal was only out of service for a short time during the year, and this method was chosen to complete this work in this short time. Finally, this area is on a steep hillside with silty material — it must be extremely watertight to prevent any failures. An underdrain was provided to collect any seepage before it entered the embankment.

Figure 2 shows details of this type of lining. Certain construction considerations are required for the PVC. After the canal subgrade is prepared by excavating, trimming, and dragging, 20-mil PVC is installed on the subgrade. A prefabricated drainage composite is installed directly on the PVC lining. The drainage composite is manufactured with the symmetrical nodal configurations on one side so that the flat backside can be installed directly on the PVC lining, and a nonwoven needle-punched geotextile is bonded to the nodal configuration. The shotcrete is then applied to the needle-punched geotextile. This is required so the shotcrete will not slump on the 1-1/2:1 surface. Several longitudinal open joints and transverse open joints every 30 feet are provided to allow drainage of water between the shotcrete and the PVC lining. The shotcrete is pneumatically applied concrete placed directly onto the needle-punched geotextile. It has a 3,000-lb/in² strength, and a wet-mix process was used to better control the composition of the mixture. Only the accelerator is allowed to be added to the mixture at the nozzle. The allowable slump for the shotcrete is 3 inches.

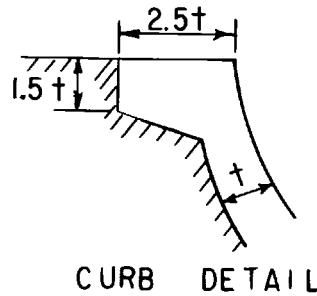


I.-Typical section in cut



II.-Typical section fill

- R = Radius of the circular section
- θ = Wetted central angle
- t = Lining thickness
- f = Free board
- w = Water width
- w' = Total width
- h = Curb height. (0 to 0.50 m)
- d = Depth



SEMI-CIRCULAR CANAL PRISM

Figure 1

Stabilizing Soils

Soils are stabilized for any combination of the benefits of reduced permeability, increased tractive force, and increased stability leading to steeper side slopes on canal prisms. The most common methods of stabilizing soils are mechanical stabilization and chemical stabilization. Mechanical stabilization includes overexcavating and refilling with suitable material or addition of fine-grain soils like bentonite to pervious soils. Common chemicals that have been used successfully for years to stabilize soils include resins, petrochemicals, sodium silicate, lime, and portland cement. Recently, fly ash has been tested for soil stabilization and has potential for being a cost-effective method.

Fly ash is a fine dust particulate material collected from flue gases of coal-burning powerplants. Since it is largely a waste product, its use for stabilization is a good method of disposal. Although the chemical composition of fly ash varies, the calcium oxide (CaO) constituent is most likely to affect soil stabilization. The effectiveness of fly ash can also be increased by combination with small amounts of portland cement, hydrated lime, or calcium sulfate. Different mixtures of fly ash are required for different soils. Tests are reported in Reclamation's report "Tests for Soil-Fly Ash Mixture for Soil Stabilization and Canal Lining," 1986.

Soil stabilization might be sufficient by itself as a canal liner or it might be used in conjunction with other methods of linings to increase their effectiveness.

Concrete Over Geosynthetic

The combination of concrete with geosynthetics is being used to solve unique canal construction problems. In India, low-density polyethylene (LDPE) film covered with brick tiles is being used successfully for canal linings. Like all hard covers, the brick protects the geosynthetic LDPE film from large animals' hoofs and from vandalism. Hand placing brick tiles, however, would be too expensive except where labor is very inexpensive. The combination of concrete with geosynthetics appears to be an important factor in successfully placing lining in existing unlined canals that cannot be dewatered. One method tested in India is a grouted mattress lining where two layers of a specially woven synthetic fabric are positioned and filled with fine-grain concrete. This sinks to the canal bed under water as it is filled with concrete.

Another method developed by the Bureau of Reclamation is a slipform method being tested on the Coachella Canal. Reclamation attempted to line a 1-1/2-mile reach of the Coachella Canal with a 30-mil PVC membrane cover with 3-inch monolithic slipform concrete. The design flow is 1,600 ft³/s; however, maximum usage is usually 1,000 ft³/s. This section is a prototype to evaluate environmental impacts, verify construction techniques, and refine cost estimates. A hard surface was chosen rather than earth to facilitate cleaning of the canal, and animal escape curbs were slipformed in the concrete (see figure 3). The concrete mixture includes antiwashout additives, and chemicals are added to the water during placement to counteract any adverse pH. Turbidity and effects on fish and wildlife are being studied. The lining was placed in the early spring when flow demands and canal velocities were low. The concrete will provide a hard surface to protect the PVC, and open longitudinal joints are spaced at 1.5-foot intervals to provide relief points for the hydrostatic pressure between the concrete and PVC lining.

Following are some advantages of underwater lining of operating canals:

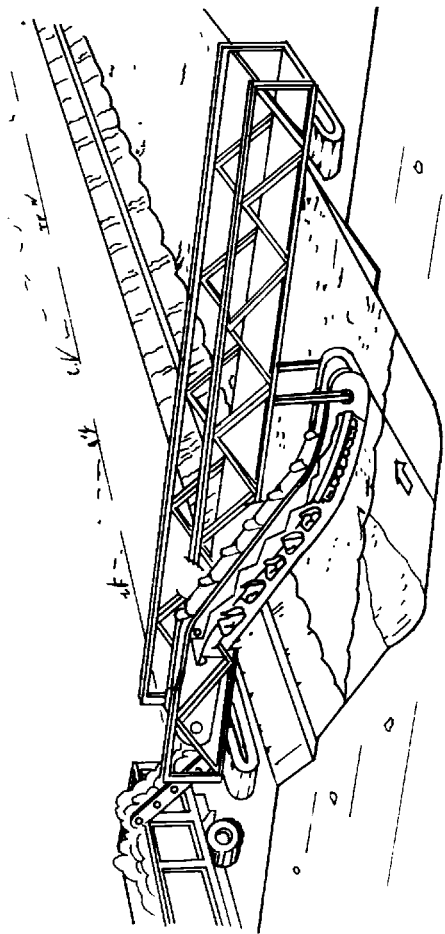
- a. Should provide substantial seepage control.
- b. No interruption of canal operations except for the brief time required to pass a turnout.
- c. The new prism will provide a larger canal prism than a relocated canal and thereby provide an operational storage pool at least as large as the one presently available.
- d. The need for acquiring additional or new right-of-way is eliminated.
- e. The hard surface concrete lining can easily be cleaned by dredge or the side slopes scraped to remove hydrilla, moss, and silt deposition.
- f. The lining will withstand relatively rapid water surface fluctuations, thereby providing desirable operating flexibility.
- g. Should provide a substantial cost savings over a relocated canal as it eliminates the need for a large excavation and canal bank construction effort and should shorten construction time. Overall construction traffic in the area should also be reduced.
- h. When all the research and environmental studies are completed and incorporated into the designs and specifications, no adverse impacts are expected from the construction. The canal should be safer for deer and large mammals and, above all, will save water.

Repair and Rehabilitation

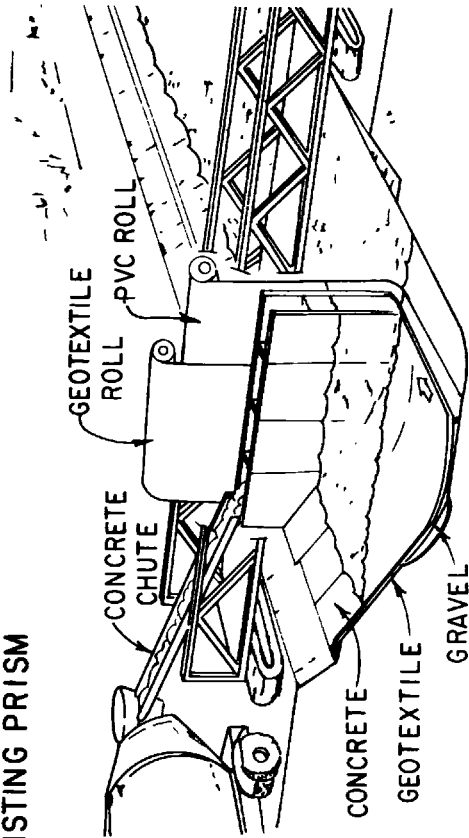
Various types of lining material have been developed that are almost exclusively used for repair and rehabilitation. Customized materials have been developed for specialized applications.

Many older canals lined with concrete deteriorated over time. When it becomes ineffective to seal cracks or replace individual panels that are damaged, the concrete can be covered with different materials to rehabilitate the canal. While the old concrete is not as watertight as desirable, it provides a hard surface subbase to support a watertight lining material. One of Reclamation's earliest experiences with this type of lining was in 1964 when 750 feet of the Contra Costa Canal was overlain with 1/32-inch butyl rubber lining. Because of shrinkage and ozone cracking, this lasted only a couple years. Recent research has shown that thick (100-mil) high-density polyethylene, Hypalon (chlorosulfonated polyethylene), asphalt with plastic sprays, or reinforced bitumen could be considered for this application. However, the material chosen must be able to withstand ultraviolet sunlight rays, weathering, and large animal traffic.

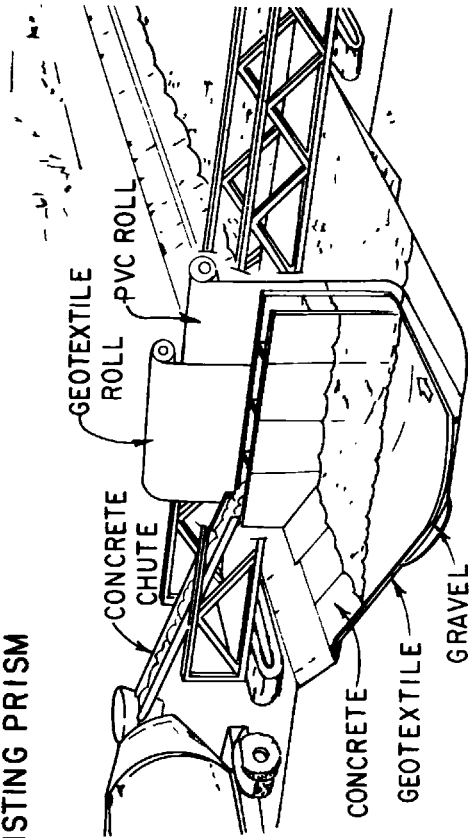
One recent example of a rehabilitation process for an existing concrete-lined canal was the rehabilitation of the Putah South Canal of the Solano Irrigation District in Vacaville, California. The designs for this job were prepared by Summers Engineering, Inc., of Hanford, California. In November 1989, 2 inches of shotcrete lining with 2 lb/yd³ of fibermesh fibers was placed over a 40-mil textured high-density polyethylene; the



① UNDERWATER PROTOTYPE TRIMMING EXISTING PRISM



② UNDERWATER PROTOTYPE RESHAPING EXISTING PRISM



③ UNDERWATER PROTOTYPE PLACING FML WITH CONCRETE COVER

CONCEPTUAL DRAWING OF UNDERWATER LINING

Figure 3

polyethylene was attached to the existing concrete lining. Approximately 5,000 feet of canal was rehabilitated at a cost of \$300,000 at approximately \$18.09/yd² (\$5.85/yd² for 40-mil textured high-density polyethylene, \$0.54/yd² for fibermesh, and \$11.70/yd² for shotcrete) for the lining, which did not include surface preparation for the concrete. Since this was a small job, this price per square yard was higher than for a large job.

Many of the same materials used to overlay concrete can be used as exposed linings to rehabilitate unlined earth canals. In 1987, the Kennewick Irrigation District in Kennewick, Washington, installed reinforced bitumen lining material over earth as an alternative to PVC lining covered with earth and gravel. Earlier installations of PVC had weeds rooting in the cover material that will eventually have to be removed with the possibility of the cover being reduced or the PVC damaged. The reinforced bitumen lining provided a watertight lining that will hinder weed growth. While the reinforced bitumen is initially more expensive than the PVC installation, some of the cost is offset by less earthwork during installation and hopefully less maintenance cost in the future.

Cost Comparison

Before any lining is chosen, comparative costs should be made to determine the most economical lining. This section presents a cost estimate for different types of lining material based on 1989 prices for large lengths of canals in the United States. This section should be used as a guide in determining the factors for a cost estimate. As with all cost analysis, new material, improved manufacturing, construction techniques, or market forces can make the analysis change in the future. This section is, therefore, only a guide to comparative costs of different linings.

a. Concrete and PVC linings.—Concrete canal-lined sections generally have steeper side slopes and faster velocities than PVC-lined canal sections. This reduces the initial right-of-way required and the total earthwork. A comparison of the installed cost per square yard of lining material without the right-of-way and other earthwork costs follows.

(1) Concrete lining per square yard.—

Preparing foundations for concrete lining (trimming)	\$ 1.00
Furnishing and placing unreinforced concrete in canal lining 3 inches thick (0.0833 yd ³ /yd ² x \$50/yd ³)	4.16
Furnishing and handling cementitious material (0.0235 ton/yd ² x \$110/ton)	2.58
Providing joints in unreinforced concrete lining (0.75 lin ft/yd ² x \$0.70/lin ft)	<u>0.52</u>
Total cost/yd ²	\$ 8.26

(2) PVC lining per square yard.—

Preparing subgrade for PVC lining	\$ 1.00
Furnishing and placing 20-mil PVC lining	1.50
Furnishing and placing gravel cover over PVC lining (12 inches thick = 0.33 yd ³ /yd ² x \$5/yd ³)	<u>1.67</u>
Total cost/yd ²	\$ 4.17

These costs are based on gross area of linings. Although the reduced area of concrete will have to be determined for the specific flow conditions, it is not uncommon for concrete sections to have 60 percent of the area of PVC sections. Therefore, the net cost of concrete is $\$8.26 \times 60\% = \$4.95/\text{yd}^2$, which is comparable to the cost of PVC lining.

b. Concrete with geosynthetics.—Concrete with geosynthetics applications increase the cost significantly as shown in the following estimates.

(1) Shotcrete over geosynthetic per square yard.—

Preparing foundation for lining	\$ 0.50
Furnishing and placing a prefabricated drainage composite	11.00
Furnishing and placing 20-mil PVC lining	2.50
Furnishing and placing 3-inch-thick shotcrete ($0.0833 \text{ yd}^3/\text{yd}^2 \times \$250/\text{yd}^3$)	20.83
Furnishing and handling cementitious material ($0.0235 \text{ ton}/\text{yd}^2 \times \$110/\text{ton}$)	2.58
Total cost/ yd^2	<u>\$37.41</u>

(2) Concrete over geosynthetic—underwater placement per square yard—preconstruction estimates.—

Preparing foundation for lining under water	\$12.00
Furnishing and placing 30-mil PVC lining under water, including geotextile	3.00
Furnishing and placing 3-inch-thick concrete under water ($0.0833 \text{ yd}^3/\text{yd}^2 \times \$100/\text{yd}^3$)	8.33
Furnishing and handling cementitious material ($0.0235 \text{ ton}/\text{yd}^2 \times \$110/\text{ton}$)	2.58
Total cost/ yd^2	<u>\$25.91</u>

c. Specialized applications.—

(1) Asphaltic concrete 3 inches thick
($0.0833 \text{ yd}^3/\text{yd}^2 \times \$50/\text{yd}^2$)

\$ 4.16

This material is often sprayed with a plastic coating for durability, and if it is placed over concrete, a drainage composite is often required between the concrete and the asphalt. These can increase the cost per square yard significantly.

(2) Furnishing and applying fly ash for soil stabilization
($0.068 \text{ tons}/\text{yd}^2 \times \$50/\text{ton}$)

\$ 3.38

This assumes fly ash is mixed 25 percent, by weight, for 6-inch thickness of soil and the unit weight of soil is 120 lbs/ft³.

(3) Furnishing and installing the following exposed linings.-

100-mil high-density polyethylene/yd ²	\$15.00
0.036-inch-thick Hypalon reinforced 10 x 10/yd ²	\$10.00
Reinforced bitumen canal lining/yd ²	\$10.00

Conclusion

Many types of materials and methods are available for lining canals, and careful comparisons are required to choose the most cost effective and engineering effective.

References

- Bureau of Reclamation, Linings for Irrigation Canals, 1963 (out of print).
- Bureau of Reclamation, Design Standards No. 3-Canals and Related Structures, 1967.
- Bureau of Reclamation, Performance of Plastic Canal Linings, Report No. REC-ERC-84-1, 1984.
- Bureau of Reclamation, Performance of Granular Soil Covers on Canals, Report No. REC-ERC-81-7, 1981.
- Bureau of Reclamation Practices for Design and Construction of Concrete Lined Canals, ASCE conference paper, 1975.
- Bureau of Reclamation, Interim Report on Canal Linings Used by the Bureau of Reclamation, 1988.
- Mitchell, Thomas E., Alternative Canal Lining Applications, paper presented at Conserv 90, Phoenix Civic Plaza, Phoenix, Arizona, August 12-16, 1990.

REDUCING IRRIGATION CONVEYANCE LOSSES

by William Morrison and Theresa Casias¹

Introduction

Both organic (plastic linings) and inorganic (soil additives such as cement, lime, and fly ash) materials are being used to reduce seepage from irrigation conveyance systems. Because the use of these materials involves different technologies, they are discussed separately.

Plastic Linings

Since the end of World War II, the rapid development of synthetic polymers has made a host of new construction materials available. In cooperation with industry, Reclamation has conducted extensive laboratory and field research on many of these synthetic materials engineered specifically for use as waterproof membrane linings. This work has led to development of plastic linings for seepage control in irrigation canals, reservoirs, and ponds.

These materials are thin, tough, impermeable plastic or elastomeric films ranging in thickness from 10 to 100 mils (1 mil = 0.001 inch). Plastic linings are also referred to as geomembranes or flexible membrane linings.

The most common plastic linings include:

- a. PVC (polyvinyl chloride).
- b. HDPE (high-density polyethylene).
- c. VLDPE (very low-density polyethylene).
- d. EIA (ethylene interpolymer alloy).
- e. CPE (chlorinated polyethylene).
- f. CSPE (chlorosulfonated polyethylene). This material is also called Hypalon, which is DuPont's trade name for the compound.
- g. LDPE (low-density polyethylene). This plastic is similar to the type used in manufacturing trash bags, such as "Hefty," "Glad," etc. For comparative purposes, trash bags range in thickness from 1-1/2 to 2 mils.

Except for HDPE, VLDPE, and LDPE, plastic linings are manufactured as roll goods (5 to 7 feet wide). The roll goods are shipped to a fabricator where they are factory seamed into large sheets or panels up to 100 feet wide and several hundred feet in length

¹ William Morrison, Materials Engineer, and Theresa Casias, Civil Engineer, are employed in the Denver Office of the Bureau of Reclamation.

depending upon the application. To facilitate handling, the large sheets are accordion folded like computer paper and palletized for shipping. The other materials (HDPE, VLDPE, and LDPE) are manufactured in rolls 20 to 30 feet wide and are shipped directly to the jobsite.

In the past, use of plastic linings (primarily PVC) was in conjunction with rehabilitation of old, unlined canals especially in areas unsuitable for compacted earth or concrete linings.

The first PVC installation under Reclamation construction specifications occurred in 1968 on the Helena Valley Canal, Helena Valley Unit, Montana. Since then, PVC has been used in rehabilitation work on the East Bench Unit, Montana; Riverton Unit, Wyoming; Farwell Unit, Nebraska; Yakima Project, Washington; and the Grand Valley Project, Colorado.

Plastic linings are now being specified for new construction. For example, a 20-mil PVC was recently used on the San Luis Project, Colorado, to line a conveyance channel for delivering salvaged ground water as a supplemental source to the Rio Grande River. The installation on the San Luis Project is the largest use to date of a plastic lining in canal construction in the United States. Over 1,400,000 yd² of PVC were installed. PVC has also been used widely since the early 1980's as a canal lining material in southern Alberta, Canada.

Plastic lining construction involves the following procedures.

- a. *Excavation.*—The side slopes should be constructed sufficiently flat to ensure that the protective earth cover over the plastic liner remains on the slopes under operating conditions. The side slopes should be no steeper than 2.5:1 (H:V).
- b. *Subgrade preparation.*—After the rough excavation is completed, the subgrade is prepared to a firm, relatively even surface. Sharp rocks, roots, and other objects that might puncture the membrane are either removed or padded by covering with a geotextile or 3 to 4 inches of sand.
- c. *Plastic lining installation.*—The lining is supplied to the jobsite in sheets wide enough to cover the canal prism and several hundred feet in length. As previously mentioned, if the lining is packaged accordion folded in both directions, it is simply unfolded and pulled into place. It is important that the plastic lining be placed in a slack condition so the weight of the earth cover will not cause severe stressing. On the San Luis Valley Project, several contractors developed equipment for the mechanized placement of both lining and protective earth cover. This was also done on some of the work in southern Alberta.
- d. *Protective earth cover.*—The earth cover is placed soon after the plastic lining is installed to eliminate possible wind or other damage. The earth cover is an essential part of a buried membrane lining system because its function is to protect the membrane from the elements, animal traffic, vandalism, and mechanical damage during canal cleaning operations.

Plastic linings are also being evaluated for special applications such as:

- a. Repair of deteriorated concrete linings
- b. Underwater lining of operating canals
- c. Bottom-only linings in soils where the seepage is primarily in the vertical directions

As the nation's infrastructure continues to age and deteriorate, use of plastic linings appears to be a viable repair method, especially under adverse conditions such as limited access, inclement weather, or short downtime.

Stabilization Using Additives

The Bureau of Reclamation has constructed a large number and a wide variety of hydraulic structures for water storage and conveyance throughout the Western United States. A variety of construction techniques and materials have been used, but soil is the material most frequently utilized. In order to make certain soil types usable, additives are required to improve soil properties. Lime and cement both have been successfully used by Reclamation to enhance soil properties. Studies are currently underway to utilize by-product additives, such as fly ash.

Lime Stabilization

Two types of clay soils have been encountered which cause difficulties for construction and operation of some water conveyance structures. The first is expansive clay and the second is dispersive clay. Lime treatment of both types of clays has been found to be an effective stabilization method.

Expansive soils exhibit significant volume change, expansion and shrinkage, with changes in moisture content. For a canal lining, volume change can present serious problems by causing lower soil densities, expansion and shrinkage cracks, and loss of soil strength.

Dispersive clays are clays that will erode in slow-moving or even quiet water by individual colloidal size clay particles going into suspension. A concentrated leakage channel (crack) must be present to initiate erosion in dispersive clay. When erosion of the walls of a leakage channel occurs along its entire length at the same time, a rapid catastrophic failure can result.

Adding lime to expansive soil has two major effects: (1) it improves workability and (2) it increases strength. The percentage of lime added to a soil depends on whether lime is being added for modification (small percent to increase workability) or for stabilization (sufficient lime to provide strength).

The Friant-Kern Canal in California was constructed from 1945 through 1951 and is an example of the use of lime to stabilize an expansive clay. About 54 of its 152 miles traverse an area of expansive clay. Of this 54 miles, 33 miles are earth lined, and the remaining 21 miles are concrete lined. Failures have occurred in both the concrete-

lined and earth-lined sections. In 1954, this portion of the canal began cracking, sliding, and sloughing.

In the early 1970's, Reclamation began rehabilitation of the two worst areas of the canal using lime to stabilize the canal slopes. One area was in an earth-lined section and the other in a concrete-lined section. The contract included 8,900 feet of compacted soil-lime lining and 1,820 feet of concrete lining on lime stabilized compacted backfill. The compacted soil-lime earth lining was 2 feet thick on the canal bottom, and the side slopes were 3.6 feet thick normal to the slope.

The soil-lime rehabilitation consisted of removing previously placed riprap from the canal side slopes. All material to be stabilized with lime was removed and taken to the canal bottom where quicklime was spread and mixed and additional rocks were removed. Water was added and the soil-lime mixture was allowed to mellow for 24 hours. The soil-lime mixture was then spread and compacted in horizontal lifts on the sides of the canal and in the bottom of the canal to provide the specified compacted thickness.

Results of laboratory tests and observation of the canal indicated that this method of rehabilitation was quite successful. Improvement was measured as an increase in soil strength, about 20 times over that of untreated soil. Because of the successful results, Reclamation completed four more contracts between 1975 and 1984 using essentially the same design, construction, and evaluation techniques. Each of the rehabilitation projects has performed very well and no new slips, slides, or sloughs have occurred in the canal side slopes. Overall, use of soil-lime for canal rehabilitation appears to be a viable, economic method of stabilization.

Soil-Cement Stabilization

Reclamation has successfully used soil-cement to line water conveyance channels and water retention structures. Almost any type of non- to low-plasticity soil can be used for soil-cement lining or slope protection. Reclamation generally uses silty sands; however, materials containing substantially higher-gravel contents (up to 55 percent) have recently been successfully used. Higher-gravel contents tend to improve erosion resistance, while soils containing higher-fines contents tend to reduce seepage rates. For most water resource applications, soil, water, and cement are mixed in a central batch plant, hauled to the worksite, and placed and compacted to a high density.

A large-scale seepage test section was incorporated into the soil-cement facing at Lubbock Regulating Reservoir, Lubbock, Texas, to determine whether the soil-cement facing could also serve as a water barrier. Test results and observation of the test section indicated that most of the seepage from the test section occurred through shrinkage cracks and along construction contact planes between layers. Seepage rates obtained during initial observations were among the highest obtained, indicating that the soil-cement tended to seal during use. Although some seepage did occur, the facing was considered semipervious to nearly impervious. The soil-cement, itself, is quite impervious.

Soil-cement has been successfully used by Reclamation for over 25 years. The erosion resistance, low permeability, and economical cost make soil-cement a viable alternative

to other lining materials. As high-quality construction materials become less available, Reclamation is continually finding more uses for these cement stabilized materials.

Conclusions

Reclamation continues to study and develop various construction techniques and construction materials to improve the long-term performance of water conveyance structures and to minimize water losses.

WATER PIPELINE LIKELY TO BURST AGAIN¹

Even if quick repair of a major water pipeline that burst in the Tampa Bay area two weeks ago can be made, there is "better than a 50-50 chance" the line will break down again when water begins to flow, says Scott Emery, director of resource management for the West Coast Regional Water Supply Authority in Clearwater.

The 84-in. pipeline that carries about half of the water to around 1 million persons in the Tampa-St. Petersburg area exploded Oct. 3, causing the ground to tremble in a rural area north of Tampa (ENR 10/11 p. 5). There were no injuries. There is no estimate yet of the replacement cost.

"This pipe is bad - real bad," Emery says of the deteriorated 17-mile spiral prestressed concrete pressure line. The stretch that failed "was one of the sections that didn't look that bad inside," he says. "There are sections that look much worse."

The line, installed between 1973 and '75, also ruptured three years ago (ENR 7/2/87 p. 15). The water authority filed suit against one of the manufacturers of the pipe, Interpace Corp., and the project consulting engineer, CH2M Hill Inc., in state circuit court (ENR 2/11/88 p. 15). A similar case brought by Pinellas County, Fla., against the same defendants resulted in a \$25-million award last year (ENR 6/21/89 p. 24). Other suits against the pipe maker are ongoing in various places around the country.

Interpace is now owned by Madison Management Group Inc., Chicago, a holding company. But its pipeline division, then called Lock Joint Products, was sold to Gifford-Hill & Co. Inc. It is now Dallas-based GHA Lock Joint Inc.

The pipeline conveyed water from the agency's major well field. It was designed to handle a surge pressure of 280 psi. Normally pressure does not exceed 100 psi and at the time of the burst it was 70 psi, says Robert C. Edmunds, president of Jones, Edmunds & Associates Inc., Gainesville, Fla. It has been inspecting parts of the pipeline. Flow averages 110 million gal per day, peaking at one-third more.

Thirsty lawns. The explosion caused the authority to ban all outdoor use of water in the area affected. That reduced use by about 15 mgd, Emery says. The water authority's six other well-field transmission systems are working overtime to meet demand. Because those systems are older, there is a relatively high risk of failure and salt-water intrusion as a result of the increased pumping.

If the major pipe from the Cypress Creek well field cannot be repaired and maintained until a new line is built or if some of the older, smaller well-pipeline operations give out, the restrictions could last up to four years, Emery says.

Meanwhile, the authority is posting signs along the route of the major pipeline warning people to stay away, says Edmunds. "When a pipe that size ruptures, it is like a bomb explosion. It blows a crater and creates flooding, and sometimes implosions, and things get sucked back into the pipeline." He says a person could easily be sucked in.

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Flaking away. Officials initially thought it could take six weeks or longer to restore service because the authority has only about 80 of the 200 ft of pipe it needs to replace the section where the rupture occurred. Its own force will make the repair.

But the authority's executive board gave permission to buy pipe from Price Brothers Co., Dayton, Ohio. It provided a portion of the original pipeline but was not named in the suit, says Robert Ghiotto, CH2M Hill vice president for professional practice in the firm's Tampa office.

Ghiotto says an inspection of the pipeline indicated there were "some flaws in the Price pipe but it was not what you could call defective." Overall, he says, only about 1% of the entire pipeline is defective.

Edmunds conducted an investigation of two portions of the interior of the line for the water authority. He contends that pipe supplied by Interpace was improperly manufactured.

Edmunds says the pipe has a 1-1/2-in. inner concrete layer, spirally wrapped with 6-gauge steel wire and covered by 5 in. of concrete. He says that in the faulty sections the inner concrete layer does not contain enough cement, the reinforcing has become hydrogen embrittled, and the outer layer is too thin, of poor quality and is breaking down.

According to documents obtained by the water authority through the discovery process associated with its lawsuit, instead of the wire being heated and drawn at 350° F as required, the procedure was conducted at 650° F.

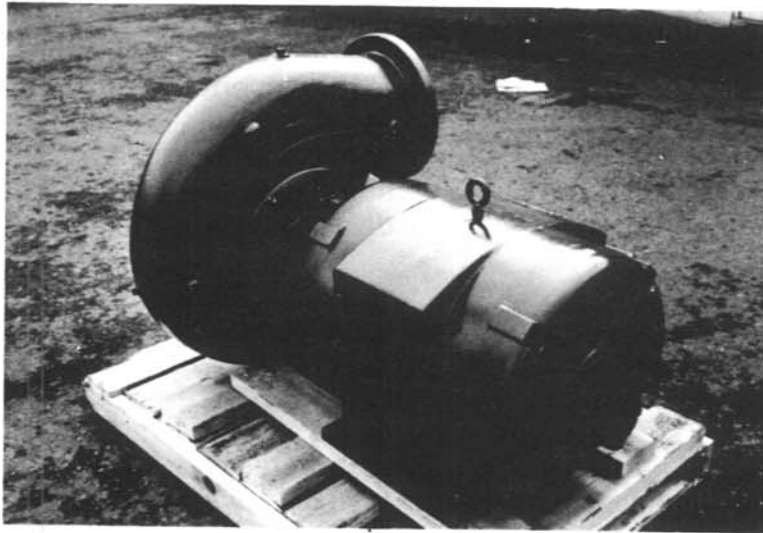
Ghiotto agrees that the break is the result of manufacturing defects. "We only specified use of prestressed pipe. I don't believe consulting engineers should be held responsible for manufacturers' quality control procedures."

In addition to taking emergency action to make the repairs, the water authority' plans to fast-track construction of a new delivery system from the Cypress Creek well field as part of a program to nearly double its delivery capacity (ENR 9/6/90 p. 11). That 50-mile network will cost between \$125 million and \$130 million. The project could be complete in about three years, Emery says, but a construction start has not been scheduled.

By Bob Boyle in St. Petersburg

PUMP CARE ENSURES TROUBLE-FREE IRRIGATION¹

by Gary Spencer²



Inspecting pumps regularly is the first step in pump protection.

Have you ever suffered through costly pump repairs and devastating downtime? If you answered yes to this question, you need regularly scheduled pump inspection and maintenance.

Why is the heart of the irrigation system often neglected until it fails? The answer is simple: Pumps have always been a mystery. Remember the old cliché, "If it's not broke, don't fix it"? It must have been created for pumps. Surprisingly, the required pump maintenance ratio per hour of work performed is extremely low.

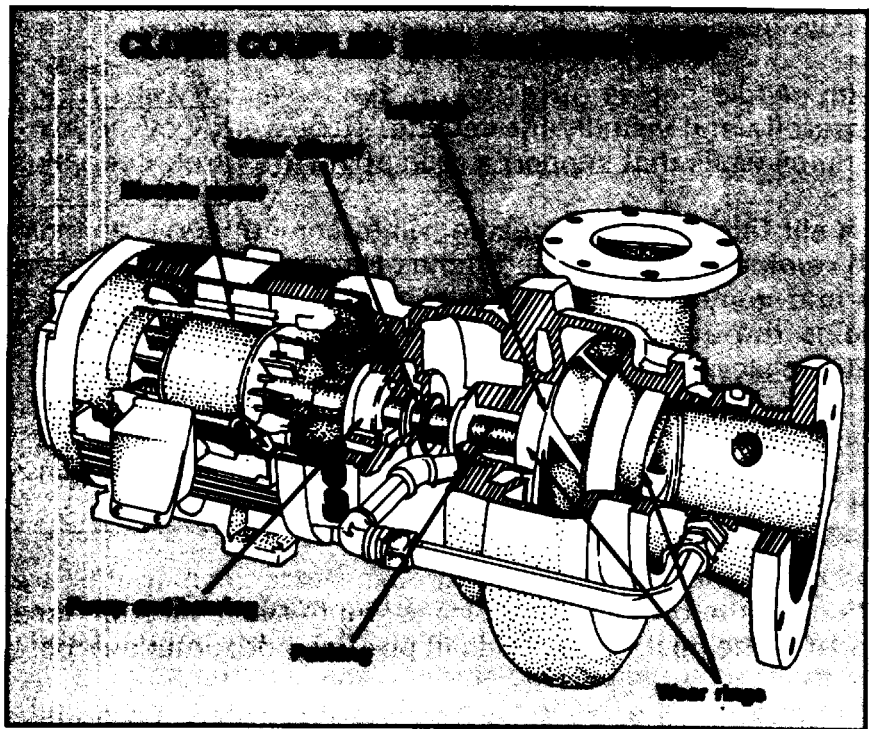
After 36 years of being a pump doctor, my advice is:

- * Purchase high-quality equipment, because the pump is the heart of your system.
- * Know and understand your equipment.
- * Conduct regular inspections and keep records and notes.
- * Use common sense by calling for help when you run into a problem you can't solve.

The days of cheap energy are gone for good. To get the most from each kilowatt-hour, it's absolutely essential to keep the pump and motor in good repair. Efficiency losses due to wear or neglect will add up to big bucks in operating costs.

¹ Reprinted with permission from the Associate Editor, Irrigation Journal, May/June 1990 issue.
² Gary Spencer is a sales representative for Cornell Pump Company of Portland, Oregon.

Inspecting the Pump.—A typical pump inspection includes a look and walk around. Regular inspections help you develop a sense of what the pump should sound and feel like.



Feel the motors and pumps. Are there any strange noises or vibrations? Can you detect a bearing or motor that is unusually hot? Is there a new odor or electrical smell?

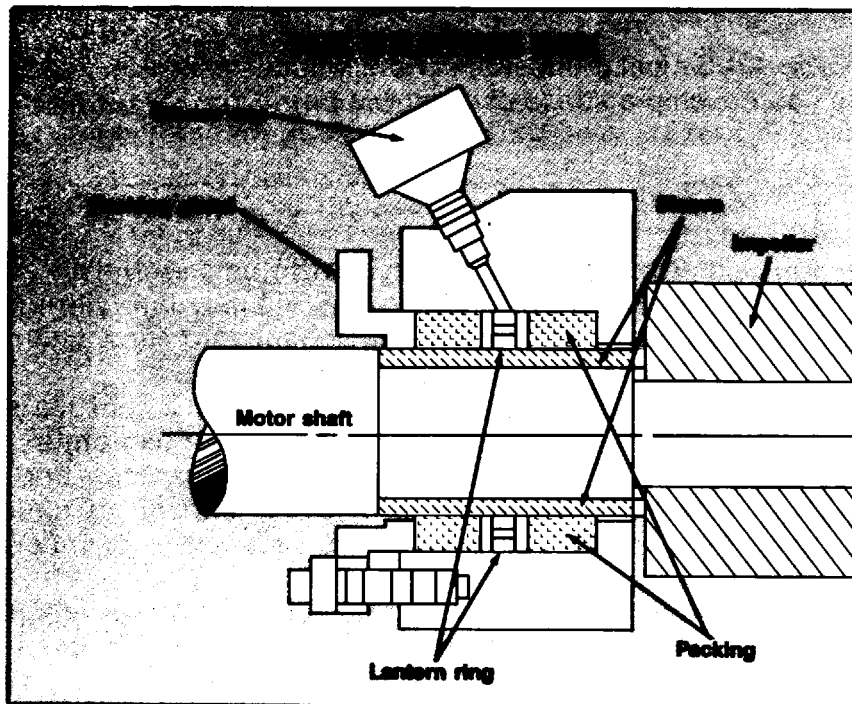
Use caution around drive couplings and electric controls. Don't hurt yourself by blundering into something unfamiliar.

You can trace many pump breakdowns back to the stuffing box. A badly leaking packing gland or mechanical seal will cause problems. Water spraying into a motor or bearing frame will infiltrate the pump end bearing. It will wash all lubrication from the bearing, causing rust and imminent failure.

If water collects under a horizontally mounted motor, the ventilation fan (which blows onto the motor winding) will pull the water into the motor. This may cause a burned-out motor. Water squirting up into a vertical, hollow-shaft motor of a vertical turbine pump will cause the same problems. *These motors are not water-cooled.*

Electric motor service life depends on a dry, clean atmosphere. Elevate a horizontally mounted pump at least 6 inches off the floor, and install a line to drain the leakage away from the motor.

Vertical turbines have drain connections in the bottom of the discharge head. Connect these to a hose and drain the head. Keep the drains open and flowing.



You can easily adjust the packing gland and grease cup to the manufacturer's instructions. Special lubrication for the grease cup and packing is available from local suppliers. The grease cup lubricates the packing and aids in priming horizontal pumps.

When you add a packing ring, be sure it's new and clean. Carefully align the gland without cocking it. Tighten evenly to achieve the manufacturer's specified leakage. This means minimum leakage with a cool stuffing box.

Replace dried and worn packing that has lost its lubrication. This requires a special tool called a packing hook. These are also available from local suppliers.

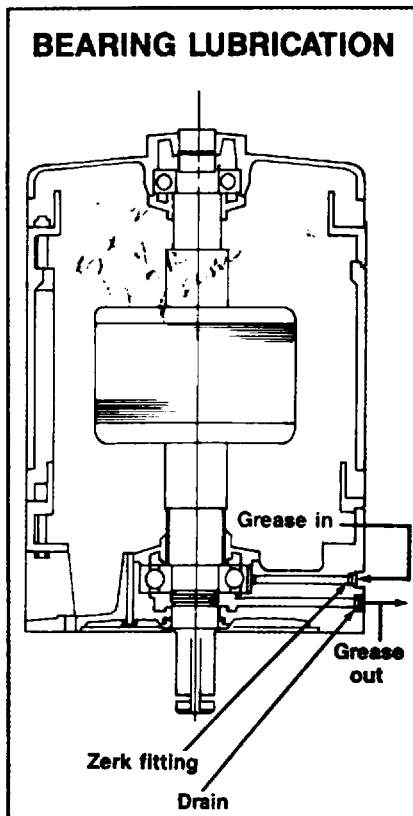
After removing all the packing, inspect the shaft sleeve. If the sleeve is grooved or worn, packing replacement will have a short life. You need to replace the sleeve. This requires disassembling the pump. If you have a horizontal unit, take it to the shop. Vertical turbines usually require motor removal and head shaft renewal.

If your pump is equipped with a mechanical seal, never allow it to run dry, even for a few seconds. Water lubricates the seal faces. A dry run merely burns out the pump.

At the first sign of a leak, replace the seal. This will require disassembly, which a pump technician normally does. You can damage a new seal if you mishandle it or improperly install it, so take care if you do your own maintenance.

Pumping sand and silt will naturally shorten the life of the packing, sleeve, seals, and wear rings. Good planning and site selection can ensure maximum service life.

If the pump is in the shop for a sleeve replacement, it's a good time to measure the wear on the wear rings. If the wear is $1/32$ of an inch or .030 per side, it's time to restore the clearances with new wear rings and impeller repair. The excess wear is costing you wasted energy (and money!) through efficiency loss.



Lubrication.—What type of lubrication should you use, and when should you use it? These questions are asked repeatedly. If your motor has Zerk grease fittings, it requires greasing. Some of the smaller sizes, usually 3- to 5-hp pumps, won't have Zerk fittings. These motors have sealed bearings and don't require greasing.

When you add grease, be sure the grease and the fittings are absolutely clean. The code number for the proper grease is EP-2. Other types, such as multipurpose, may work, but bearing manufacturers recommend only EP-2. The exception is if the motor or pump manufacturer specifically recommends a different lubricant.

To lubricate electric motor bearings, remove the relief grease plug. Using a hand grease gun, pump the new grease into the fitting until it shows at the drain. Do this when the unit is not running so you avoid getting grease into the motor. I like to leave the drain plug out for a few days to let the excess grease work its way through the drain, not into the motor.

The bearings will run usually hot for about 20 minutes after greasing, because the bearing is purging the grease from the balls and race. As the bearing warms up, it turns the grease to oil. It's this mist of oil that actually lubricates the bearing. Therefore, it's absolutely essential to use the Code EP-2 for proper melting temperature.

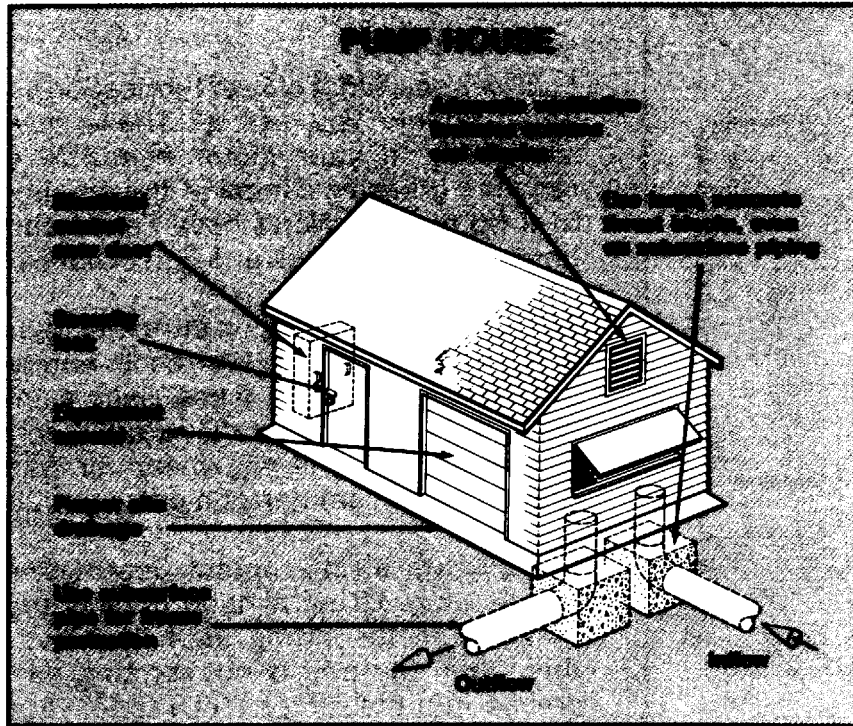
Pumps mounted on bearing frames (those that have a separate motor) are normally greased through the bearing cover. Excess grease accumulates in the large cavity of the frame. It takes years to fill the frame. Follow the manufacturer's instructions in the operator's manual for greasing frequency. A drain plug is usually a pipe plug near the bottom of the frame.

Proper motor ventilation is just as critical as lubrication. The temperature of the motor winding determines its life. Normal temperature means a long life.

Many motors have rodent screens installed on the vents. These are essential to keep critters out, but they require periodic cleaning. Keep them free of lint, chaff, weeds, dirt, and other debris to ensure a free, cool airflow.

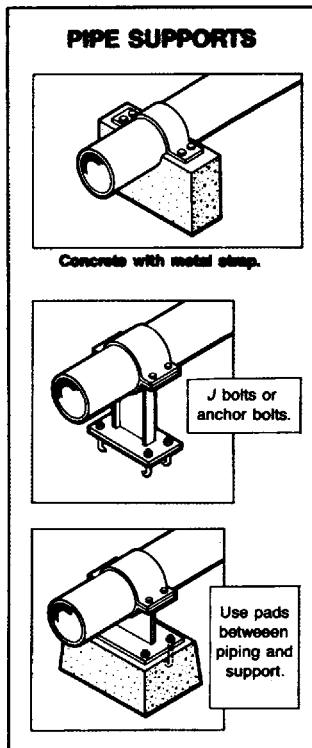
I am a believer in well-ventilated shelters that protect pumping equipment and switch gear from sun and rain. The sun's direct rays can add 10 to 20 degrees of ambient temperature to the motor temperature. For every 18 °F temperature rise above the motor nameplate rating, the expected motor life is reduced by one-half. Thermostat-controlled exhaust fans in pump houses help keep the inside temperature and airflow cool.

Vibrations.—What does an extreme vibration signal? It could be the result of a misaligned drive coupling or the start of bearing failure. Some pump units can actually twist on their bases if the base construction is too light, or if they are not secured and grouted properly to the foundation.



Pipeline misalignment can also lead to vibration. Unsupported pipelines full of water put a tremendous weight load on the pump casing. Pipelines can break the casings if the weight load is severe enough.

The pipelines must be supported so the pump can be removed with no stress or strain on it. I like to see one flexible-type pipeline coupling in either the inlet line or discharge line.



A noise developing in a pump that has otherwise been running quietly usually indicates that a bearing is beginning to fail. Replace the bearing immediately. Neglect could irreparably damage the motor or the frame.

A bearing that repeatedly fails indicates a possible misalignment or strain. Occasionally I have found that the bearing is either the wrong type or not heavy enough for the application. If you're in doubt, request a B-10 bearing life calculation from the pump manufacturer.

The Electric System.—Electric switch gear needs periodic inspection and maintenance, just as the pump and motor do. This requires an electrician who is experienced in controls and pump starters. He should check the contacts in the starter and replace any that show signs of uneven or heavy pitting. If neglected, these are going to heat and cause high current to trip out the overload protection device.

If you want to burn out the motor, install overload heaters with too high a rating or adjust the overload trip rating

up too high. I have actually seen a motor starter jammed shut by a stick wedged against the door. The price tag for this "good idea" – a 150-hp motor rewind.

Have the electrician check and tighten each and every screw in the panel. After several years, normal heat and temperature changes tend to loosen the terminal screws. A loose connection will cause heat, burn out wiring, damage the contactor, and/or cause short motor cycling and overheating. Remember, maintaining a low temperature rise in the electric motor will ensure a long service life.

WATER CONSERVATION: TOMORROW HAS ARRIVED¹

by Steve Swenerton²

In California and the Southwest, water has been the subject of heated discussions for as long as anyone can remember. But recently the debate has taken a significant turn, as California enters its fifth straight year of drought.

This time the talk is not of rights or agricultural runoff or water treatment, but of trade — of the buying and selling of water among the haves and the have-nots. Anyone whose business depends on the availability of water cannot ignore the water conservation issue any longer. This is true not only of the West but of the entire United States.

Water is a natural resource, but it has never been treated in the same way as other natural resources, such as coal or oil. It has never been subject to free-market forces. Huge federal water reclamation projects always produced supply that met demand. Accordingly we, as consumers, equated our water resources with manna from heaven. We do not have that luxury any longer.

First of all, there is a real shortage of potable water. Scientists and environmentalists have been talking about it for years. In the simplest terms, we are using up our water supply faster than nature can renew it.

The Ogallala aquifer, the main source of water for the Midwest and High Plains states, is seriously threatened by overuse and pollution from agricultural runoff. For every gallon of water pumped out, only a teacupful is restored by the natural process of aquifer recharge.

Recently, the effects of drought have been demonstrated vividly in the Southeast, the Northeast, the Midwest, and even the Pacific Northwest. During New York City's recent long drought, strict sanctions on water use were imposed, and the city's first law mandating water meters in all buildings was passed.

Episodes such as these remind all of us that our water supply is finite, but economic forces are making a more persuasive case.

Federal belt-tightening has much to do with changing attitudes. The \$16.3-billion water projects bill passed by Congress in 1986 was the first such bill in 10 years. That bill contains a very important provision. It requires that the states pick up 25 to 30 percent of the cost of these projects. Past bills, if they contained any requirements for local participation at all, called for a token 5 percent or so.

Some states are assuming that the federal faucet has been shut off for good. The Western Governors Association recently adopted a water policy calling for a realignment of federal, state, and local laws to encourage conservation and reallocation of existing water

¹ Reprinted with permission from the Associate Editor, Irrigation Journal, November/December 1990 issue.

² Steve Swenerton is director of sales for the Toro Irrigation Division in Riverside, California.

supplies. The association viewed the new policy as a free-market approach which would allocate existing water to developing areas and raise the price of water to market rates.

This concern with conservation marked a major reversal in attitude. Federal water policy has long been based on the "use it or lose it" dictum, which provided no incentive to conserve.

The Central Arizona Project illustrates how times have changed. The project, conceived almost 40 years ago, was meant to make the desert bloom with cash crops. When the 190-mile pipeline finally opened in 1985, it was clear that Arizona's growing cities, not its farms, would use most of the water from the project.

Why? Urban and domestic users can pay more for water than farmers, who account for only 2.4 percent of the state's gross revenues.

One thing is certain: The price of water will go up and, with it, consumer concern about its use. This will signal a change in the irrigation market, and we welcome it.

At Toro, we feel that our industry can no longer sit back and ignore these warning signs. Water conservation is vital to our continuing growth and long-term health. Educating customers on proper irrigation practices and informing them about the most water-efficient products is now more necessary than ever, both in agriculture and landscape applications.

After all, we are experts in water use. Because a significant portion of our customers are in the Sunbelt, Toro has a history of developing irrigation products for arid and drought-prone regions. For years, we have sponsored and run irrigation design schools and customer training programs to promote good water use practices. We are firmly committed to leading the irrigation industry in promoting such practices and developing new products which help conserve water and energy through more efficient usage.

None of us in the irrigation industry can afford to forget that water is the source not only of livelihood but of life. Irrigation has made things possible that were not possible before, and consumers are not about to give up these gains. Whether they be growers or city dwellers.

In the face of increasing demands on a finite water supply, we of the irrigation industry owe it to ourselves and future generations to do our part in ensuring that the future for all America is green.

U.S. TACKLES LEAKING TANKS¹

by Virginia Fairweather

As many as 400,000 underground storage tanks across the U.S. are leaking petroleum into surrounding soils, according to EPA estimates. At an average cost of \$70,000 each to bring those tanks up to standards set forth in EPA's Underground Storage Tank program, the cost will run in the billions. Ground water is at risk, and states are hastening to meet compliance deadlines. Civil engineers are major players in the effort to stanch those leaks.

Ground water is a drinking water source for half of the U.S. population, according to EPA. The agency also estimates that there are about 2 million underground petroleum storage tanks across the nation, and that about 25 percent are leaking. The consequences are serious, and the Underground Storage Tank, or UST, program is intended to correct this potentially dangerous state of affairs. About 90 percent of the current compliance programs are overseen by consulting engineers, says Jack Kramer of the Texas Water Commission (TWC), which is in charge of UST activities in that state.

UST was set up in 1984 under amendments to the Resource Conservation and Recovery Act (RCRA). To describe the program in its simplest terms, EPA has promulgated regulations with a series of deadlines over the next decade, beginning in 1989 for tanks installed before 1969. These deadlines are for site investigation, bringing tanks into compliance with UST and for remediation where necessary. "Compliance" includes options for corrosion and leak protection in tanks and in piping, providing for spills during deliveries, and monitoring and testing for the life of the tanks.

States administer the program, and Kramer describes his agency's activity as "barn burning" in its intensity. Events in Texas are a good indicator of UST activity. The state has many tanks and considerable ground-water dependency, two factors EPA considers in awarding federal trust funds to states to help pay for compliance. The state's capabilities to spend the funds, another measure of its aggressiveness, is also factor in awarding money. Dea Larsen of the agency says it has received about \$10 million so far, compared to the base of \$300,000 every state receives. Michael Kalinoski, also of EPA, adds that several other states exceed that \$300,000 base award as well.

The fund, which helps pay for cleanups whose owners are unidentifiable or unable to pay, was set up under the additional amendments to RCRA in 1986 and comes from a tax on wholesale gasoline. The fund has reached its statutory limit of \$500 million, so the tax is no longer collected for this purpose, says Larsen.

The Texas Commission has slightly more stringent rules than EPA's. Deadlines are sooner in some categories, and smaller tanks are regulated, for example. Formal EPA approval includes ensuring that state programs are at least as stringent as the federal regulations,

¹ Reprinted from Civil Engineering, ASCE, December 1990 issue.

that the state will provide adequate enforcement, and that a "viable" financial arrangement is set up to guarantee \$1 million in insurance funds.

Texas' program is not yet formally approved, but so far only Mississippi and New Mexico have official EPA approval, according to the agency's Greg Waldrip. However, 37 states have statutes to set up local funds to pay for the program.

Nonetheless, Texas, like most other states, is steaming ahead in seeking to avert ground-water contamination. Kramer says there are over 131,000 registered tanks in Texas now. Under the law, deliveries cannot be made except to registered tanks, so compliance was swift, he says. Kramer thinks about a billion dollars will be spent over the next 5 to 10 years bringing the state's leaking tanks into compliance, assuming that about 25 percent are leaking. He estimates an average cost of \$75,000 to bring a tank into compliance and correct problems. There could also be many more tanks — "every time you cut a road," he says, "you find another tank." Texas will help owners out with a state trust fund paid for by means of a delivery fee at bulk terminals.

If deadlines are not met, tanks must be pulled out of service and filled with an inert material within 30 days, he says. The TWC will have to be on site to insure compliance. If the soil is contaminated, the commission will order and oversee remediation.

Texas' Edwards Aquifer, says Kramer, is a special concern. It is the sole source of drinking water for San Antonio and some other municipalities, the only such aquifer in Texas, and 1 of about 20 so designated across the nation. Under the regulations, all tanks overlying these aquifers will have to be replaced with double-walled tanks. These tanks are preferred in other areas as well.

Double-Barrel Approach

Houston has enlisted the services of two consultants to attack their tank problem. One, McClelland Consultants of Houston, is a consulting engineering firm. The other is management consulting firm Deloitte & Touche, whose Houston office undertook "rationalizing" the city's fuel tank locations, delivery cycles, and general city policy, according to Gerry Mendelbaum of the firm. Using software they had previously used for product distribution analysis, Deloitte modeled various scenarios to optimize the city's vehicle-fueling operations.

John Grubbs of the city's General Services department, which took the lead in the UST work, says the city is run on a decentralized basis. City officials realized, he says, that they had too many fueling sites for the city's nine departments. They also knew they had the largest municipal fleet in Texas. It could have been "pure chaos," he says, if they tackled the problem from within those separate departments, and this was the driving force behind commissioning the Deloitte study.

"While you dig and fix, why not examine a system to see if all tanks are needed?" says Mendelbaum. All tank owners have to investigate, upgrade and, when necessary, remediate existing fuel tanks to comply with UST requirements, so it is an opportunity to check the entire system's rationale—if there is one. In looking at Houston, for example, Deloitte & Touche found that city vehicles did not always use the nearest fuel tank, especially if it belonged to another city department. Instead, drivers traveled to their

own department tank, using more fuel and contributing to traffic, air pollution, and wear and tear on vehicles.

As a result of the study, Deloitte & Touche recommended that Houston close about 30 city fueling sites, where some 50 city tanks now sit. The firm is currently joining forces with McClelland to market this dual approach to UST to other owners with many underground fuel tanks.

Rick Anderson is McClelland's project manager for the firm's considerable UST work. The firm has about the same number of projects in the public and private sectors, including contracts with the U.S. Postal Service in Dallas, San Antonio, and Oklahoma City; with the U.S. Navy, also in Texas; with Harris County, where Houston sits; and with several other public and private tank owners. To give an idea of the numbers, the Postal Service has over 125 tanks in Dallas and the Navy has over 175 tanks in the state. Houston has 450 tanks scattered throughout the city that belong to its nine departments.

Houston has a 5-year tank plan, and will likely spend over \$5 million to bring those tanks into compliance with state and federal regulations, says Anderson; and it will spend at least another \$4 million to remediate contaminated sites. McClelland has a two-phase contract with the city, he says. The first phase, now completed, included visiting each UST site, reviewing the city's needs, and addressing compliance needs. As part of that phase, in June, McClelland gave Houston a 600-page report on the city's tanks and a computerized database. In the future, the city will be able to update the database when tanks are upgraded or eliminated.

Phase one also included prequalifying contractors to do the upgrading and replacing tanks. McClelland compiled a questionnaire for contractors who want to work on the program. The firm screened and ranked respondents, and whittled the list down to eight finalist firms, who will do the actual work in phase two. Houston's Grubbs says the city checked out bonding histories and may repeat the entire qualification process in the future if more firms are needed. McClelland and the city also prequalified tank testing services. Under the regulations, tanks must be tested at intervals over their lifetime. Anderson's group will also provide nine training sessions on the regulations for city employees.

McClelland set up the scope of work and will develop site-specific bid packages for each job under phase two. Site work begins in early 1991, says Anderson.

Phase two has a more impressive scope: it includes CM of all construction work, generic design plans for replacing and upgrading tanks, and all environmental oversight responsibility. Soil gas surveys of tank sites and tank testing will be conducted by McClelland as part of the assessment process. If contamination of soils or ground water is found—and Anderson thinks it likely, based on EPA statistics—McClelland's scope of work will change and the firm will provide engineering services for remediation. Describing the firm's soil gas surveys, Anderson says conventional boring to get the relevant data costs about \$7,000 to look at 4 points, while their equipment can collect data on 15 points for \$2,500. The firm has created a system that hydraulically pushes a continuous 20-foot tubing with a porous element at the tip. Discrete vapor samples can be taken and analyzed in the field as the tubing advances, he says.

Disposal of contaminated soils is part of the high cost of remediation. Texas sets standards and tests for acceptable contamination levels for its landfills. If soils are only marginally contaminated by gasoline, the disposal fee is \$7.75/yd³. For contaminated soils, the fee can be \$50/yd³.

Corrosion Correction

To meet UST regulations, all new tanks have to be steel coated with fiberglass or have a cathodic protection system. Or they may be all fiberglass. James R. Myers, of JRM Consulting, is a corrosion consultant based in Franklin, Ohio. He puts the average cost of removing an old tank, excavation, and installing a new tank at about \$80,000-\$90,000. Out of that, the tank itself costs roughly \$10,000, whether fiberglass or steel.

EPA's Michael Kalinoski says steel and fiberglass tanks are being installed on about a 50/50 basis across the country. Leaks and failures are due more to improper installation, soils and water types, and improperly tightened joints in piping than to materials used. In addition, the agency estimates that up to 70 percent of tank leaks are due to piping failures. A 1988 study on tank failures funded by EPA concluded that tank wall thickness is more important than age in predicting tank failure; that small steel tanks are more likely to perforate than larger tanks due to the thinner-gauge steel used; and that most tanks are in worse shape than testing demonstrates. For the study, 500 steel tanks and 12 corrosion-protected tanks were removed from the ground in Suffolk County, New York, for 18 months.

Myers agrees that soil type is a major factor relating to corrosion and says that where soil has low resistivity, cathodic-protection anodes can self-destruct. Fiberglass tanks will never corrode, he says, but installation "must be done precisely in accordance with manufacturers' instructions" or the fiberglass may crack. Backfilling is tricky, especially under projections at the ends. And since the material is lighter than steel, fiberglass tanks must be anchored securely to prevent uplift relative to ground-water changes.

"Workers tend to cut corners when installing tanks," says Myers, and this is a major cause of tank leaks. Installation of all tanks must be watched carefully, he says.

In addition to installing new tanks where needed, UST compliance requires leak-detection equipment, and the installation of overflow- and spill-prevention devices such as catchments. Housekeeping includes a schedule of tightness and other leak-prevention testing, inventory, and other recordkeeping.

Myers thinks proper training is crucial to the program. He cites California, Ohio, and Iowa as exemplary in training state employees about UST. For example, he is one of the instructors in an Iowa-sponsored course for 750 public employees. While the state's many farm fuel tanks are exempt from EPA's regulations, Myers thinks as many as 10 percent of the nation's farm fuel tanks may be "leakers." Even though states can set standards more stringent than EPA has done, there does not seem to be a movement toward regulating farm tanks at this time.

John Hartmann of Hartmann Management Services, Barrington, Illinois, refers to the UST "juggernaut" driving the consulting industry. His firm has been around for 30 years as a consultant to the petroleum equipment industry, but presently UST work comprises

about 75 percent of their business, he says. The firm does consulting for owners and conducts training courses for program compliance. Looking at progress across the nation, Hartmann cites Philadelphia and Chicago as being "disaster areas." But like corrosion expert Myers, Hartmann points to Iowa as "enlightened" in its approach to UST. Notably, many of Iowa's citizens get their drinking water from ground water.

Iowa not only relieves contractors of the liability potential, but the state also has a fund for owners who cannot afford insurance, and it also provides insurance. In addition, Iowa provides low-interest loans for underground tank upgrades.

The state also requires training courses before they certify and license UST contractors. Hartmann says there is no way to qualify as an expert in this field and highly recommends that consulting engineers take UST courses. EPA, he says, "toyed" with the idea of requiring that only professional engineers oversee this work. But being registered, says Hartmann, does not guarantee expertise in this field. He strongly urges engineers to take courses before entering this strong market.

A billion dollars may be spent in Texas in the next decade to bring underground tanks into compliance.

Fuel Tank Futures

The UST market will continue to grow as underground fuel tank owners are forced to comply with regulations or shut down. The engineering and construction are not particularly esoteric in most cases, but the size of the problem and the need to meet deadlines make the program challenging.

Dealing with the contamination from tanks that leaked in the past is another matter. Here consulting engineers have some real technical challenges. Richard W. Klippel of Malcolm Pirnie Inc., Liverpool, New York, tells of a UST job in which the site soil contamination was unexpected. This and other factors conspired to delay work and double the projected cost. A utility wanted to boost their backup oil supply by replacing two existing underground oil tanks with four.

The existing tanks had passed a UST tightness test, but when excavation began, it was clear that slow leaks over a long period of time had caused widespread soil contamination. Large amounts of contaminated soil had to be removed, disposal permits had to be approved, and the cost of that disposal was \$190 per ton. During the process, the landfill was closed for other reasons, causing further delay. The tank excavation itself had to have sheet piling along all four sides to stabilize the site. Finally, weather was bad, pushing construction from a summer to a winter completion. Ironically, the original idea was to save the utility money by using oil as a backup when the cost of an uninterrupted supply of natural gas skyrocketed. Had the total cost of the UST installation including the cleanup and disposal of contaminated soil been known, the decision on the use of gas versus oil might have been different.

Oil-contaminated soil does not have to be excavated and hauled off to a costly disposal site. Aside from the physical constraints, permitting can be a problem. Bioremediation is another approach, one that can be effective in situ. Peter Westerhaus of Biotrol, Inc., in Chaska, Minnesota, says hydrocarbons respond well to bioremediation, readily

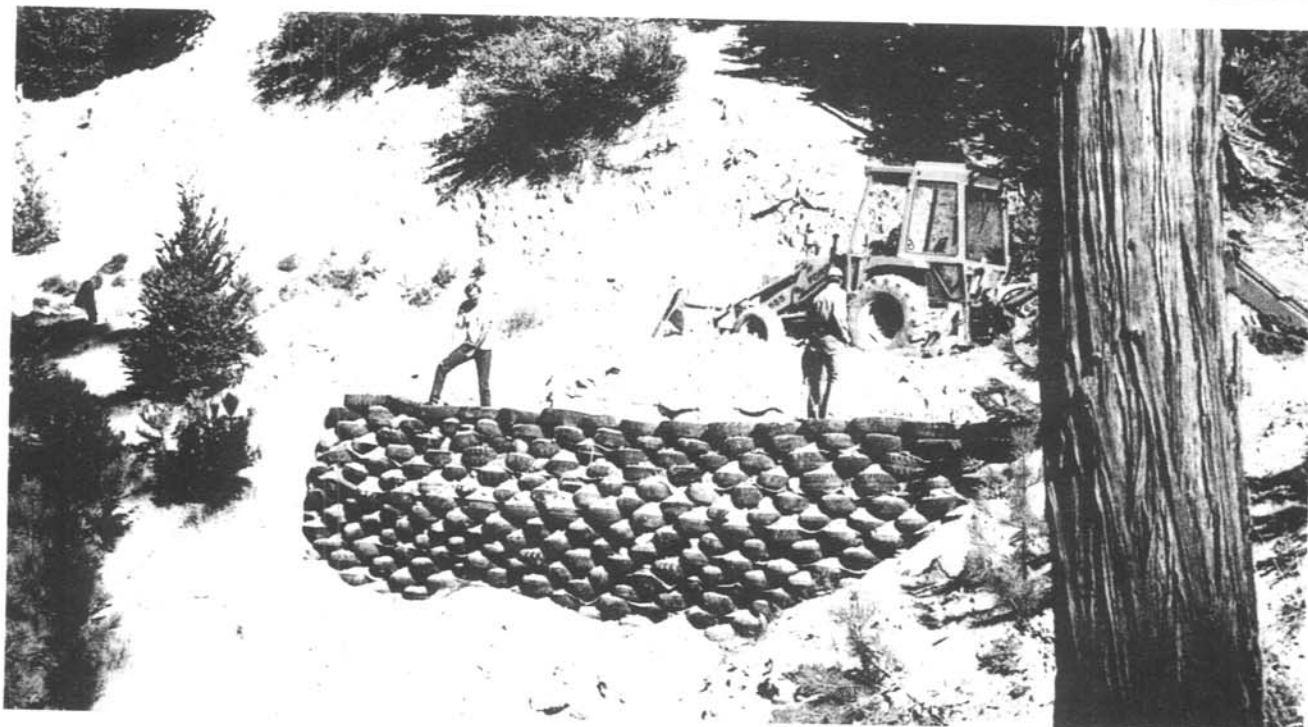
degrading in the presence of "bugs." The track record is pretty good, he says and probably about a dozen firms now provide this service. His firm is currently working on two such projects, both for private clients. Typically, a firm such as Biotrol is called in as a sub to the prime consultant on a UST or other contaminated-site project, says Westerhaus.

Others are looking at the future when alternative vehicle fuels may be stored in underground tanks. The Steel Tank Institute, Zurich, Illinois, recently commissioned a study on methanol and corrosion in carbon steel. The Corpro Companies, which conducted the study, found that methanol did not accelerate corrosion.

RETAINING FOREST ROADS¹

by Gordon Keller

The U.S. Forest Service manages more than 250,000 miles of roads throughout America's national forests. They range from major paved federal highways to local, narrow, native surfaced roads in mountainous terrain. When it comes to supporting the road system, innovation is the agency's watchword — in both materials and design.



A tire-faced wall in a California forest.

Stacked tires, used culverts, railroad ties or chain link fences—the U.S. Forest Service is undeterred when it comes to inventing effective, inexpensive retaining structures along forest roads. Many standard structures exist throughout the forest road system, but steep terrain, unstable ground, difficult site access, economics, and public safety force the agency to look for unique designs and materials.

Most nonstandard retaining walls are located in Alaska, California, Pacific Northwest, and Rocky Mountain forests. But these methods would work well on most private, local, and county roads. They do, however, require detailed site investigation and geotechnical design analysis. Many factors influence wall selection, such as site conditions, economics, safety, the environment, available materials, local experience, and design life. Considerable information on alternative wall use and design has been compiled by the Federal Highway Administration.

¹ Reprinted from Civil Engineering, ASCE, December 1990 issue.

In our experience, driven H pile walls with timber lagging work best on steep slopes in weathered bedrock or shallow residual soil over bedrock. For walls 8 to 12 feet high, tiebacks help resist earth pressures and lessen the effects of bending moments.

When pile driving is not possible, drilled or anchored H pile walls work on steep slopes with competent bedrock. Piles or piers are placed into footing holes drilled several feet into solid bedrock for toe support. A footing and anchors at the toe and top of the piles, tied to rock bolts or deadmen, can also provide support. Since alignment of the piles can be controlled, precast concrete panels can be used to replace timber lagging.

Large, anchored, horizontal sheet piles and vertical culvert pipe walls have been built using available surplus construction materials. Passive earth anchor plates or strips buried in the backfill support them. Small, nonstandard gravity structures constructed out of stacked used tires, stacked sack concrete, precast concrete blocks, GEOWEB cells, logs, and culvert pipe material can support roadway shoulders or low-cut slopes.

Vertical sheet-pile walls can protect waterfronts, especially in Alaska, where some areas experience wide tidal fluctuations. This wall type is also good for constructing boat ramps and log-loading facilities. Backfill material is a free-draining 8-inch minus shot rock. Where there is periodic submergence corrosion and battering by drift debris and logs, concrete panels or blocks can serve as facing members.

Alternative earth-retaining structures

Type of structure	Height (ft)	Cost (dollars per sq ft)	Advantages/disadvantages
Reinforced fills	15-50	4-12	Slope typically 1H:1V, ½H:1V slope with extra measures
Tire-faced walls	10	12-17	Inexpensive, moderate face settlement, visually questionable
Timber-faced walls	18	14-19	Best wall considering cost, durable and attractive, easy to construct
Geotextile walls	10-20	15-25	Minimum material cost, good temporary structures, irregular and nondurable face
Lightweight walls	28	15-20	Special geotextile walls suited for landslide terrain, moderate settlement with sawdust
Chain link fencing	22	20-25	Similar to welded wire walls, requires a custom design, accommodates face settlement
Welded wire walls	6-30	20-29	Most common Forest Service wall, good construction support from manufacturing, standard designs available

Earth Reinforcing

Because they are relatively inexpensive and easy to construct, the Forest Service builds many earth-reinforced structures. For walls under 25 feet high, costs typically range from \$15 to \$25/ft² of face. On most projects, we use local or onsite backfill material; easily fabricated, flexible reinforcement elements; and both frictional reinforcement systems (geotextiles) and passive-resistance reinforcement systems (welded wire and geogrids).

Welded wire walls.—Throughout the forest road system, welded wire structures up to 30 feet high retain the roads. They are relatively easy to construct, and adapt well to grades and curves. Costs on medium-size projects are competitive, ranging from \$20 to \$29/ft² of face.

Designs for wire walls are readily available. Several groups publish design procedures. The Transportation Research Board, for instance, publishes NCHRP 290, Reinforcement of Earth Slopes and Embankments. Other designs are available from manufacturers. Their design tables, with given wall heights and loading conditions, will result in conservative, routine walls that satisfy internal stability requirements. The foundation design should be double-checked for external stability, however, since this is the most common wall failure.

Wire walls are often built too short for the site. Perhaps it is difficult to envision a three-dimensional structure during design or to work with the 8-foot increments in which wire walls are assembled. Consequently, the end of the wall may not catch the adjacent ground slope. If the ends of any wall are overexcavated, material has to be replaced on a slope of 1-1/2 horizontal to 1 vertical (1-1/2H:1V). In either case, a debris chute may form at the end of the wall and backfill material may not catch. Eventually, this results in a narrow road section and the additional expense of a wall extension.

Fine backfill material can lead to face settlement from both poor compaction and fine soil migration through the wall's wire face. It is important to satisfy a filter criterion. A layer of heavy, ultraviolet-resistant geotextile against 1/4-inch wire mesh can lessen face settlement. Tamped pea gravel or coarse material is generally preferred.

Reinforcing wire with a standard, 0.4-oz/ft², commercial galvanized coating has a 50-year design life in noncorrosive soils. Specifying 2.0-oz/ft² (or larger), hot-dip galvanizing wire increases design life for a small price increase.

Geotextile walls.—Geotextile-reinforced walls were pioneered by the Forest Service in the Pacific Northwest. Manufacturers now offer design procedures for walls of moderate height. Reinforcement lift thickness varies between 6 and 18 inches. Thicker lifts are difficult to form. The base geotextile embedment length is usually dictated by the length needed for overall stability and for averting slide failure.

Material costs for geotextile-reinforced soil walls are as low as \$1.25/ft² of wall face. While low material costs should result in lower overall construction costs, our experience shows that geotextile walls cost only slightly less than most other walls. Due to the fabric's flexibility, temporary forms must support the wall face as each lift is constructed. This is a slow, labor-intensive and, consequently, costly process. Geotextile walls cost from \$15 to \$25/foot of face.

Most forms are made with 2-inch by 12-inch lumber and metal L brackets. A series of hay bales placed along the face of a wall is one semipermanent form tried by the Forest Service. One layer of geotextile envelopes the soil while an additional layer wraps around the hay and holds it in place.

Because geotextiles need protection from sunlight and abrasion, we often apply a Gunitite layer to the wall face. In remote areas, we may only apply a protective coating of asphalt emulsion several times during the wall's service life. Although the final face is usually irregular, it is a good solution for temporary construction.

A variety of woven and nonwoven fabrics are suited for geotextile walls. A slit-film woven fabric is best because it has high tensile strength at low strain values, with a cost equal to or lower than comparable geotextiles. A disadvantage of these fabrics is their tendency to repel asphalt emulsion coatings.

Lightweight geotextile walls.—The Forest Service has built several of these walls in Washington forests with wood chips or sawdust, some up to 28 feet high. When wrapped in a geotextile, this material produces an ideal lightweight structure for crossing a slide area. Design and construction are roughly similar to that of a normal geotextile wall, since wood chips are a high-friction-angle material of 25° – 40°.

Wood chips are compacted in 18-inch lifts between the reinforcing layers. Compaction is difficult to measure, but several passes per lift create a moist density of around 40 lb/ft³. The gradation of wood backfill ranges from clean, 3-inch-maximum chips to sawdust. This range produces materials with similar strength and performance properties. Drains have been placed behind the walls because of the material's low long-term permeability due to wood swelling.

One structure, built in 1984, cost \$12.25/ft² of face. After 6 years, material settlement has been limited to about 5 percent of the structure height. Shredded used tires should also work well as lightweight fill material.

Chain-link-fencing walls.—Several walls of chain link fencing, built up to 22 feet high, retain the roads in the Siskiyou and Siuslaw forests in Oregon. Conventional 9-gauge, galvanized chain link fencing is placed in 12- to 24-inch lifts in the backfill material. Pullout resistance and strength properties for chain link material are similar to those for welded wire material.

Constructing the face is similar to building a geotextile wall. A 1/4-inch galvanized hardware cloth at the wall face confines the backfill material. The irregular mesh texture of chain link easily handles face settlement. The materials are cost competitive with those for welded wire walls at about \$22/ft. Chain link fences, however, must be custom designed.

Timber-faced walls.—These walls combine the ease and low cost of geotextile- and geogrid-faced walls with the durability and aesthetic qualities of timber. The rustic appearance fits a rural setting. Several walls as high as 18 feet have been built for forest roads. Walls in Colorado are faced with railroad ties and geogrid reinforcement. Cost varies between \$14 and \$19/ft, depending on the price of treated timbers or ties.

A geotextile or geogrid can support the wall and timber face, sandwich the timbers or wrap around them. One effective method places an intermediate board between the main timbers. The resulting lattice structure tolerates some deformation and reduces needed face timber by 25 percent.

Spikes or rebar can also pin timbers together. The timbers must be tied to the reinforcing members at every timber—or at least every other timber—at a 6- to 16-inch vertical spacing. Although wide reinforcement spacing may satisfy tensile reinforcement needs, narrower spacing for face connections, which is dictated by lift thickness, often controls the design.

Tire-faced walls.—While not as attractive as timber-faced walls, tire walls are, from a distance, texturally and visually interesting. They work well on low-use, rural road repairs, since many walls that support a road prism are rarely seen by the road user.

Old tires and a slit-film woven geotextile reinforcement serve as facing members for a 10-foot-high reinforced wall at the Plumas National Forest in California. Used tires are abundant and geotextiles relatively cheap. Tire-faced walls cost under \$13/ft² of face, including the installation of a drain. At the Plumas Forest, the actual cost was \$17/ft² due to slow rates for backfill compaction with a whacker.

Layers of geotextile with 15-inch vertical spacing and two rows of staggered tires sit to the front edge of the fabric (and wall face) between each fabric layer. Compacted soil lifts of 7–8 inches are behind each of the 16 layers of tires. Backfilled local material is hand compacted into each tire.

Tire-faced walls need a 1H:4V face batter. Staggering the tires horizontally prevents the backfill soil from falling through the hole and the space between the tires. Additional offset between the tires could provide planting space in the holes.

The backfill compaction, done with lightweight equipment at the two-tire-per-lift-wall face at Plumas, caused little tire movement. A layer of fabric threaded through the tire hole and buried in the backfill would resist movement from heavier equipment.

Lateral movement of the unattached tires and long-term settlement of the tire face are potential problems. Yet 2 years of monitoring wall settlement shows little deformation. Face settlement for the top row of tires is less than 1 foot, or 10 percent of the wall height. There is no deformation in the road surface.

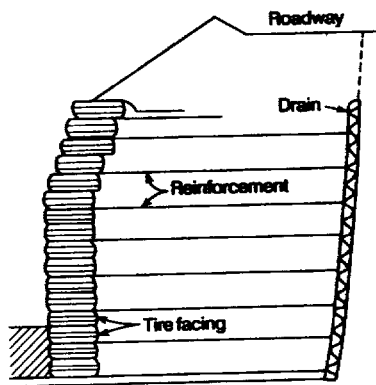


Figure 1. – Tire-faced wall.

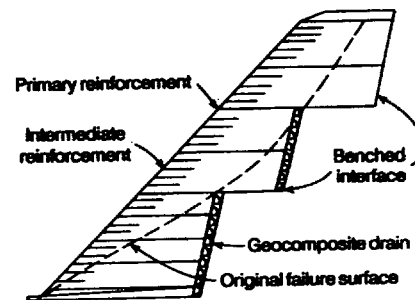


Figure 2. – Reinforced fill.

Reinforced Fills

Reinforced fills with a 1H:1V or steeper face slope offer a cheap alternative to retaining structures. This is true when the ground is too steep to catch a conventional fill slope, yet flat enough to catch an oversteep reinforced fill or a ground slope in the 67–150 percent range. Reinforced fill heights are 15–50 feet high on forest projects.

Layers of reinforcing members (geogrid or fabric) provide tensile resistance to prevent shear failure. Primary reinforcement spacing provides the tensile strength to support an oversteep fill slope and prevents a deep seated slope failure. Spacing varies between 2 and 5 feet and depends on soil parameters, height of the fill, and strength of the geogrid. Intermediate reinforcement consists of narrow strips (around 5 feet wide) of low-strength geogrid placed along the fill face on a 1-foot vertical spacing. They prevent shallow failures between the primary reinforcement layers, particularly during construction.

A reinforced fill costs more than a conventional fill but less than a retaining structure. Cost savings occur when either forms are avoided or facing members are not needed.

Geogrid installation is easy, but care is needed to orient it correctly. Actual construction costs may be higher than expected until contractors become familiar with this design concept. Bid prices in 1987-89 averaged \$10-\$15/yd³ for controlled compaction of the material, plus \$4-\$8/yd² for the installed reinforcing geogrid. This included both the primary and intermediate reinforcement members. These same costs, expressed per square foot of vertical fill face, range between \$3.50 and \$12. Costs are lower on wide sites where equipment can easily operate.

With reinforcement, the final fill face can vary between 1-1/4H:1V and 1/2H:1V, depending on the soil and extra measures taken. The steepest slope face possible with granular, low-plasticity backfill material typical of mountainous terrain is 1H:1V. Good compaction is difficult because the outer edge of the fill face is unsupported. Without adequate density, soils on a steeper slope will not hold. Attempts to construct an unsupported 1/2H:1V fill face failed, even with a moderately clayey soil and a 1H:1V slope.

A material with significant clay content allows construction of a slightly steeper slope. In granular, nonplastic material, such as decomposed granitic soil, a 1-1/4H:1V face is the most stable slope. A steeper slope ravel or needs additional support. Wrapping the reinforcement material or netting around the face can support a steeper face slope. The Siskiyou National Forest in Oregon has used 8-inch quarry rock on the fill faces to achieve a stable 1H:1V slope.

Stabilizing with vegetation helps achieve 1/2H:1V slope face on low fills. At the San Juan National Forest in Colorado, workers placed a mixture of straw, clay-rich soil, manure, and seed in 1-foot lifts along the outer fill face between geogrid reinforcing layers. The straw provides both tensile strength to support the 1/2H:1V slope and erosion protection. When the seed germinates, it also adds root support. This method, however, is labor intensive and costs \$9.50/ft².

Workers at the San Juan Forest also developed a 3/4H:1V fill slope face by pneumatically shooting expanded fiberglass strands into the outer fill face while fill material was being dumped with a backhoe. This method appears promising and inexpensive. Only 0.1 percent, by weight, of fiberglass reinforcing is added at \$3.50/ft² of face. This amount includes the cost of the geogrid reinforcement within the fill.

Because of conditions under which the Forest Service works, we constantly look for safe, practical, economical, and environmentally compatible designs to satisfy the needs of our land-management and transportation-system needs. Nonstandard, innovative wall designs provide the answer.

THE DENVER OFFICE GEOSYNTHETIC TEAM

By Bob Dewey¹

If you agree that engineering is a profession where one uses natural materials to help mold the shape of our world, then geotechnical engineering is engineering in its purest form. What could be a more natural material than dirt? To be sure, geotechnical engineers often alter the state of the soil material by sorting or compacting it to build things, but until recently, geotechnical structures were composed almost entirely of natural materials. However, new synthetic materials are making it both possible and cost effective to construct geotechnical structures with materials having properties exceeding those that can be naturally obtained by soil or altered soil alone. In order to include the new manmade products into their structures while maintaining their pure image, geotechnical engineers have named these synthetic materials "geosynthetics." Geosynthetics perform six major functions: soil separation, filtration, reinforcement, drainage, erosion control, and barrier to water. The types of geosynthetics currently available to perform these functions are varied and many. Geosynthetics can be grouped into four different categories, named (probably for purist reasons): geotextiles, geomembranes, geogrids, and geocomposites. Each of the categories describes a unique family of products that performs one or more of the above functions.

Geosynthetics are not new to the Bureau of Reclamation. For example, Reclamation has been using geomembranes to line canals for over 30 years. Now, interest in geosynthetics has developed within several organizational segments of Reclamation. In order to coordinate this interest, a geosynthetics team has been formed in the Denver Office. The mission statement of the team is as follows:

"The purpose of the Denver Office Geosynthetics Team is to encourage understanding and proper use of geosynthetics on Reclamation projects. This will be done through the network of team members who will disseminate information, provide training opportunities, support research, provide Project/Design support, and develop design and materials standards."

Members of the team were selected based on personal interest and their organization's applicability to geosynthetics. The current team members from the Denver Office and their mail codes are:

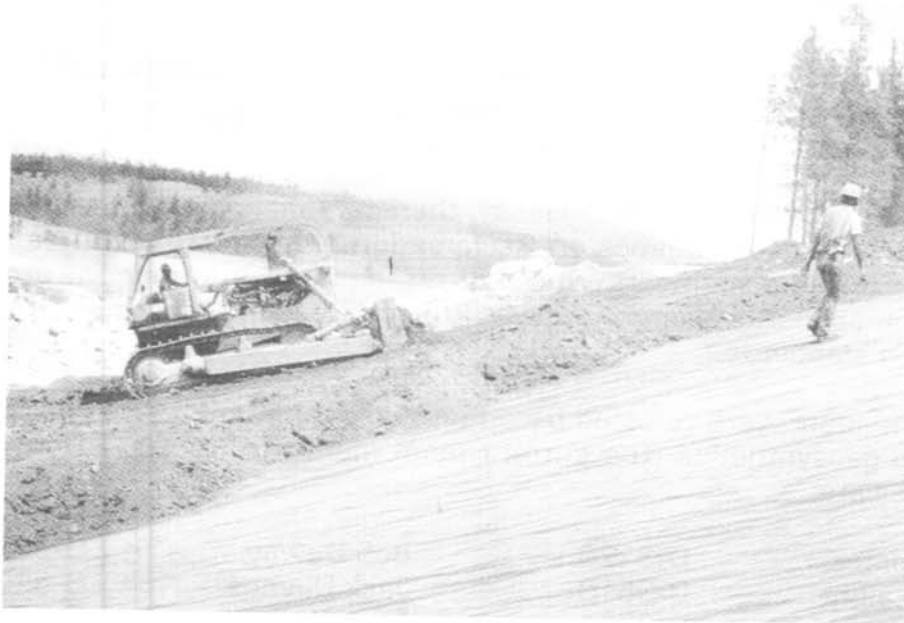
Alice Comer	D-3120	Bob Dewey	D-3620
Elmer Haight	D-3510	Jack Haynes	D-5222
Bill Kepler	D-3731	Dave King	D-5210
Bill Morrison	D-3732	Rich Straubinger	D-3120
Jay Swihart	D-3732	Richard Young	D-3735

Membership on the team is not exclusive and anyone interested in the team activities is welcome to participate. The team meets about once every 2 months, and the meetings are open to all (call Jay Swihart, telephone 236-6195, for details pertaining to the future meetings or the minutes of previous meetings).

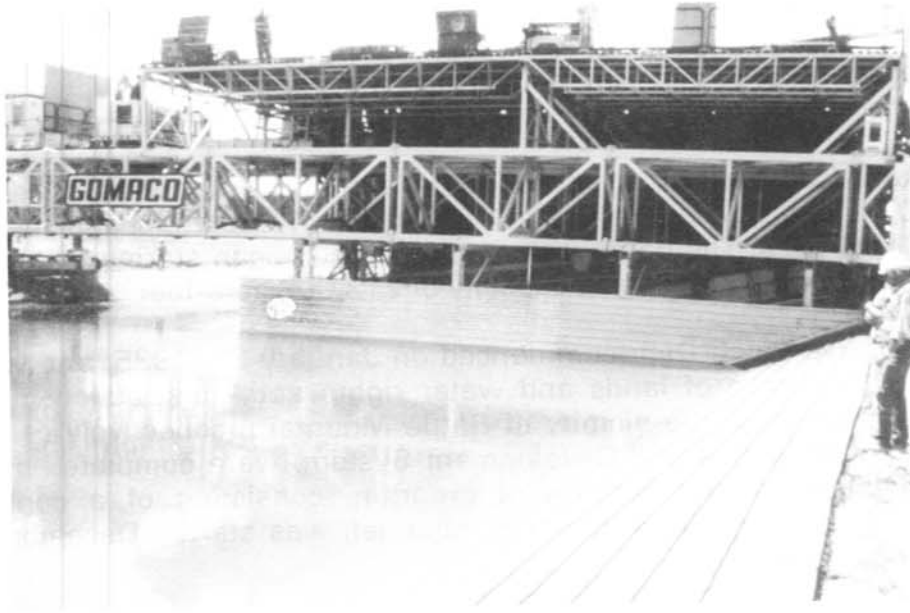
¹ Bob Dewey is a Civil Engineer employed in the Bureau of Reclamation's Denver Office, Geotechnical Engineering and Geology Division, Denver, Colorado.

Bill Morrison is the current team leader. Through his efforts, Reclamation has become a member of the Geosynthetics Research Institute (GRI) of Drexel University, Philadelphia, Pennsylvania, affording Reclamation the opportunity to influence and participate in a wide variety of useful research. GRI publications and training are also readily available to any Reclamation employee through the team.

Within the last 10 years, many Reclamation projects have been designed and built with a wide variety of geosynthetics. A few examples shown in the following photographs include a geomembrane liner at the Mt. Elbert Forebay, underwater canal liner at the Coachella Canal, and geogrid placement at the Davis Creek Dam. Reclamation does not hesitate to consider the use of geosynthetic materials within its structures. Although not yet comfortable with specifying a geosynthetic material as the sole substitute for a major internal component of a large dam without assurance of adequate performance, Reclamation is interested in using geosynthetics in combination with conventional designs and multiple lines of defense to increase safety, promote water conservation, or realize cost savings. The Denver Office Geosynthetics Team exists to facilitate the appropriate use of these new materials. As Reclamation gains more experience and additional field performance data become available on these products, it is expected that geosynthetics will be used more often.



Geomembrane liner at Mt. Elbert Forebay.



Underwater canal liner at Coachella Canal.



Geogrid placement at Davis Creek Dam.

SPOTLIGHT ON RYE PATCH DAM AND RESERVOIR

Humboldt Project, Nevada

Rye Patch Dam is an earthfill structure with a structural height of 78 feet and a crest length of 1,074 feet. The outlet works will release 1,000 ft³/s and the spillway will discharge 20,000 ft³/s. The dam was completed and began storing water in 1936. The reservoir is 21 miles long and has a capacity of 213,000 acre-feet.

Construction of Rye Patch Dam commenced on January 31, 1935, and was completed June 1, 1936. Purchase of lands and water rights and construction of minor works by Government forces in the vicinity of Battle Mountain, collectively called the Battle Mountain Water Collection and Development System, were completed by January 21, 1939. A rehabilitation and betterment program, consisting of a control dam and improvements to existing dikes and river channel, was started December 5, 1955, in the Battle Mountain area.

In 1976, a rehabilitation and betterment project raised the height of the dam by 3 feet and the normal water surface elevation by 2 feet. This increased the storage capacity of the reservoir an additional 23,000 acre-feet to a total storage capacity of 213,000 acre-feet.

The principal crops are alfalfa hay, alfalfa seed, wheat, and barley. Much of the produce is used for feeding the large numbers of cattle and sheep brought in from the upper Humboldt Basin and the Central Valley of California. The livestock are fattened before being shipped, principally to west coast markets.

The Rye Patch Reservoir provides the usual types of water-based recreation. Facilities have been developed and operated under the administration of the Nevada Division of Parks. Fishing for trout and warm water species is under the management of the State Fish and Game Commission.

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Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.



The purpose of this Bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful O&M ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin! So let us hear from you soon.

Prospective material should be submitted through your Bureau of Reclamation Regional office.