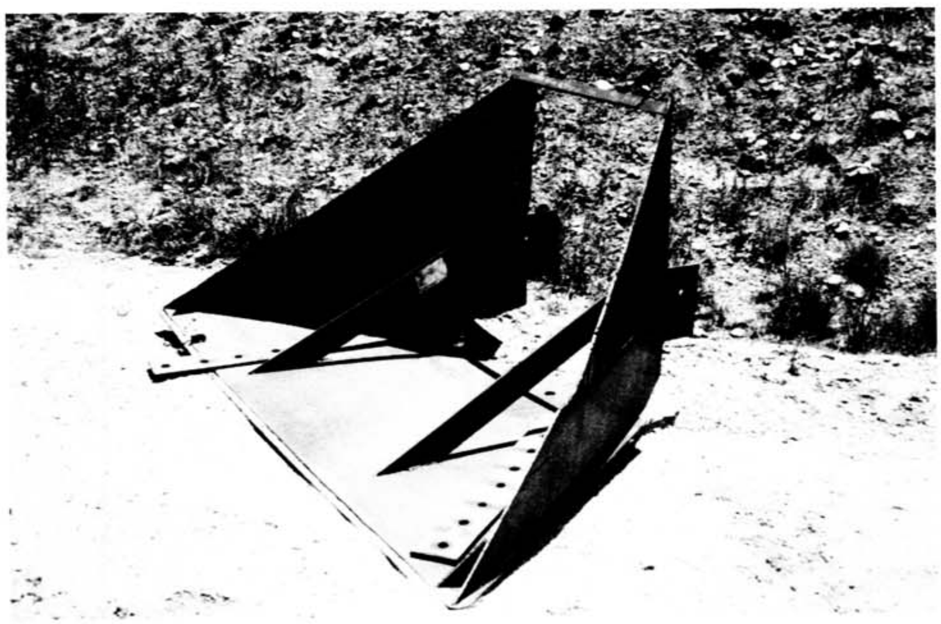
WATER OPERATION AND MAINTENANCE

BULLETIN NO. 167

MARCH 1994



IN THIS ISSUE

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

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.

While every attempt is made to insure high quality and accurate information, Reclamation cannot warrant nor be responsible for the use or misuse of information that is furnished in this bulletin.

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Cover photograph:

"Grand County Dipper" – excavator bucket attachment.

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"GRAND COUNTY DIPPER" MAKES ITS DEBUT

by Bill Bouley[1]

Necessity becomes the inventor of many useful devices and the "Grand County Dipper" certainly fits the description. After struggling to develop a means for removing spring snows from their canals west of the Continental Divide, the Northern Colorado Water Conservancy District manufactured a wider, deeper attachment to the bucket of their large excavator.

Spring snows can fill the canals on the west slope of the Colorado-Big Thompson Project making water diversions impossible. The dipper, when attached to their large excavator, allows the equipment operator to remove large amounts of snow from the canals. Snow removal that took several days with a conventional excavator bucket can now be performed with half the personnel.

Attaching the dipper to the district's conventional bucket takes very little time. The dipper can be removed after snow removal duties are completed each spring, but is ready to be attached when the weather forecasters are wrong.

For more information regarding the "Grand County Dipper" bucket attachment used by the Northern Colorado Water Conservancy District, contact Noble Underbrink at the Granby Pumping Plant, telephone (303) 887-3814.

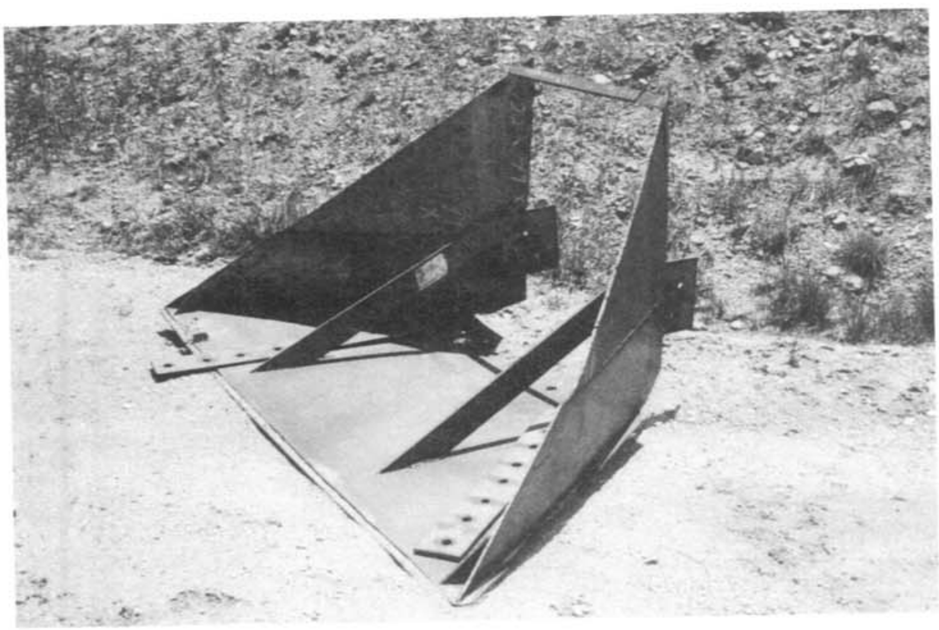


Photo 1. – Excavator bucket attachment.

1 Bill Bouley is a Civil Engineer, Bureau of Reclamation, Denver Office.

Photo 2. – Bucket attachment installed to make "Grand County Dipper."

Photo 3. – "Grand County Dipper" in action.

MULTIPURPOSE CONSTRUCTED WETLANDS
HEMET SITE DEMONSTRATION PROJECT

By Douglas C. Andersen, Ph.D.[1]

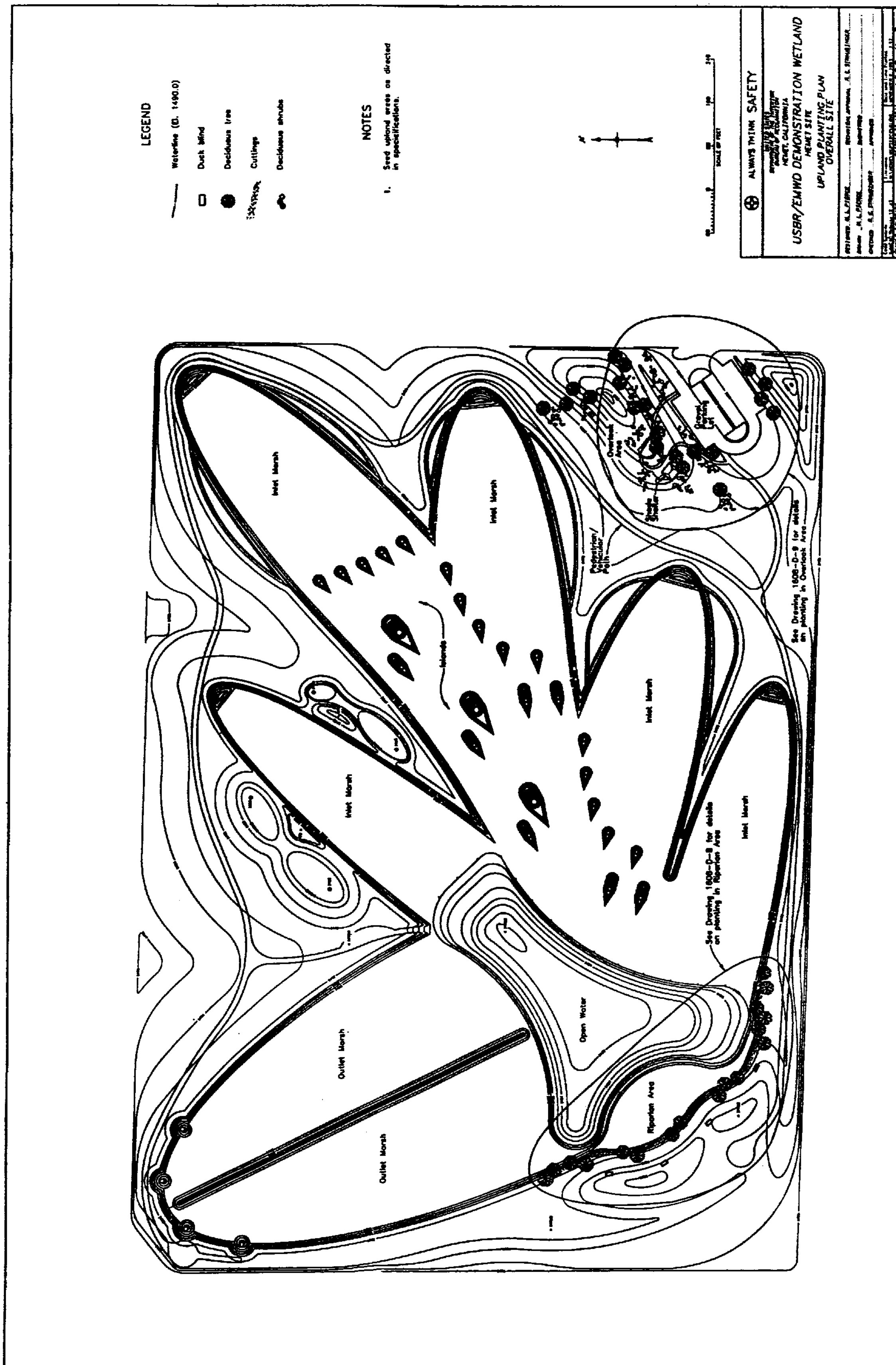
Constructed wetlands are marshes or other vegetated wetlands designed, built, and operated for a particular purpose, often in a site that was not formerly a wetland. They are often designed for industrial or municipal waste water treatment, but they may be multipurpose insofar as the construction design can include features to enhance benefits from such secondary functions as the provision of recreational opportunities, public education, or creation of wildlife habitat. Although the amount of wetland wildlife habitat created as a result of the development of constructed wetlands is currently small, the continued decline of natural wetlands and the rapid increase in interest in constructed wetlands implies they will increase in importance, especially in the arid and semi-arid portions of the United States and elsewhere.

The Bureau of Reclamation and Eastern Municipal Water District of San Jacinto, California, have joined together to design and build a multipurpose wetland near the District's San Jacinto treatment plant for demonstration and research purposes. The two organizations will jointly study how secondary treated water can receive additional tertiary treatment as it moves through the wetland. The facility will not only aid in the development of design criteria and operation guidelines, but also provide opportunities for researchers to learn how constructed wetlands can help achieve regional water management goals while helping to maintain or even improve regional ecosystem health by providing wildlife habitat. The design team, all Bureau of Reclamation personnel, is made up of a botanist, a research civil engineer, a hydraulic engineer, and a wildlife ecologist.

Wildlife attracted to wetlands may increase or decrease net water treatment benefits. The relationship between a constructed wetland's design, operation, and maintenance, and its intentional or unintentional use by wildlife is poorly understood. The plants growing within a constructed wetland lead to improvements in water quality and also provide resources for a wide variety of wildlife, from insects to waterfowl. The wildlife attracted by the availability of these resources, however, could have either positive, negative, or no effect on the wetland's capability to improve water quality. Positive benefits would accrue if wildlife aid in the transfer of matter; for example, by stimulating plant growth or by consuming plant tissue and then exporting the material when the animals leave the wetland. In contrast, herbivorous species, if present in sufficient numbers or at a particularly critical time, could negatively affect wetland functioning by reducing plant productivity and associated nutrient uptake. Wildlife feeding outside the wetland but defecating or dying within it would also serve as a source of nutrient loading that could negatively affect the quality of wetland outflow. Which animal species, if any, should be actively managed for their beneficial effect on constructed wetland functioning? Which species are detrimental, and how might their effects be minimized?

A goal of the Hemet Site Demonstration Project within the Multipurpose Constructed Wetlands Program is to provide a facility that will contribute to local and regional biodiversity by attracting a large variety of wetland-dependent wildlife species. To achieve this goal, the site will contain habitat features that, based on published reports or species-specific natural history information, are likely to attract specific (desirable) species. Feeding areas for wintering waterfowl and islands for nesting waterfowl and other birds are both desirable system attributes, and appropriate features have been incorporated into the physical layout and planting designs. Additional amenities are being considered to further enhance

[1] Dr. Andersen is presently employed by the Bureau of Reclamation, Environmental Sciences Section, Denver Office. Even though he will be transferring to the National Biological Survey (upon its creation), he will continue his involvement in this project.


LEGEND
Waterline (El. 1490.0)
Duck blind
Deciduous tree
Cuttings
Deciduous shrubs
NOTES
1. Seed upland areas as directed in specifications.
ALWAYS THINK SAFETY
HEMET, CALIFORNIA
USBR/EMWD DEMONSTRATION WETLAND
HEMET SITE
UPLAND PLANTING PLAN
OVERALL SITE
1608-D-7
Inlet Marsh
Inlet Marsh
Inlet Marsh
Inlet Marsh
Inlet Marsh
Islands
Outlet Marsh
Outlet Marsh
Open Water
Riparian Area
Overlook Area
Pedestrian/Vehicular Path
See Drawing 1608-D-9 for details on planting in Overlook Area
See Drawing 1608-D-8 for details on planting in Riparian Area

wildlife value, reduce the potential for populations of mosquitos or other invertebrates to reach nuisance levels, and/or to protect the physical integrity of the wetland. These amenities take the form of artificial nesting, resting, and basking structures for waterbirds, turtles, bats, and other species.

As part of the design process, a benchtop laminar-flow hydraulic model was built to evaluate several wildlife-related questions of importance in multipurpose wetland design, including:

1. How does the size, shape, orientation, placement, etc., of a waterfowl island or group of islands affect the spatial pattern and pace of waterflow within a constructed wetland?

2. How does the size, shape, orientation, placement, etc., of open-water areas intended to attract waterfowl (areas deep enough to prevent establishment of emergent vegetation) influence the flow of water through a constructed wetland?

Non-uniform flows and/or nutrient loadings can be expected to influence the structure and functioning of vegetation and invertebrate population dynamics, and these in turn are determinants of the wetland's water-treating effectiveness as well as its value to wildlife. The model also allowed researchers to address more general questions concerning flow distribution, inlet and outlet effects, and the combined characteristics of the integrated system proposed for the Hemet demonstration facility.

Investigations using the benchtop physical model have led to a teardrop design for islands. This shape is predicted to minimize downstream "dead space" in the wetland while providing resting and nesting space for various bird species. The final design showing the size, orientation, and location of islands is completed; and construction is scheduled to begin in early 1994. Other wetland wildlife features (e.g., open water area, open water areas adjacent to islands, and moist soil areas), as well as upland features, have also been incorporated into the design. Facilities constructed for visitors are designed to be compatible with wildlife use of the wetland.

In addition to the hydraulic model, a plant propagation nursery has been established to investigate propagation, transplanting, and growth and establishment of wetland vegetation. Ultimately this nursery will supply the vegetation stock for the large wetland systems and replacement materials as required.

The key to functional design of wetlands is an understanding of the underlying relationships through experimentation using replicated treatments and controls. A wetlands research facility for manipulative experiments has been constructed to aid this learning process. This facility consists of a series of eight rectangular constructed wetlands (cells) that can be independently manipulated. Four of the cells are a one-phase system design, entirely planted with homogeneous vegetation; whereas, the other four are a three-phase system identical to the one-phase system except that an open water area replaces a central portion of the homogeneous vegetation. Research at this facility will be oriented toward optimizing treatment processes, operating principles, and other characteristics that lead to improved design guidelines. The one-phase and three-phase systems (serving as "control" and "treatment," respectively) will be compared in terms of specific performance; for example, removal of nitrogen from the water flowing into them. The research program anticipates the need to overlay compatible studies and adjust individual research cells to address additional specific issues as they emerge over time.

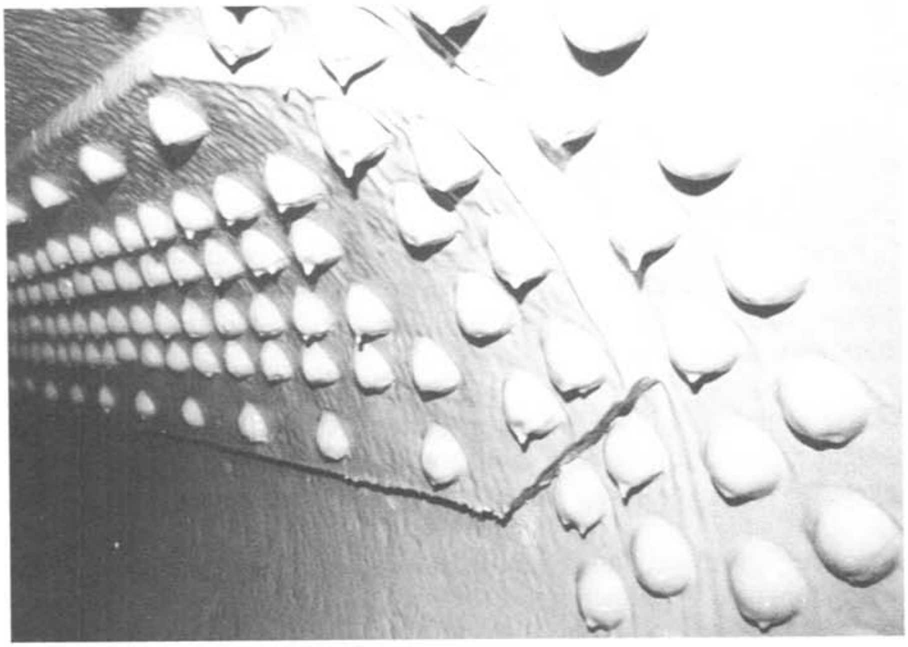
The demonstration wetland will tend to be more conducive to evaluating the comprehensive multipurpose attributes of constructed wetlands such as large system processes, wildlife value, economics, maintenance requirements, public uses, and the relationship to water resource management objectives.

INNOVATIONS IN PENSTOCK LINING[1]

by Richard D. Stutsman[2]

Urethane can be a good choice for lining and relining steel penstocks, owing to its ability to resist abrasion and stop leaks. Pacific Gas and Electric Company is using urethane as a penstock liner with good results.

Through laboratory and field testing, Pacific Gas and Electric Company (PG&E) has determined that 100 percent urethane used as a penstock lining offers several advantages over conventional lining materials. PG&E plans to reline eight steel penstocks stretching 14,000 linear feet with urethane in the next 3 years. The material resists abrasion and corrosion and prevents leakage. Holes can be repaired without performing weld repairs. Urethane can be applied quickly, and the penstocks can be returned to service within 24 hours. However, one disadvantage is that urethane is more complicated to apply than conventional lining materials. Results from PG&E's tests can help hydro plant owners and operators weigh the advantages and disadvantages of using urethane as a penstock lining.



Some dripping occurred on the overhead rivet heads when urethane lining was applied to the interior of one of the penstocks at PG&E's Caribou No. 1 hydro project. Although runs and drips may not be attractive, they don't cause any problems. As applicators gain experience with urethanes, these cosmetic problems should be remedied.

Steel Penstocks in PG&E's Hydro System

PG&E is an investor-owned California utility having 73 hydroelectric facilities installed throughout its system. These facilities are located in a territory extending 400 miles — from the Pit River near Redding in northern California to the Kern River near Bakersfield in southern California. The average age of the

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1 Reprinted with permission from the Editor-in-Chief, Hydro Review, May 1993 issue.

2 Richard Stutsman is a senior civil engineer and program manager for the penstock safety program at Pacific Gas and Electric Company, San Francisco, California.

hydro facilities is over 50 years. Their installation dates span a century — the oldest began operating in 1890 and the most recent in 1987. The hydraulic head varies from 26 to 2,558 feet.

Each facility has at least one penstock conveying water from a dam, forebay intake structure, tunnel, or canal to the powerhouse. The majority of the penstocks are fabricated from steel, with varying methods of construction depending on age:

- Penstocks of 1800's to 1920 vintage: shop-riveted longitudinal seams and field-riveted circumferential seams
- 1920 to 1925: shop forge-welded longitudinal seams and field-riveted circumferential seams
- 1925 to 1960: shop-welded longitudinal seams and field-riveted circumferential seams
- 1960 to present: shop-welded longitudinal seams and field-welded or mechanically coupled circumferential seams

To preserve the structural integrity of these steel penstocks, PG&E installed corrosion protective interior linings. These linings and their expected lives have changed over the years:

- Linings used from the 1800's to 1940: molten coal tar, 15- to 20-year life. Use discontinued due to embrittlement over time, which resulted in cracks.
- 1940 to 1960: coal tar enamels, 20- to 30-year life. Discontinued because of a declining market for the product and the emergence of environmental regulations controlling use of coal tar enamels.
- 1960 to 1980: coal tar epoxies, 15-year life. This material could only be applied in thin films; therefore, it tended to have a shorter life than coal tar enamel, which could be applied much thicker. Also, environmental restrictions applicable to coal tar have resulted in its limited use.
- 1980 to present: high-performance 100 percent epoxies, expected 25- to 30-year life.

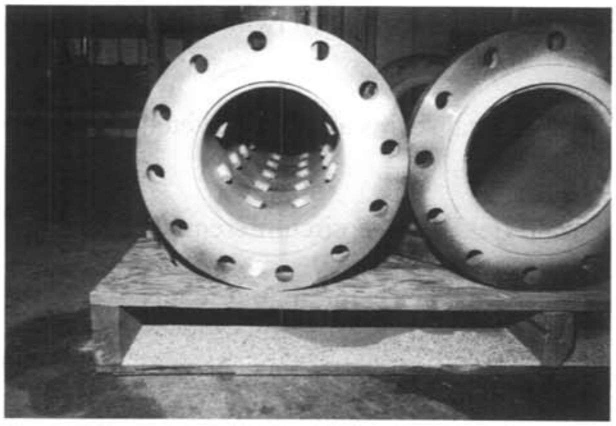
The life of the lining material depends on the quality of application, pH and mineral content of the water, microbiological activity, amount and type of sediments entering the penstock, and atmospheric/environmental conditions.

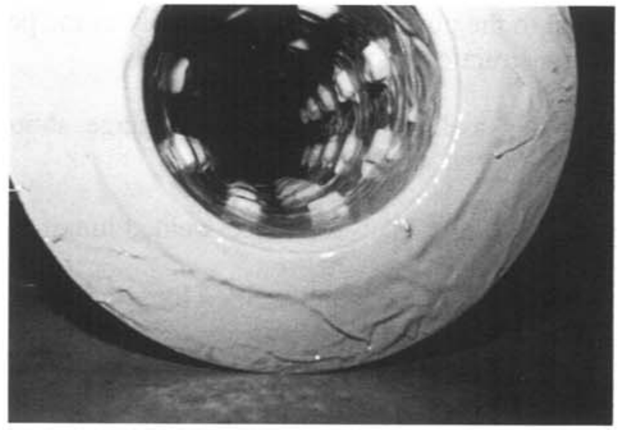
Due to aging, many of PG&E's penstock linings have deteriorated, and severe corrosion and interior abrasion damage is becoming apparent. Since all of the penstocks have not had full internal inspections, it is not known exactly how many will require relining. However, PG&E anticipates that those constructed prior to 1950 are good candidates for relining. Furthermore, the old riveted penstocks are leaking at the butt straps and rivet heads, which may require relining to prevent leaking and external corrosion.

In response to these problems, PG&E has embarked on an extensive laboratory and field testing program of an interior lining material – 100 percent urethane – that recently became available.

The 100 percent urethane resembles a sprayed-on rubber. Historically, it has been applied over sandblasted steel surfaces using plural component spray equipment (specialized spray equipment using two pumps and a mixing tube). The urethane exhibits good abrasive characteristics, as well as good elastomeric properties. These properties are important for penstock applications because of migration of sands and gravel along the penstock inverts and the large temperature differentials that can occur between watered and dewatered conditions.

The particular urethane lining system tested by PG&E and described in this article is called Polibrid 705, manufactured by Polibrid Coatings, Inc., of Brownsville, Texas. It is a solventless, elastomeric polyurethane.





To evaluate the effectiveness of 100 percent urethane to prevent leakage in older riveted penstocks, PG&E performed three laboratory hydrostatic tests using 8-inch-diameter, 3-foot-long pipe sections. In the first test, the pipe section had five rings of eight 3/4-inch bolts installed through 13/16-inch-diameter holes. This design simulated a penstock with loose and leaking rivets. The photograph on the left shows the interior view of the bolt heads after sandblasting. The photograph on the right shows the section after application of 40 mils of Polibrid lining material. Because of the small size of the pipe, applying a uniform thickness of material was difficult.

Testing Urethane in the Laboratory

PG&E conducted laboratory tests to demonstrate the effectiveness of the Polibrid urethane lining applied to surfaces having conditions that may be encountered in relining penstocks. These were limited tests and were intended only to provide some general guidelines for the use of the material. Tests examined leak and abrasion resistance.

Resisting Leaks

To evaluate the effectiveness of the material to prevent leakage in older riveted penstocks, PG&E performed three laboratory hydrostatic tests using 8-inch-diameter, 3-foot-long pipe sections:

Test No. 1. - The first pipe tested was designed to simulate a penstock with loose and leaking rivets. After sandblasting the interior of the pipe, 40 mils of urethane was applied over the interior surface. With blind flange test heads installed, the pipe was hydrostatically tested to 1,100 pounds per square inch (psi) and held for 5 days. During the hydrostatic test, three minor leaks occurred. All three leaks resulted from damage to the lining caused by moving the pipes at the test site; they were not due to the lining system itself. Other than these leaks, the lining system performed as expected.

Test No. 2. - The second section of pipe had three rings of five holes drilled through the shell. This test was to determine what size holes the urethane could span without any reinforcement. The hole sizes varied from 3/32 to 5/32 inch. With test heads installed, the pipe was hydrostatically tested to 1,100 psi and held for 5 days. No leaks occurred. This test demonstrated that 40 mils of reinforced urethane will span holes up to at least 5/32-inch diameter to a pressure of 1,100 psi.

Test No. 3. - This test was designed to determine what size holes 40 mils of urethane could span using nylon mesh reinforcement. With test heads installed, the pressure was raised to 950 psi and held for 2 hours. Upon initial filling, two holes began leaking because of application defects and a third due to a cracked weld on a coupling. With these plugged off (weld not repaired), the system was slowly pressured in 50 psi increments (5-minute intervals) to 700 psi. At this pressure, one 1/2-inch hole and one 1-inch hole failed. After plugging these off, the system was again pressurized up to 950 psi. Between 950 and 1,000 psi, five holes, from 1/2 inch to 1 inch failed. The pressure was held at approximately 1,000 psi for another day when the test was discontinued because of leaking coupling welds. During this period of time, two more 1/2-inch holes failed. This test demonstrated that 40 mils of reinforced urethane can span holes up to 3/8-inch diameter to 1,000 psi and from 1/2- to 1-inch diameter to 500 psi. The significance of this finding is that corrosion or abrasion holes of these sizes can be repaired with a reinforced lining system instead of by performing weld repairs.

Resisting Abrasion

In early 1990, Pacific Corrugated Pipe Company performed an L.A. Rattler abrasion test (American Society of Testing Materials test G-8) on a sample of Polibrid material. This test is a procedure developed by the California Department of Transportation to evaluate aggregate quality. Pacific Corrugated Pipe used the test to evaluate the abrasion characteristics of the lining material.

A 7- by 11-inch 40-mil sample of Polibrid was bolted to the inside wall of a tumbler (drum), as specified in the test. The tumbler was allowed to run for 1 million revolutions at a speed of 50 revolutions per minute, approximately corresponding to 5 feet per second of water velocity. In the test, the Polibrid lost 30 grams of overall weight. According to Pacific Corrugated Pipe, these results indicate the 100 percent urethane has a high abrasion resistance compared to other epoxy and urethane lining materials.

Current Testing Program

PG&E recently completed additional research work on a variety of lining materials to compare surface preparation techniques. In PG&E's research laboratory, researchers tested 15 urethanes and epoxies to evaluate adhesion and cohesive strengths on both sandblasted and waterblasted surfaces of corroded steel penstocks. These tests indicated adhesion strengths in excess of 1,000 psi can be obtained using urethanes applied without a primer on both sandblasted and waterblasted surfaces.

Atlas Test Cell tests were performed using the Polibrid 100 percent solids polyurethane and 100 percent solids epoxy on sandblasted and waterblasted plate samples. The Atlas Test Cell is a method of accelerating coating failure. This failure is generally due to disbondment of the material to the substrate. Coated plate samples are submerged in heated water (140 °F) until the water permeates the material and causes a coating failure. These tests were not intended to evaluate the lining material, but to determine how a waterblasted surface compares to a traditional sandblasted surface. Test results indicate that, in general, the waterblasted samples perform as good or better than the sandblasted samples.

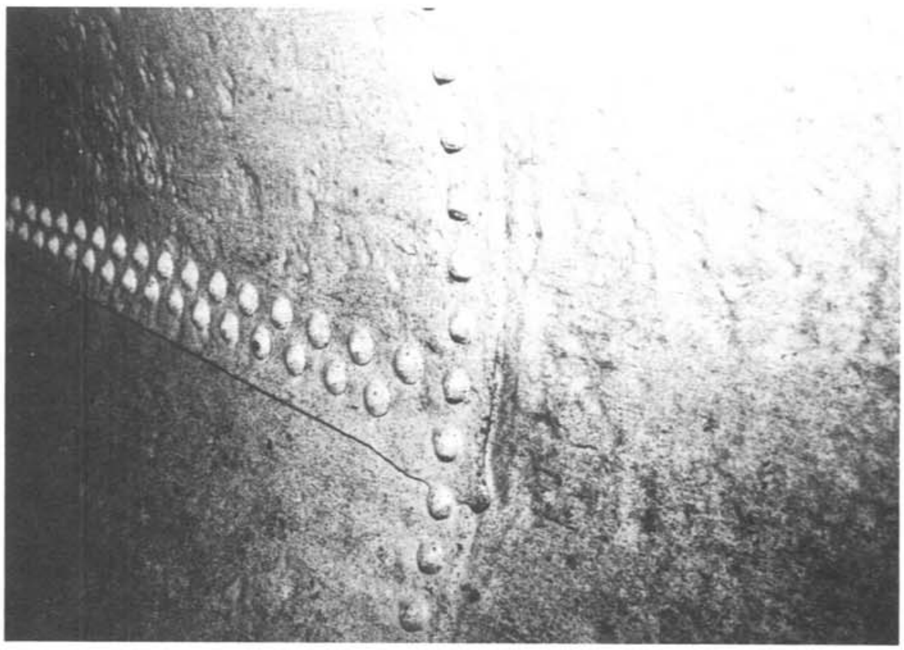
PG&E also conducted tests to determine the maximum distance that heated Polibrid can be pumped and applied in penstocks ranging from 36 to 48 inches in diameter. In the tests, heated material was successfully applied at pumping distances of 750 feet. Because the plural component pump system was well below its maximum operating pressure (3,000 psi) and the material was properly applied through the spray nozzle in the tests, PG&E determined that the material could be applied to distances greater than 1,000 feet.

Applying Urethane in the Field

The PG&E has applied urethane linings to two penstocks since 1989, and these linings have performed well to date.

Deer Creek Penstock

In 1989, PG&E inspected a 100-foot section of 48-inch-diameter, 1940 vintage riveted steel penstock and found severe corrosion pitting, owing to lining failure. The corrosion was so severe that there was some through-wall pitting. This penstock operates at approximately 30 psi. PG&E decided to sandblast and line the interior with 30 mils of Polibrid urethane. At the location of the through-wall pits, the urethane was reinforced with small pieces of nylon mesh. An interior inspection performed after 1 year of operation indicated that the lining was in very good condition.



One year after sandblasting and lining the interior of Deer Creek penstock with 30 mils of Polibrid urethane, PG&E conducted a visual inspection. Visual inspection indicated the lining was in very good condition. This photograph shows the interior penstock wall surface lined with Polibrid. The appearance of a rough surface is actually the original corrosion pitting under the lining.

Caribou No. 1 Penstock

In October 1990, PG&E lined 50-foot sections in each of four penstocks at the Caribou No. 1 hydro plant with the Polibrid urethane lining. These sections were immediately upstream of the powerhouse where the operating pressure is 525 psi and the internal diameter is 42 inches.

Because of its age, the original interior lining had failed. Consequently, the penstock had experienced significant internal corrosion and pitting and extensive leaking at the rivet heads and butt straps.

The application specification required the interior to be sandblasted to a near-white condition with a 2- to 3-mil profile, applying 3 mils of primer and 60 mils of Polibrid on the shell surfaces; 120 mils was required over the rivet heads and to a minimum of 3 inches on either side of the butt straps.

Several difficulties were encountered during the lining application:

Sandblasting. - The corrosion pitting was so severe (greater than 100 mils), that the coating contractor, George M. Stein, Inc., spent a considerable amount of time attempting to remove all of the original coal tar enamel from the pits. Initially, the contractor attempted to achieve a Steel

Structures Painting Council SP 10 surface condition; however, PG&E eventually determined that complete removal was not necessary or practical. What was actually achieved was closer to a SP 6. In addition, because of the amount of time spent on removing the tar, flash rusting (rusting of clean metal due to air exposure) was occurring. The actual sandblast profile achieved was 4 to 5 mils.

Primer application. - The primer used was a 100 percent solids, high-build, modified amine cure epoxy. Because of cold weather conditions (45 °F to 65 °F), the penstock substrate temperature remained at approximately 50 °F. As a result, the primer required excessive thinning (10 to 15 percent) and a cure time of 2 days. (Curing usually takes several hours.)

PG&E's subsequent laboratory testing of Polibrid determined that an intermediate primer is not required with a 4- to 5-mil sandblast profile. Adhesion tests on unprimed steel resulted in greater than 500-psi adhesion strengths.

Urethane application. - No application problems were experienced with the Polibrid except where the material was sprayed overhead to fill voids around the bases of the 1-1/4-inch rivet heads and butt straps. At these areas, the material flowed out of the voids. Application techniques were refined to ensure that the rivets and butt straps were fully coated.

The Pro's and Con's of Urethane Lining

100 percent urethane offers several advantages over other lining materials. It has high abrasion and corrosion resistance and prevents leakage around riveted joints, butt straps, and small through-wall penetrations, thus avoiding expensive and time-consuming weld repairs. Individual coats can be applied within an hour, and a single coat can be as thick as 60 mils (conventional epoxy materials are typically applied 10 to 15 mils thick). This greater thickness minimizes the chances for "holidays" (pinholes).

Owing to the moisture insensitivity of urethane, penstocks can be returned to service within 24 hours after application. Final curing of the material, which will take approximately 7 days, can occur with the penstock in full operation.

Disadvantages of urethane include:

- More difficult to apply than conventional lining materials
- Requires the use of plural component spray equipment versus airless equipment
- Requires that the applicator dress in full protective clothing and be outfitted with fresh air breathing equipment
- Must be heated to approximately 120 °F to achieve optimum performance in the lining material, which, in turn, requires using heat traced lines for long runs between the application spray tip and the plural component pump

Because of these restrictions and requirements, the minimum size of penstock in which a urethane lining can be applied may likely have to be large enough for a person to physically work within for surface preparation, application, and inspection.

The unit cost (per mil) for urethane materials is competitive with other 100 percent solids lining systems. The cost of this raw material is approximately two-tenths of a cent per mil per square foot. However, the costs for surface preparation and application can vary greatly, depending on the project's remoteness, the penstock diameter, the size and spacing of rivets/butt straps, the penstock's inclination, distance between manhole access points, the amount and type of existing coating to be removed, and the severity of the pitting in the underlying metal.

The life expectancy of urethanes is a "guesstimate" because, unlike other lining materials such as coal tar epoxies, they have not been in existence long enough to provide the data for accurate estimation. However, initial tests indicate that urethanes will last as long as, if not longer than, coal tar materials, owing to their adhesion characteristics and flexibility. PG&E is expecting 20- to 30-year service lives from these materials. This estimate is based on incorporating a high quality, documented inspection program that includes surface preparation and cleanliness, proper material proportions and adequate mixing, specified mil thickness, and a holiday-free surface.

Other urethane materials are on the market; however, prospective users should thoroughly investigate a material to ensure that it meets their specific job requirements. This not only includes its mechanical properties, but also application, curing, and inspection parameters.

Acknowledgment

Portions of this article appeared in *Waterpower '91: Proceedings of the International Conference on Hydropower, 1991*, as a paper, "New Interior Lining for Welded and Riveted Penstocks."

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LOW-COST SEDIMENTATION CURE TESTED[1]

Lincoln, Nebraska. — An inexpensive, low-tech, and environmentally sound means of removing sediment from reservoirs is being successfully used in Nebraska and could end up being a water supply solution for the Third World.

Over the past summer, researchers from the University of Nebraska at Lincoln have utilized sections of 6-inch irrigation pipe to move sediment over the dam at century-old Atkinson Reservoir in the north-central region of the state. With one end anchored at the bottom of the lakebed, the flexible pipe carries sediment over the dam to empty into the Elkhorn River. A valve controls downstream flow.

While limited in scale, initial testing of the pipe method for sediment removal was successful in Nebraska over the past summer. Researchers used a clear section of plastic pipe on the downstream end to monitor the volume of sediment being moved.

Noting that pipe removal of sediment requires no power to operate, University of Nebraska civil engineer Rollin Hotchkiss said the method actually has been used for decades by the Chinese and Algerians. "It's kind of a rediscovery," said Hotchkiss. "Although our effort involves looking for optimal aspects of the basic principle," he added. Using irrigation pipe donated by the Lower Niobrara Natural Resources District, the Nebraska experiment has proven to be successful, Hotchkiss said, and next year will be applied to a larger project of removing sediment from Spencer Dam on the Niobrara River. Spencer Dam is full of sediment, he explained, and the reservoir currently has to be drained three to four times a year.

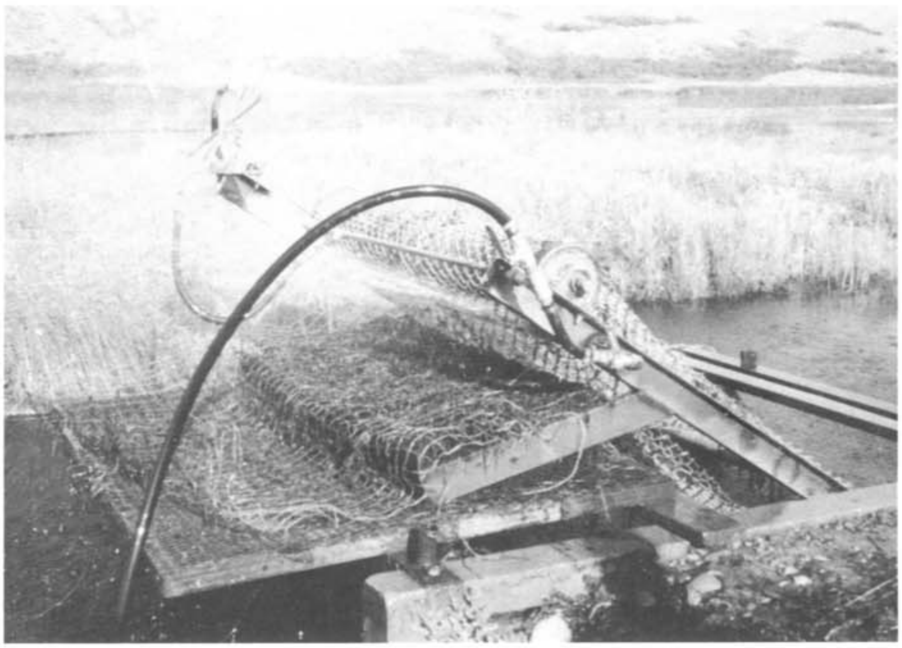
After being used primarily to improve recreational uses of Nebraska reservoirs, Hotchkiss would like to see the pipe method exported to developing countries, where active damming is under way for drinking water supplies. In many instances, he said, dams are built with a life span of 50 to 100 years, and decisions on dam construction are often guided solely by economic factors. "That may not be the best way to build a dam," he said.

1 Reprinted with permission from the Editor, U.S. Water News, 230 Main Street, Halstead KS 67056, October 1995 issue.

ELLIS SELF-CLEANING SCREEN[1]

Automated Screen Saves Manpower

What does a five-generation-family-owned cattle ranch north of Medicine Hat, Alberta have in common with an irrigation farmer? The answer is simply aquatic weeds and filamentous-algae plugging their pump intake suction boxes. The Ellis family's many years of overcoming difficulties that arise in a ranching operation contributed to their success in solving their aquatic weed problems. This self-reliance is characterized in Terry Ellis' latest invention, a self-cleaning screen, designed and built from parts of equipment that were on the ranch.



Ellis self-cleaning screen in operation.

The screen was built for a pump intake for a pivot sprinkler that irrigates 280 acres from a Ducks Unlimited Canada Project. Filamentous algae and floating vegetation from the impoundment were plugging up their suction boxes on their pumping units so badly that frequent cleaning was required to keep them running.

> "In fact," says Ellis, "we often had to clean the suctions boxes every two hours."

The idea for the screen was simple says Leigh Morrison, irrigation specialist with Alberta Agriculture, Food and Rural Development. The Ellis's wanted something that would catch and lift the aquatic weeds out of the water before they become trapped on their suction box. The screen had to be self-cleaning.

They designed and built a catenary-type screen measuring 2.4 meters (7.9 feet) long and 1.5 meters (4.9 feet) wide. It is placed in the channel narrows that separates the Ducks Unlimited impoundment and the dugout-sized pumpsite. Cast-in-place concrete wing-walls support the screen and maintain the

[1] Reprinted with permission from the Editor, The Water Hauler's Bulletin, Volume 52, 1993 issue.

channel. The drive mechanism is adapted from the water hydraulic drive of an old Heinzman pivot and the screening is 25-mm (1-inch) galvanized chain-link fencing. To supply power for rotation of the screen, a 25-mm- (1-inch-) diameter polyethylene hose diverts water from the sprinkler system supply line to pressurize two 5-mm- (.2-inch-) diameter nozzles that drive the spinner arms from the Heinzman. The spinners drive through a 58-1 gear drive reduction. A chain drive connects the 200-mm- (7.9-inch-) diameter sprocketed top roller. The roller is supported on pillow blocks with greased bearings. Threaded rod is attached to the pillow blocks to adjust tension and alignment of the screen. Screen slippage and alignment problems are prevented by welding a sprocket in the center of the roller. The submerged roller has sealed bearings.

As the loaded chain travels over the top, the weeds and debris fall off or are jetted off by the high velocity of the water emerging from the 3-mm (.1-inch) holes in the spray bar. The spray bar is located near the top roller but inside the traveling screen. The weed pile that accumulates on the steel platform must be forked away.

Operated successfully for two seasons, the screen rotates continuously whenever the sprinkler system is running. "There has been no problem or breakdown, a record the Ellis family can be proud of," adds Morrison.

For more information, please contact Leigh Morrison, Irrigation Specialist, Alberta Agriculture, Food and Rural Development, 1015-30 Street SW., Medicine Hat, Alberta, Canada T1B 3N3; telephone (403) 529-3616.

NEW DIMENSIONS OF CONSERVATION USED TO STRETCH WATER SUPPLIES[1]

Innovative Pricing System Limits Water Wasting in Delaware Basin

West Trenton, New Jersey. — Sliding retail water pricing is successfully being used to limit water wasting in communities administered by the Delaware River Basin Commission, which regulates water distribution in a 13,000 square-mile area that is one of the most populated in the nation.

Effective at the end of June last year, any water utility in the basin planning new or expanded withdrawals of more than 1 million gallons per day must submit a conservation plan to agencies in each of the individual states of New York, New Jersey, Pennsylvania, and Delaware. Two of the conservation requirements, implementation of metering programs and fixing leaks, are fairly predictable water conservation measures these days. Another water conservation possibility, sliding retail water pricing, is fairly unique, according to Jeff Featherstone of the Delaware commission.

Structured retail pricing, said Featherstone, is a solution to many of the water-wasting practices prompted by old pricing structures. Among these old practices, he said, are rates in which the unit price decreases as consumption increases and set fees per unit of time. "Setting fees at a rate of $25 per month, no matter how water is used, does nothing to conserve water," Featherstone said. "And decreasing the price with consumption may have the reverse effect."

Featherstone said the commission suggests a variety of retail pricing structures for utility conservation plans. The most obvious is an increase in unit price with an increase in consumption. Another, which has already been adopted by several utilities, is increased seasonal (summer) rates or surcharges for high consumption. The commission also suggests an increase in rates based on long run costs for such conservation measures as fixing leaks and the cost of adding the next increased unit of supply.

Featherstone said it is still too early to make a conclusion about actual conservation figures resulting from the new regulation. But there are a number of promising developments. "Many utilities," he said, "are adopting one or more of the retail pricing options even though they are not asking for increased supplies."

1 Reprinted with permission from the Editor, U.S. Water News, 230 Main Street, Halstead KS 67056, December 1993 issue.

Editor's Note: *These methods can be used also for dam and streambank repairs.*

INNOVATIVE METHODS FOR LEVEE REPAIR[1]

by Edward B. Perry and Milton Myers[2]

The Flood of 1993 has caused extensive damage to levees in the Upper Mississippi River and Missouri River Basins. With the recession of the flood waters, repairs will have to proceed expeditiously for the levee systems to be restored to readiness prior to the spring high-water stages in 1994. A complicating factor is the extremely short "window" for accomplishment of repairs because of the time required for assessment and categorization of damages, low equipment mobility at some sites for an extended period after cessation of flooding, and the possible onset of adverse construction weather in late 1993 or early 1994. For these reasons, application of innovative methods of levee repair which can contribute to rapid, economical, environmentally acceptable, and permanent restoration of the flood-control system is highly desirable.

Overtopping of levee, Columbia, IL (photo courtesy of George Sills, Vicksburg District).

Typically, levees are subject to flood damage in six different ways: (a) overtopping, (b) current and wave attack on the riverside slope, (c) surface erosion of slopes and crest resulting from rainfall, (d) through-seepage causing softening and sloughing of the slope in the vicinity of the landside toe and associated piping problems, (e) underseepage resulting in uplift pressures on the landside impervious top stratum with associated sand boils and piping problems, and (f) slope instability in the form of deep-seated or shallow surface slides. The type of repair selected, whether conventional or innovative, will depend on

[1] Reprinted from Volume 10, Number 3, September 1993 issue of The REMR (Repair, Evaluation, Maintenance, and Rehabilitation) Bulletin, U.S. Army Corps of Engineers, Waterways Experiment Station.
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the cause and extent of the damage which the levee has experienced. Table 1 shows conventional and innovative methods of levee rehabilitation for the various types of damage outlined.

Table 1

Conventional and Innovative Rehabilitative Methods for Various Levee Problems

Problem	Conventional Method	Innovative Method
Overtopping	Rebuilding Vegetation Concrete blocks Precast post and panel wall	Lightweight material to raise levee Inflatable dams/water structures/geotextile tubes Geotextile-reinforced grass Geocells Concrete block systems Soil cement/roller-compacted concrete
Current and wave attack	Vegetation Revetment (riprap, concrete rubble, articulated concrete mattress, gabions)	Geotextile-reinforced grass Revetment (used tires, soil cement blocks, etc.) Soil cement/roller-compacted concrete Fabric forms for grout placement
Surface erosion	Vegetation Chemical stabilization	Geosynthetic systems such as erosion nets and excelsior blankets
Through-seepage and underseepage	Pervious toe drain Conventional cutoffs Riverside blankets Landslide seepage berms Pervious toe trench Pressure relief wells	Geocells (with vegetation) Biopolymer drains Bentonite sealing Slurry trench cutoffs Jet-grouted cutoffs Inflatable dams/water structures/geotextile tubes
Slope instability	Drainage Removal and replacement of soil (slope flattening and benching) Conventional restraint Structures Chemical treatment	Mechanically stabilized soil Tiresoil (soil and tire parts) Soil nailing with geotextiles Fly ash and lime injections Gravel trenches Slide suppressor walls Pin (micro or root) piles Continuous polymer thread injection Randomly distributed synthetic fibers Prefabricated geocomposite drainage systems Vegetation

The conventional methods for levee rehabilitation listed in Table 1 have been used for many years. Additional information about these may be obtained in EM 1110-2-1913, *Design and Construction of Levees*, March 31, 1978. Since conventional procedures are often costly and time consuming, innovative methods may offer solutions that are more feasible. While the majority of these techniques have not been used for levee rehabilitation, there is a high probability that they would be suitable for such an application.

OVERTOPPING

Lightweight Material for Raising Levee

Lightweight material such as expanded polystyrene blocks (ESP), shredded tires (or tire chips), and wood fiber (chips or sawdust) may be used to raise an existing levee to prevent overtopping. The weight of the material, ranging from 1.5 lb/ft^3 for ESP to 45 lb/ft^3 for shredded tires, allows construction over soft foundation soils without appreciable additional settlement. ESP blocks must be protected from flotation and petroleum spills. They have been used as lightweight fill in hundreds of projects in Norway and Japan and by the Colorado Department of Transportation to reconstruct a highway embankment on U.S. 160 near Durango, Colorado.

Inflatable Dams/Water Structures

Water structures are created by filling two or more flexible inner tubes with water and confining them within a durable and flexible "master" tube. In June 1990, these water structures were used to add height to existing levees along the Trinity River near Liberty, Texas. The water structures could also be used in lieu of sandbags around sand boils adjacent to levees. The length of these expedient structures can be virtually unlimited, and heights ranging from 1 to 10 feet can be achieved. The tubes can also be stacked to achieve greater height. They last up to 3 years and are said to be 95 percent faster to install than sandbags. Costs range from $4/lin ft for a 1-foot-high tube to $88/lin ft for the 10-foot height (figure 1).

Figure 1. – Inflatable water structures.

A similar system composed of geotextile tubes has been used to provide dikes up to 4 feet high within dredged material storage areas. Geotextile tubes are constructed of woven geosynthetic materials and are pumped full of dredged material (sand or fines). They can also be stacked to achieve greater height. In a similar way, this type of barrier can be attached to the top of a floodwall to be inflated as the requirement arises for raising the height of the wall. Such inflatable barriers are currently in permanent use at some structures, such as the Jonesville Lock and Dam in the Vicksburg District.

Geotextile-reinforced Grass

Grass has long been used to protect and stabilize earth surfaces subject to intermittent flow of water with high velocity, such as embankment overtopping. The use of a geotextile-reinforced grass embankment enhances the engineering functions of grass while retaining its environmental and economic attributes. The entire surface area is grassed, and the roots bind around the geotextile to form a geotextile/soil/root mat. This mat results in improved erosion resistance to overtopping flows. The risk of the mat's being uplifted becomes significant when flow velocities exceed about 16 ft/s. Disadvantages include root survival during drought and requirements for management of the vegetation.

Geocells

Over steep slopes where vegetation is difficult to establish or the forces causing erosion overcome the strength of the root system, a geocell may be used to ensure that the surface soil is retained on the slope (figure 2). Geocells are three-dimensional honeycomb structures featuring a unique cellular confinement system formed by a series of self-containing cells. The cells physically confine the soil placed inside the cells, thus avoiding a mass sliding of the surface layer while vegetation is being established.

Figure 2. – Geocells being installed on slope to prevent erosion and foster vegetation establishment.

A larger geogrid-type structure is also available. It is a galvanized (plastic-coated if desired) wire mesh construction on the order of 3 to 4.5 feet square with lengths up to 30 feet. It can be used to raise levees, build ring levees around structures, form closures, and "ring" sand boils. This system is best suited where a relatively firm foundation is available to allow equipment (front end loaders or backhoes) to operate to fill the cells. This technique has been used for shoreline protection at Craney Island, Portsmouth, Virginia.

Concrete Block Systems

Articulated concrete block revetments (a series of individual blocks placed together to form an overlay) can achieve a high degree of stability under high-velocity flow conditions for a relatively low cost ($3 to $6/ft^2 installed).

Soil Cement/Roller-compacted Concrete

When the anticipated flow velocities are large (greater than 25 to 30 ft/s), the use of soil cement or roller-compacted concrete may provide an acceptable method of protection. The cost is in the range of \$40 to \$80/yd^3 installed. Addicks and Barker Dams in Houston, Texas, had roller-compacted concrete installed for overtopping protection in 1988.

CURRENT AND WAVE ATTACK

Used Tires for Revetment

Used auto tires have been successfully recycled as both mattresses and bulkhead to protect streambanks (figure 3). The tires must be banded together, and the ends of the mattress must be tied into the bank. Used tires are effective except for occasional vandalism problems and sliding of mats on steep granular slopes. Stone rather than random earth fill should be used in bulkheads.

Figure 3. – Used automobile tires being recycled as slope revetment.

Fabric Forms for Grout Placement

Other systems employ large fabric forms pumped full of grout into pillow shapes and used as artificial riprap for protection of shoreline structures. While these fabric forms are in relatively common use, better methods are needed for anchoring the forms and the molded pods which are produced. Better information on the optimum materials to use in the forms is also needed.

Surface Erosion

Many geosynthetic systems such as erosion nets and excelsior blankets are available for use as surface erosion protection.

THROUGH-SEEPAGE

Biopolymer drains

The biopolymer drain was recently developed in response to the need for an economical method for constructing deep (toe or chimney) drains. This system is based on basic slurry trench technology, but instead of bentonite slurry, a natural or synthetic organic compound is used to maintain an open trench. Natural biopolymers may come from plant, tree gums, or algae. Synthetic biopolymers are generally cellulosic derivatives. Once the trench is excavated, it is backfilled with a drain material. Wells can be inserted and pipe laterals placed under slurry. Once the installation is complete, the biopolymer slurry is chemically and biologically "broken," allowing the system to function as a drain. Although this has never been used for levee rehabilitation, it has great potential for reducing uplift pressures on the landside of a levee.

Bentonite Sealing

Bentonitic clay, either pelletized or powdered, can be used on the riverside slopes of levees to seal the levee surface against through-seepage. Deposited in the dry or underwater, the bentonite coating reduces the permeability of the levee. Incorporation into the soil to a depth of 12 to 18 inches is desirable. The Memphis District has applied this technique to reduce the permeability of a reach of levee constructed of silty sand.

UNDERSEEPAGE

Slurry Trench Cutoffs

The slurry trench cutoff is a viable method for control of underseepage. A trench is excavated through the pervious foundation, and a sodium bentonite and water slurry is used to support the sides. Alternatively, cement may be introduced into the slurry filled trench, which is left to set or harden, forming a cement-bentonite cutoff. Detailed guidance on constructing slurry trench cutoffs is given in *Seepage Analysis and Control for Dams*, EM-1110-2-1901, September 30, 1986.

Jet-grouted Cutoffs

Under some conditions, such as coarse granular foundation soils underlying a levee, jet grouting may be used for constructing a cutoff wall underneath the levee.

SLOPE INSTABILITY

Mechanically Stabilized Soil

Mechanically stabilized backfill systems have the potential to stabilize slides in levee slopes. Mechanically stabilized soil is described in *Retaining and Flood Walls*, EM 1110-2-2502, September 29, 1989. Use of mechanically stabilized backfill allows steeper slopes to be constructed, thus requiring less backfill material. Possible problems include the need to wrap reinforcement or place netting around the face of the slope to prevent raveling (figure 4).

Tiresoil (Soil and Tire Parts)

Tire chips, discussed previously under overtopping, may be mixed with sand to form mechanically stabilized soil. The advantages are a weight reduction of about 25 percent and good adjustment to differential settlements. Research into tiresoil is continuing in Europe.

Soil Nailing With Geotextiles

The stabilization of slopes by nailing consists of placing inclusions into an existing or potential sliding surface. The inclusions are generally installed with a uniform density either in a critical zone at the toe of an unstable slope or throughout the sliding mass. A wide variety of techniques and reinforcing elements, including timber piles, large-diameter piles, micropiles, and driven rails, have been used. The design of soil nailed slopes, particularly the role of bending moments, has not been resolved.

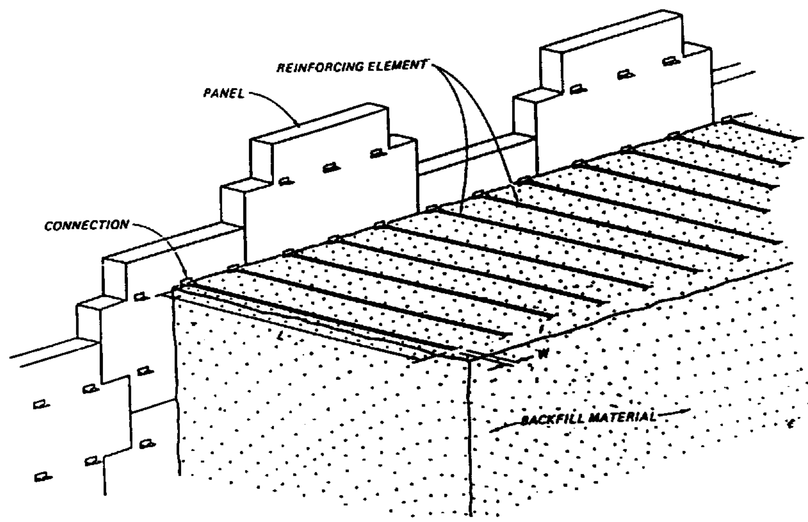

Figure 4. – Diagram of reinforced earth retaining wall, a mechanically stabilized backfill system.

Fly Ash and Lime Injections

Fly ash and lime injections have been tried as a method for slope stabilization along levees on several projects. Questions to be resolved include the long-term strength of the lime modified soil.

Gravel Trenches

A recent method which has been tried to stabilize slopes involves lining narrow trenches with high-strength geotextile and filling the trenches with coarse sand, gravel, or crushed rock. The granular material is compacted in thin layers to increase the effectiveness of the method. Gravel trenches function as drains that will lower the pore water pressure, and the geotextile prevents clogging. They also function as reinforcement and increase the stability of the soil.

Slide Suppressor Walls

Slide suppressor walls consist of precast, prestressed concrete panels placed behind drilled piles to form lateral support along a slope and thus prevent sliding. This method has been used in plastic clays that are susceptible to shallow surface sliding. Slide suppressor walls are practical in areas where right-of-way is restricted and the slide surface is not deep-seated.

Pin (Micro or Root) Piles

Slope stabilization by means of pin piles in cohesive soil may be advisable when conventional methods are not applicable. The loading mechanism between the pin pile and the soil is identical to the passive horizontal loading of pile foundations. However, the boundary condition at the top of the pin pile is not uniquely defined. Therefore, the design methods for this approach are not finalized.

Continuous Polymer Thread Injection

A continuous polymer thread injection where yarn is mixed with sand has been used extensively in France to stabilize soil. This method appears to have possible application for stabilization of levees constructed with an outer zone of sand.

Randomly Distributed Synthetic Fibers

Randomly distributed synthetic fibers are being used in conjunction with various soils in laboratory and field studies to investigate the possible application to slope stability. This technique is experimental at present, and little information is available as to design methods or case histories other than researchers projections.

Prefabricated Geocomposite Drainage Systems

Prefabricated geocomposite drainage systems are being widely used in pavement edge drain applications. Such drains could be used to construct trench drains to stabilize levee slopes.

Research is currently underway to develop guidelines for applying innovative methods to levee rehabilitation. The opportunity now exists for field testing and demonstrating some of the most promising methods which have been identified.

Dr. Edward B. Perry should be contacted for additional information at (601) 634-2670. Dr. Perry is a graduate of the University of Mississippi, Mississippi State University, and Texas A&M University; and is Principal Investigator for REMR Work Unit 32646, *"Levee Rehabilitation."*

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