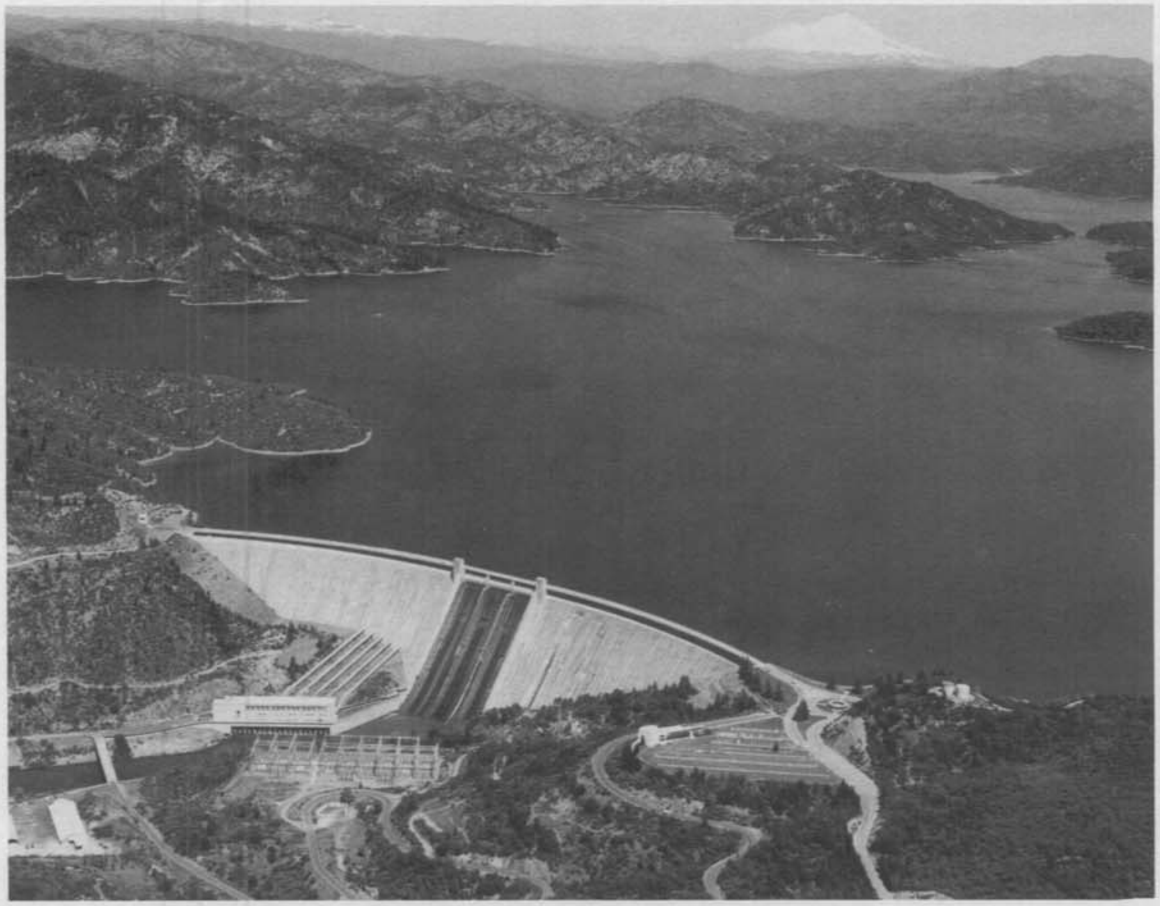
WATER OPERATION AND MAINTENANCE

BULLETIN NO. 149

September 1989



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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 ensure 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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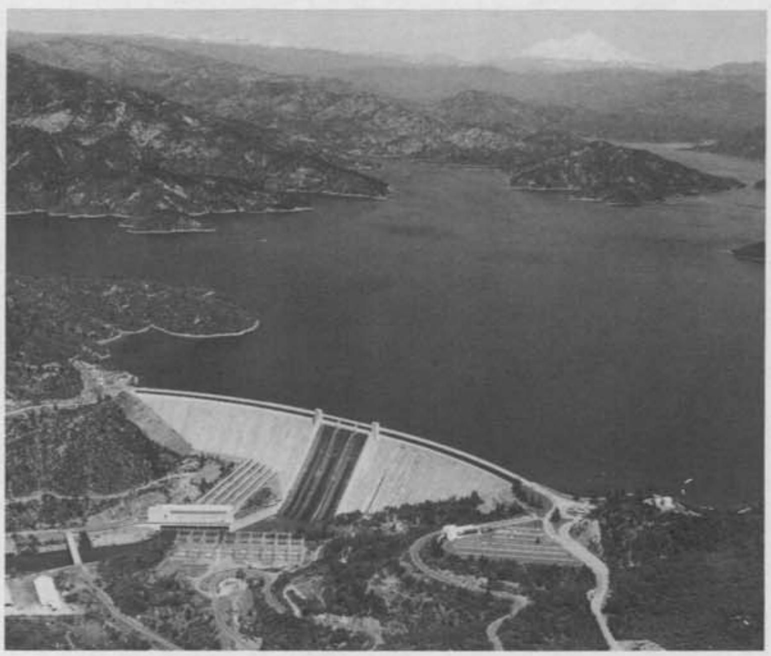

Cover photograph:

Shasta Dam & Reservoir - Central Valley Project, California

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

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FLASH!

ALL RADIO TRANSMITTERS MUST BE LICENSED!

and must have posted, on or nearby the transmitter, a copy of the "Radio Frequency Authorization" (RFA). Printed horizontally on 8-1/2- by 11-inch paper, across the top and bottom is stated: "U N C L A S S I F I E D." Below that are the words: "RADIO FREQUENCY AUTHORIZATION"; and below that: "ISSUED BY THE U.S. DEPARTMENT OF COMMERCE, NATIONAL TELECOMMUNICATIONS & INFORMATION ADMINISTRATION."

This requirement is not just for Power O&M people or construction folks, **it is for all, repeat ALL, Government agencies and employees using, owning, or operating radio transmitters**. (This is covered in Reclamation Instructions 254.) A GOES transmitter is a radio transmitter and must have an RFA. The "address assignment" and "time slot" received from NOAA-NESDIS are not RFA's (but those must be obtained before you can apply for an RFA).

Other interesting items to remember:

You may not name your radio stations arbitrarily. They should be named (XAL and RAL fields on Reclamation form 7-2109) with the name of the nearest identifiable feature on the appropriate 1:250,000 Geological Survey Map.

Preventative maintenance must be accomplished on all base and repeater transmitters at least every 6 months (and reported to D-5210 on form 7-2200); and on mobile transmitters every year (reports to D-5210 are not required on mobile transmitters).

If the antenna is moved, changed from one type to another, or if the output power or usage of the transmitter is changed, a new RFA must be obtained.

Since May 1, 1989, RFA's are applied either electronically or on a floppy disk using any IBM-compatible word processor in ASCII format. The region will forward the application to D-5210 in the Denver Office.

Federal Government agencies may transfer neither RFA's nor frequencies to non-Federal government agencies; e.g., water user entities, local law enforcement, etc. Government frequencies are assigned and authorized by the Interdepartment Radio Advisory Committee (IRAC). Non-Government frequencies are assigned and authorized by the Federal Communications Commission (FCC). The frequencies used by each are in different bands and may not be used by the other. Transfer of radio equipment from the Federal Government to a non-Federal government agency may only be permitted if the equipment can be converted to FCC frequencies and is rendered inoperative on Government frequencies. The gaining entity must apply for and receive authorization to operate the transmitters from the FCC.

If you have any questions, please feel free to contact Dave Bryant or Dick Gebhardt, FTS 776-1065/1066; commercial (303) 236-1065/1066. Mailing address is PO Box 25007, code D-5210, Denver, Colorado 80225.

DOWN ON THE FARM[1]

by Stephen Putnam, W. Thomas Gallier, and Carl Houck[2]

A "total approach" to sludge handling,
from nitrogen management to subsurface injection,
helps grow corn in Colorado.

At first glance, Fort Collins, Colorado, seems to be handling its wastewater sludge as it always has - applying the stuff to farmland as a corn and wheat fertilizer. The 86,000-person community now owns a 320-acre farm, and there has been no talk of incineration or landfilling.

What is not clear from the first glance, however, is that engineers and utility personnel have gone a long way to keep things looking so simple. Fort Collins, like many communities its size, has upgraded wastewater treatment over the last dozen years. One of the consequences has been a greater production of sludge.

With the city's current production of sludge — up to 300,000 gal/d — storage cannot be relied upon during periods of bad weather and low agricultural needs. A variety of sludge application and treatment procedures is needed.

The 320-acre farm, which currently is growing corn only, is located 1 mile from the treatment plant. The farm is a hub for sludge management operations. Some sludge arrives on flatbed trucks in a "cake" form. This sludge is spread over the ground surface. Other sludge arrives as a liquid, having been pumped through a new pipeline to the farm, and is injected into the ground. The farm also has a large composting facility, where sludge is turned into a marketable product.

The flexibility of application procedures, which is important because of varying climatic and ground surface conditions, is matched by flexibility in sludge treatment at the main plant. There, nitrogen levels and solids levels are controlled by thickening, dewatering, and digestion.

The increased sludge volume has also forced Fort Collins to cater to private farmers. Up to 50 percent of the city's sludge can be used on private land. The farms are mostly dry land wheat, a crop grown extensively in northern Colorado's arid conditions. Cake sludge is applied over the soils. Each year, every other strip is farmed.

Fort Collins' early success in its revamped sludge farming program can be traced back to its pretreatment program. This program's policy, as stated in brochures, is "clearly clean and safe." Its purpose is to benefit community and industry. Careful interpretation of Federal, State, and local regulations is the key.

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[1] Reprinted with permission from Civil Engineering, a monthly publication of the ASCE (American Society of Civil Engineers), March 1989 issue.

[2] Stephen Putnam is a technical advisor for the wastewater division of the city of Fort Collins, Colorado. W. Thomas Gallier is the manager of the wastewater division in Fort Collins. Carl Houck is a project manager with Black & Veatch Engineers-Architects, Aurora, Colorado.

Flexibility at the Plant

Flexibility in sludge management begins at the main treatment plant. Although Fort Collins has a second, older plant, its sludge is discharged into a 4-mile interceptor sewer that takes the sludge to the main plant, where it ties into the influent.

Some 13 months ago, the loading rates into the main treatment plant were significantly increased when a beer brewery opened. At maximum, the added wastewater is the equivalent of 70,000 people. Pretreatment currently occurs at the brewery, before the effluent is tied into the municipal wastewater system.

Sludge treatment is keyed around two different processes to pre-thicken waste activated sludge. Under normal conditions, secondary sludge is treated with dissolved air flotation thickening. A backup treatment is provided by a smaller scale centrifuge and rotary screen thickener combination. The upper limit for solid concentrations of the sludge that can be pumped to the farm is 4 percent.

These pre-thickened secondary sludges and primary sludges from the clarifiers are both fed to anaerobic digesters for further treatment. The sludges may be digested separately, or combined, in one of three digesters. Separate digestion can help combat foaming problems and help combat the lower output solids concentration associated with digestion of secondary sludge. Solids output from the digestion process is currently 5.4-9 dry MT per day. After digestion, the product sludge is either pumped to the farm at digester solids concentration, post-thickened or dewatered.

The ability to control the forms of nitrogen at the treatment plant allows operators to produce a variety of fertilizers. Nitrogen content can be manipulated by adjusting the degree of thickening or dewatering. The city has found that thickening anaerobically digested sludge to concentrations of about 4 percent solids removes 26 percent of the available nitrogen. Dewatering the sludge to about 18 percent solids removes up to 83 percent of the nitrogen.

The nitrogen removed by thickening and dewatering is returned to the brewery treatment stream, which is nitrogen deficient. The methane gas produced in the digesters, meanwhile, is used for digester and building heat. As plant scale increases, additional methane energy uses will become feasible.

Transport and Compost

The price of the pipeline to the farm was balanced out by the costs of transporting liquid sludge in tanker trucks. The dewatered sludge cake, meanwhile, is trucked in 18-wheel ram box trailers or dump trucks. Trucking the cake allows dewatering equipment to be located at the main plant site, while taking advantage of the space, isolation, and compost storage facilities at the farm.

During nice weather, large trucks haul cake or compost with a minimum number of trips. During snow and ice, smaller trucks make more trips but with greater safety. Smaller trucks also provide for satellite distribution to remote sites.

EPA pathogen requirements are met by two sludge handling processes. Anaerobic digestion at the plant satisfies the current requirements for a "process to significantly reduce pathogens" (PSRP). These PSRP sludges are best suited for agricultural uses, where people are not in direct contact with the sludge.

The second handling process is composting on the farm followed by a 1-year storage period. This process allows sludge to meet the "process to further reduce pathogens" (PFRP). The PFRP sludges are more suitable for public contact use, such as bagged fertilizers and use in urban areas.

The ability to produce both PSRP and PFRP sludges allows operators to react to user end demands and regulatory dynamics. If more organic matter is needed at the farm, it is available in the covered aerated windrow compost system located at the farm. This facility also provides a means of storing sludge in instances when weather or land availability interferes with sludge application. In addition, the compost system can also be operated at elevated temperatures to meet EPA criteria without any storage.

The finished compost is marked for urban/suburban uses, and initial targets are new landscape construction and open space maintenance. These markets are growing, and are increasingly closer to the compost facility. If demand is slack, compost may be readily stored or used as an agricultural soil amendment.

Wood chips are used as the bulking agent for the aerated windrow compost process. Organic amendment is provided by previously composed sludge and commercial sawdust.

Experiments are also being conducted to determine if part of the farm's produce - corn stalks - can be used as organic amendments and bulking agents. A small test crop of cottonwood trees has also been planted, which would be harvested annually for wood chips. Wood waste could also be obtained from the county landfill. The concept of a balanced municipal ecosystem provides the orientation for all of these efforts.

Choosing the Application

The specific sludge application process affects how the sludge acts as a fertilizer. Choosing among cake spreading, liquid surface application or liquid injection is based on weather, time in the growing season, and the crop at hand.

Liquid application, for example, allows fields to be fertilized quickly under certain cropping conditions. At times, more organic material and less nitrogen may be desired in the soil. (More organic matter promotes better soil structure and greater moisture retention.) The application of thickened liquid sludge is a first step in this direction, due to centrate nitrogen removal. For even greater organic matter application, with minimized nitrogen application, dewatered sludge cake or compost may be surface applied.

Application techniques are also selected based on nitrogen needs. Different application techniques release different amounts of nitrogen. Surface application, for example, allows volatilization of the ammonia and therefore is not a great source of nitrogen for crops. Subsurface injection is sometimes preferred, because in Fort Collins case it can provide 248 pounds of nitrogen per dry ton.

The mineralization rate of organic nitrogen varies, and is significantly related to the liquid loading rate, especially in a dry climate such as northern Colorado. A review of literature provided mineralization rates ranging from 20 to 35 percent in the first year after application. A general observation is that the lower mineralization rate is most applicable to low liquid loading rates, and the higher mineralization rate is most applicable to high liquid loading rates. Soil nitrogen tests provide the only final answer as to the amount of nitrogen available in the soil for crop growth.

If odors become a problem at a site, subsurface incorporation of any sludge form is best. Concern over runoff has been a major reason why surface application of liquid is rarely used on the farm.

Off the Farm

Surface application of the cake is practiced on the privately owned wheat farms to minimize odor and runoff. The surface application also reduces tillage related soil erosions. These locations are governed by state sludge regulations. Application is controlled at agronomic rates, and the principal crop is dry land wheat.

Wheat requires relatively small amounts of nitrogen, and the soil is improved by organic matter not present in commercial fertilizer. Additionally, the wheat is cropped in a summer fallow crop rotation, which makes wheat land available during a large portion of the year. A very light coating of cake sludge dries quickly, producing little odor and little runoff.

The city has obtained several of these state-approved sites, located in different directions from the farm. The availability of several sites reduces weather interruptions, as localized storms that may affect one area frequently miss another. Cake sludge is transported from the treatment plant to private farms in ram-box trailers.

Monitoring and Backup

After application at the farm, the soil and ground water are monitored. The farm operates under a "certificate of designation" as a beneficial sludge use site. Currently, cake and compost sludge is being applied without difficulty, but liquid application is being increasingly restricted.

As a result of a cooperative agreement between the city of Fort Collins and Larimer County, a final short-term backup is available to land application and the compost system. The city has recently agreed to accept septage which had been going to a troubled lagoon treatment system in the county landfill.

Each dry ton of septage treated allows for one dry ton of dewatered sludge meeting State and Federal regulations to be returned to the landfill. Treated septage dry tons may also be banked, so that large quantities of dewatered sludge may be brought in for short periods. Landfilling of the sludge is not the most desirable option, but the alternative is an important opportunity to provide environmental benefit in a flexible manner.

GEOSYNTHETIC SHIELDS FOR DAMS[1]

by Dan Morse[2]

During its first 25 years of service, the 360-foot-high Paradela Dam in Portugal leaked an average of 132 gallons of water, every second. Copper waterstops and rubber sealants were applied, but they failed repeatedly.

In 1981, the reservoir was emptied and construction crews applied over 18 acres of asphaltic-impregnated geotextile to the 37° upstream face. Since then, the dam has leaked an acceptable 4 gal/s — a 130-fold improvement.

That success story is one of many taking place in Europe, where the faces of more than 30 large dams now contain geotextiles and geomembranes. In many cases, the geosynthetics are the only water barrier in the entire structure.

For remotely located dams — where transport of heavy compaction equipment is virtually impossible — geosynthetics are chosen instead of asphaltic-concrete. Geosynthetics, due mainly to their minimal installation time, are often the least expensive option, says Jean-Pierre Giroud of GeoServices, Inc., an engineering firm in Boynton Beach, Florida, that specializes in geosynthetics.

Progress has been slower in the United States. While geosynthetics are now regular components of landfills and surface impoundments, they are rarely used in dams.

"I have reservations about geosynthetics as the only upstream barrier," says Charles Gardner, chief of the land quality section for the State of North Carolina. "We just do not have enough confidence in the performance and durability of geosynthetics."

Others like Giroud and Robert Koerner, director of Drexel University's Geosynthetics Research Institute, point to the success in Europe.

Says Giroud, who worked in France until 1978, "Besides the successful performance of the recent dams in Europe, there are older dams still performing well. In 1970, at the Valcros dam in the south of France, geotextiles were used for the toe drain and as a foundation for the upstream riprap. Many people have gone in and taken samples of the geotextiles. The dam has been the subject of many papers. The amount of deterioration is very, very small."

Repair in Europe

Constructed in an area void of impermeable soils, Portugal's Paradela Dam is a rockfill structure with a concrete face. The dam supports a 90-MW hydroelectric plant.

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[1] Reprinted with permission from Civil Engineering, a monthly publication of the ASCE (American Society of Civil Engineers), 345 East 47th Street, New York, New York 10017, January 1989 issue.
[2] Daniel Morse is an Assistant Editor for Civil Engineering.

In 1980, when evaluating methods to waterproof the face, engineers calculated the asphaltic-impregnated geotextile to be less expensive than a layer of asphaltic-concrete. Instead of requiring heavy roller equipment — which would have had trouble operating on the 37° slope anyway — the geosynthetic face was laid with a small "dip and stick" machine. As the machine was pulled up the dam face by cables, the geotextile was unrolled, dipped into a liquid mixture of neoprene latex and bituminous emulsion, and laid over the face.

The tackiness of dip solution allowed the lining to adhere directly to the concrete. No glues were necessary. In addition, each successive strip of lining attached to the 4-inch overlap of its predecessor, so no seaming was necessary. Eventually, the new lining would become hardened.

Engineers from Hidroelectrica do Cavado, a local designer, decided that the impregnated geotextile did not need a protective covering.

Pietro de Porcellinis, a product manager for Rodio-Cimentaciones Especiales, the suppliers of the rodimperm membrane, believes that repair ease will make rodimperm a permanent solution. According to de Porcellinis, the neoprene latex causes the submerged portion of the membrane to become tacky. Repairs can be made underwater by laying a new membrane on the already tacky membrane.

In order to monitor settlement of the concrete slabs beneath the covering, engineers had a large geodetic grid painted on the membrane. In addition, the entire top 82 feet of membrane was painted to protect it from ozone and ultraviolet sunlight. Giroud takes his hat off to those who worked on the 37° face.

"It is an extremely impressive angle when you're standing in the middle of the dam face," he says. "You cannot walk on the slopes - you must walk on ladders."

To reduce construction time, the ladders were sometimes substituted by a different way up and down the slope - the seaming machine became a sort of construction gondola, carrying as many as five workers up and down the slope.

At a cost of $800,000, the rehabilitation was completed in 3months. It included preparatory sealing of crevices and fissures, particularly around the intake tower.

In Italy, *vertical* dam faces are being repaired with geomembranes and geotextiles. One of the highest faces was the 131-foot-high Lake Nero concrete dam, located near Bergamo. The dam was built from 1924 to 1929.

In 1981, a 1.9-mm-thick (approximately 1/16-inch-thick) PVC geomembrane was trucked to Lake Nero. Engineers concerned that the geomembrane would be damaged from waves, floating debris, and the dam's existing face had the geomembrane strengthened at the factory. A 10-oz/yd^2 nonwoven geotextile was heat-coupled to the geomembrane.

The strengthened geomembrane was unrolled down the face of the dam in 6-1/2-foot-wide sheets. Each strip overlapped its predecessor by 4 inches. Construction workers, lowered on scaffoldings much like those used by skyscraper window washers, welded the strips together. The workers then attached the geomembrane by bolting metallic strips over the seams and into the dam face.

During drawdowns, when there is no pressure pushing against the geomembrane, the metallic strips have held the heavy geomembrane against the dam face, says Giroud. It is these periods of low water that make installation procedures so crucial.

"It has to be as taut as possible," says Giroud. "If the material is sucked by the wind, it may be damaged."

New Dams in Europe

Between 1968 and 1983, seven new dams were built in France using geosynthetics as the singular waterproofing element on the upstream facings. The dams ranged in height from 39 to 92 feet, the fill being both earth and rock.

Engineers designing the 92-foot Codole Dam, located near Corsica, had intended to use asphaltic-concrete as the waterproofing element. But after installation costs were evaluated, geosynthetics proved to be less expensive.

The face at Codole was constructed in four separate layers. The first layer, an inexpensive and pervious layer of asphaltic-concrete, is designed to protect the geosynthetics from the rockfill. The asphaltic-concrete also provided a flat construction surface for the geosynthetics. The second layer, a 1.9-mm (approximately 1/16-inch) PVC geomembrane strengthened by a 12 oz/yd^2 geotextile, was glued together at the geosynthetics factory. The next layer, an independent 12 oz/yd^2 geotextile, serves two functions: an outer protectant for the geomembrane and a drainage medium for water that passes through the fourth layer, a 6-inch wall of reinforced concrete. Called "rather strong protection" by Giroud, the concrete was placed to protect the geomembrane from sticks, trees, and other debris.

The geosynthetics were installed on a 30° slope. They arrived at the site in long strips; no horizontal seaming was required on the dam face. Lateral seams were made by a special machine, hoisted up the slope by cables. Seams were welded using hot air. Since it was completed 5 years ago, the Codole Dam face has been "quite reliable" says Giroud, who was a design consultant for Codole. He had previously worked on the 85-foot-high L'Ospedale Dam, a rockfill dam constructed in 1978, also located near Corsica.

Says Giroud, "At the L'Ospedale Dam, it was impossible to get big, asphaltic-concrete rolling equipment to the dam. There was just very limited access. For construction of the geosynthetic face, all that was required were the rolls of geosynthetics and standard civil engineering tools. Everything could fit in a regular sized truck."

In addition to a pervious layer of asphaltic-concrete, L'Ospedale's face has four components: a geotextile that protects the liner from the asphaltic-concrete, an asphaltic-impregnated geotextile that provides the waterproofing, another geotextile that protects the waterproofing and provides drainage, and a 3-inch wall of interlocking concrete blocks that guards the geosynthetics against wave action and waterborne dangers.

Because the asphaltic-impregnated geotextile was produced at a factory, the in situ "dip and stick" process used at Paradella was not necessary.

During its first 3 years, the new facing of the L'Ospedale Dam performed well. In the winter of 1982, however, a vicious storm displanted some of the blocks. In some areas, the outer drainage geotextile was also damaged. But in no areas, says Giroud, was the impregnated geotextile damaged.

Those blocks have since been repaired, but Giroud feels that others will be damaged by the return of a similar storm. For future dams, he advises against the interlocking block concept for protection, unless the blocks are much larger than the 10- by 8-inch pieces used at L'Ospedale.

U.S. Expectations

"At some point, possibly by the end of the century, the U.S. will mobilize itself and start repairing dams. It could reach the rate of one dam per month," says Giroud, comparing the effort with today's waste management operations. "A large number of people will tell you that many of the 100,000 dams in the U.S. will need repair very soon."

Indeed, the first market for geosynthetics in large U.S. dams will probably come from dams that need repair, not dams that need to be built. According to the National Council on Public Works Improvement, more than one-third of U.S. dams will be at least 50 years old by the year 2000.

Based on the European experience, rockfill dams with a concrete face are plausible sites for geosynthetic repair. Giroud points to the specific dangers of these dams: "Small holes in the face produce a very high pressure water jet into the dam's permeable core. This can produce large fissures and weaken the entire structure."

Though Giroud does not know what fraction of U.S. dams can be repaired by geosynthetics, he states that "there are certainly a lot of U.S. dams with difficult access. We will need a technique that can get to the dams."

Over the next 11 years, Giroud expects dam repair to begin receiving some of the attention now given to waste management. "There have been several recent dam failures in the U.S., but they have not been big enough to attract the attention of the public or the Congress in the way that ground-water contamination has."

"And, any political attention given to dam protection will carry the designers with it. Now, most of U.S. geosynthetic design talent is in waste management."

One designer who works with waste management and dam facings is Ed S. Smith, vice president of Morrison-Knudsen Engineers, Inc., San Francisco.

Says Smith, "For dam repair designs, we do not spend a lot of time with geosynthetics because we know we will not get them by the state (dam safety) agencies. Very few states want to be the first to authorize a new technology. And the owners of private dams tend to follow the guidelines of the state agencies."

Begging to differ is Alan Pearson, head of the dam safety branch for the Colorado Division of State Water Resources.

"We keep an open mind about the methodology," says Pearson. "It is up to the design consultant to come up with cost effective proposals using geosynthetics. Right now, we allow geotextiles to be used as a bedding for riprap in noncritical applications."

Over the last 12 years, as the nation has begun to address municipal and hazardous waste problems, EPA regulations and guidelines mandating the use of geosynthetics have disposed of much of the state-by-state approval process. If dams were suddenly viewed as an emergency, could this type of regulation be expected for dams?

"I don't think so," says Drexel's Koerner. "EPA has more authority to set up regulations than those overseeing dams: BuRec and the Corps of Engineers."

One Dam at a Time

For the time being at least, any application of geosynthetics in U.S. dams will be on a deliberate, dam-by-dam basis. Mark Glenn, president of Gwin, Dobson & Foreman engineers, Altoona, Pennsylvania, recently used geosynthetics as the waterproofing element on a 55-foot-high earthen dam in Altoona.

A 50-mm (2-inch) geomembrane, sandwiched between two geotextiles, was placed on the 27° upstream face. The geosynthetics were placed on a 9-inch layer of sand and covered with 8 inches of crushed stones and a layer of riprap.

Glenn's design was approved by the State of Pennsylvania, where officials saw the geosynthetic application as a natural extension of the recent designs for lagoons and landfills. The geosynthetics were calculated to be $250,000 less expensive than lining the face with asphaltic-concrete.

"Geosynthetics used in dams and dam repair need to be a site specific solution," says Glenn. "If the slope was any greater, it would not have held the outer coverings."

This brings us back to Giroud, who is concerned that basic civil engineering design may be ignored if there is a rush to cover U.S. dams with geosynthetics.

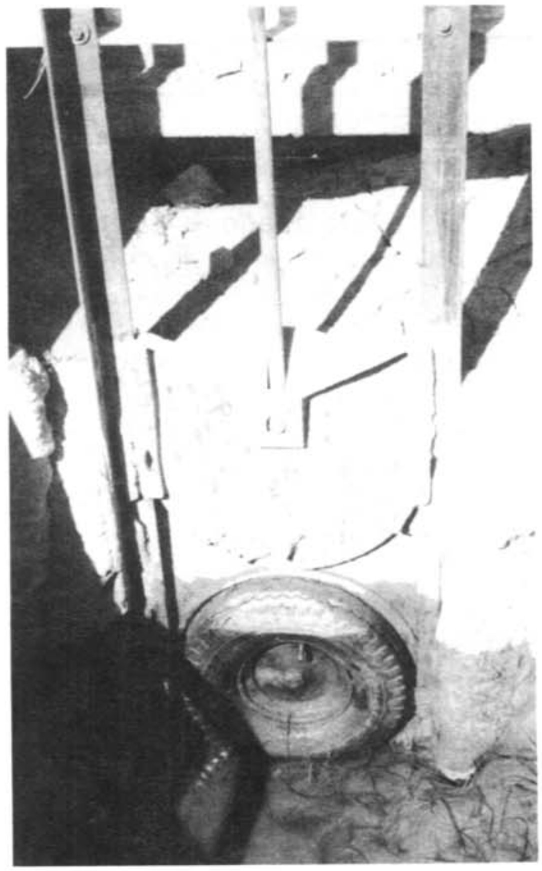
Says Giroud, "You can't just design an asphaltic-concrete face and then substitute a geosynthetic lining system. You are dealing with a totally different material, with an entirely different set of mechanical properties."

A WINTER PIPELINE PLUG WITH A DIFFERENCE[1]

Who Says Old Tires and Rims Aren't Useful

With the changing colors and the onslaught of winter just around the corner, district personnel have changed their thoughts from delivering water to one of removing it from their pipeline works. Winterizing of a pipeline is probably one of the most important procedures in this annual seasonal change. If this job is not done properly, the damage and expense can be horrendous come next spring.

In most situations, "winterizing the pipeline system" is a straightforward and very simple procedure. District personnel simply open all the valves along the line, then either open the gravity drain outlet or pump the entire line dry. Once the system has been dewatered, a final check is made to make sure the inlet gate is tightly closed to prevent rodents from taking up residence in the pipeline.



Inflated tent trailer tire with bolt center holes welded shut provides a 100 percent seal against water entering the pipeline during offseason.

In the problem cases, the pipeline is submerged by water trapped against it or from storm runoff. Without much head, the slide gates often leak and the ditchrider no sooner gets the line pumped dry, but water trickling back in soon fills it. When this happens,

[1] Reprinted with permission from the Editor of The Water Hauler's Bulletin, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, Canada T1J 4C7, Fall 1988 issue.

some special dewatering techniques may be required. The best solution is to seal the pipe inlet off completely.

The St. Mary River Irrigation District (SMRID) has been experimenting with various pipe sealing methods for years trying to find a solution to this annoying problem.

Sandbags do work, but they are messy to clean up and are not a 100 percent seal. In 1986, the SMRID sprayed a polyurethane foam on a pipe inlet gate to seal it against leakage during the winter. This foam was a complete success in sealing the pipeline inlet, but some of the foam entered the system during spring startup and caused major problems with valve and sprinkler nozzle operations. A better solution had to be found.

In the fall of 1987, the district's superintendent of construction, Russ Olson, developed an inflatable plug. The plug is made from an ordinary vehicle tire and rim with the center hole and lug bolt holes welded shut. Installation is as simple as raising the slide gate to its fully open position, inserting the deflated tire and rim assembly, then inflating the tire. Olson states "the plug worked well and is a 100 percent positive seal." To remove it in the spring, the tire is simply deflated, and the tire and rim assembly pulled out. Cost for buying a secondhand tire and rim and welding the holes shut is about $75. A very small cost when compared to one or two men having to go back time and time again throughout the fall and winter to pump a pipeline dry.

For Russ Olson and the SMRID the old adage, if at first you don't succeed try and try again, has certainly paid off in a positive, low-cost winter pipeline seal.

For more information, please contact Russ Olson, Superintendent of Construction, St. Mary River Irrigation District, PO Box 278, Lethbridge, Alberta, Canada T1J 3Y7; telephone (403) 328-6712.

CANAL GETS NEW LINING — UNDERWATER[1]

The trick, 9 ft under, will be to prevent washout of the fresh concrete

The Bureau of Reclamation is experimenting with ways to reline old, leaky irrigation canals without draining the water. If this underwater paving proves successful, 66 miles of two canals may be relined at a cost of $170 million.

Expensive — but BuRec officials say it is considerably less costly than building new concrete canals just to abandon leaky sections. That was done in the 1970s when the bureau abandoned the initial 49 miles of the Coachella Canal, southeast of Palm Springs, Calif.

Coachella Canal in southeastern California is being relined to reduce water seepage.

In the 1930s and 1940s when water was abundant and cheap, BuRec diverted water from the Colorado River to make the desert bloom in southeast California's Imperial and Coachella valleys. Building canals in sandy desert soil, lining only a few sections with clay, the bureau anticipated some water seepage.

Today, the combined seepage of both canals is an estimated 90,000 to 115,000 acre-ft each year, or enough water to provide service to an additional 100,000 to 150,000 households.

That's water craved by thirsty coastal cities. If the relining experiment is successful, the canals' other leaky sections will be relined by the Metropolitan Water District of Southern California, which serves half the state's population (ENR 3/31/88 p. 32).

The contractor for the test project began site preparations this month on 1-1/2 miles of the Coachella Canal. "There are a lot of canals that have been lined, but we just had to figure out how to do it with water in it," says Conway Narby, area manager for Kiewit Pacific Co., Santa Fe Springs, Calif., which beat out about a dozen other bidders for the $5.2-million contract.

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[1] Reprinted from ENR, February 2, 1989,

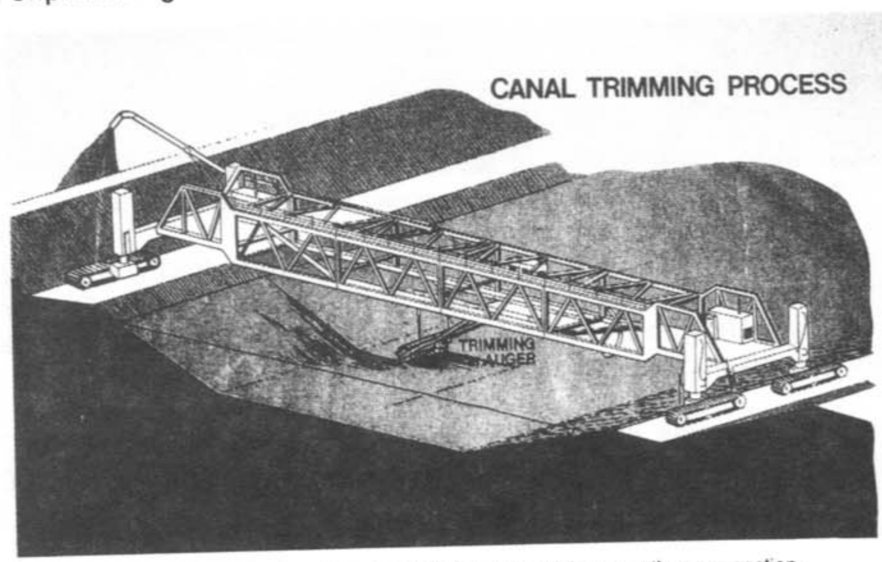
The trick in this experiment will be to prevent washout of the fresh concrete. When experimenting with mixes, BuRec scientists tried several anti-washout agents.

In the lab tests, underwater, a cellulose-based material was best at resisting washout of cement from the aggregate. That intrigued researchers because fly ash or silica fume was better at imparting stickiness and cohesiveness to the concrete out of water, says James S. Pierce, chief of the bureau's concrete and structural branch, research and laboratory services division in Denver.

BuRec scientists decided on a slipformed concrete topping after first experimenting with other materials. They even tried wax — a paraffin-type emulsion — meant to stick to the sides and bottom of the earthen canal.

In the final analysis, polyvinyl chloride sheeting was preferred for its water tightness. But since PVC cannot withstand abuse, and canals must be periodically maintained and the aquatic weeds trimmed, there was a need for a protective cover. Clay or gravel were considered unsatisfactory.

Slipforming underwater. A 3-in.-thick concrete cover will be placed to protect the PVC in the test section. In 9 ft of water, divers and underwater video cameras will monitor the 7,500 ft of slipforming.

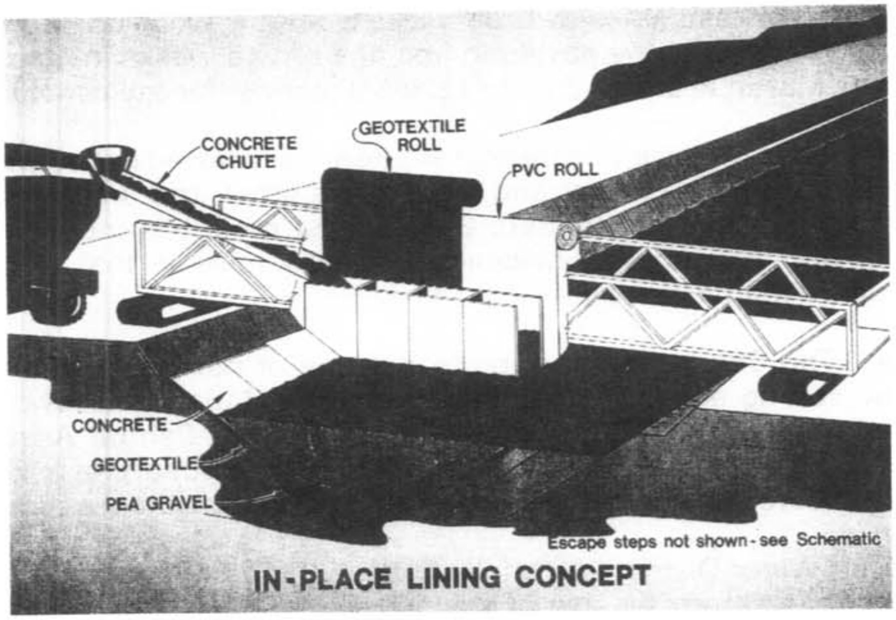


Dredge will trim and grade the sides and bottom of canal for smooth cross-section.

In the operation's first stage, a dredge will trim and grade the sides and 48-ft-wide bottom of the canal to make a uniform, smooth cross-section.

Next, in a single integrated operation, specially-designed paving equipment will place the plastic sheeting, plus a layer of geotextile on the sides of the canal to help the concrete adhere to the slope, and finally the slipformed concrete.

Trimming and grading equipment will be supported by trusses spanning the canal's 103-ft width. The equipment resembles typical paving configurations, with several refinements to control starting and stopping the concrete flow underwater. The equipment supplier, GOMACO Corp., Ida Grove, Iowa, is releasing few details because of its proprietary interests.



Paving equipment will place plastic liner, geotextile and 3-in. concrete cover underwater.

All this alkaline concrete will be dumped into a canal swimming with 16 species of fish. BuRec biologists will monitor the pH of the water, adding acid if necessary. There's also concern about the elimination of the aquatic weeds that grow on the canal's earth bottom, providing food and hiding places for the fish. As an experiment, artificial reefs will be installed - nothing fancy, really, just tires bound together to provide nooks and crannies for windblown silt in which moss can root.

In this dusty, parched desert where summer temperatures often exceed 110 °F, the canals are a favorite source of water for burro deer and bighorn sheep. They come down from the nearby Chocolate Mountains and sometimes slip and drown while trying to drink from a lined canal.

Unable to gain a foothold on the slippery, moss-covered concrete sides, they become exhausted or injured trying to escape. And in places where escape ramps and steps exist, these often go unrecognized by wild animals.

At the urging of a local private organization, Desert Wildlife Unlimited, BuRec will test a new escape system: narrow ledges, 1-1/2 in. deep and 18 in. apart that will be continuously slipformed into the sides of the canal.

The steps will serve another purpose, too. In an average year, six people — most of them illegal aliens crossing the border from Mexico — drown in the All-American Canal. The steps will deflect what BuRec once described as the major negative social impact of the relined canals: a potential increase in human drownings.

The feasibility of the relining program, however, is still uncertain. Cost estimates reflect the unknowns of a new technology. Along one 28-mile stretch of the All-American Canal, BuRec considered building new sections next to leaky ones at an estimated cost of $133.6 million. That is nearly $50 million more than the estimated cost to retain the old sections and reline them underwater.

The accuracy of such estimates will be verified during work on the prototype. "The contractor aims to complete the paving in just one or two weeks in March. That's pretty ambitious," says Martin P. Einert, BuRec's project planner for the canal lining.

Once the technique of in-place underwater slipforming is tested and refined, it's expected to prove popular in the Southwest and the world's other arid areas where year-round delivery of irrigation water is required. But the test project is more than a showcase for new technology. It's concrete evidence of a new mission that was announced by BuRec a little more than a year ago.

Cutting edge. "The Coachella Canal project is one of our first large-scale, important projects on the cutting edge of conservation," says a BuRec spokeswoman in Denver. When the bureau's current line-up of big projects — the Central Arizona Project and the Central Utah Project — is finished in the 1990s, its primary task will be to modify existing water resource projects — with local financing paying the way wherever possible.

The Metropolitan Water District will totally finance the relining of the All-American and Coachella canals, in return for use of the conserved water for 55 years, says Jan P. Matusak, a senior engineer with the agency who participated in the negotiations between it, the Imperial Irrigation District, Coachella Valley Water District, and Palo Verde Irrigation District. In keeping with legislation signed by President Reagan last November, no federal funds will be used for the canal relining except for the $6-million experiment. BuRec is paying 40%, the Imperial Irrigation District 6%, and MWD 54% for the prototype.

In addition to the Metropolitan Water District's plan to spend $170 million for the relining, it signed a 35-year agreement last month to finance 16 Imperial Valley water conservation projects totaling $118 million. These include new reservoirs, automated control structures and additional canal relining — for an expected annual water savings of 100,000 acre-ft.

By David B. Rosenbaum

FOUNDATION PROBLEMS ARE BLAMED FOR RESERVOIR EMBANKMENT FAILURE[1]

Foundation weakness is the prime suspect as the cause of collapse of a large earth saddle dike in southwestern Utah late New Year's Eve. The failure released a gush of 25,000 acre-ft from Quail Creek reservoir. No one was killed or injured. Residents 15miles downstream had been warned of the danger or evacuated.

"We had one weak zone and Mother Nature found a way to disguise it," says Gerald W. Stoker, area engineer in nearby Cedar City for the Utah Dept. of Natural Resources, which is responsible for dam safety. The zone was in the foundation of the dike, which is limestone laced with soluble gypsum. The dike had been plagued by leaks requiring major repair since the reservoir was first filled.

The dike, 1,980 ft long and as high as 70 ft, is part of a multipurpose project completed in 1985. It also includes a main earthfill dam 210 ft high and stretching 1,000 ft across the creek. The two embankments form an offstream reservoir designed to hold 40,000 acre-ft just above a bend in the Virgin River near the town of Hurricane. It is fed by a pipeline from a small diversion dam on the Virgin.

Earth dike that burst had a history of leakage that required an ongoing grouting program

The breach released a flood that surged down the Virgin River in waves 10 to 40 ft high, inundating parts of St. George and several other small towns. Three small bridges were swept away, along with a 98-year-old irrigation dam. The flood also disintegrated half a mile of Utah Route 9, where water thundered through a narrow highway cut adjacent to a bridge about a mile downstream. The surge ripped out utility lines at the crossing, including a newly-completed 8-in. gas line.

Ample warning. Prior to the breach, the Washington County Water Conservancy District, which owns the project, worked for 12 hours to stanch a leak at the toe of the embankment.

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It initially was spilling 25 gpm. WCD crews loaded the piping area with heaps of gravel and built a small cofferdam to contain the material.

Late in the afternoon, WCD officials advised county emergency management director Tony Hafen to prepare for downstream evacuation. "When they called, they said, 'We don't think it's anything to worry about, but the water is discolored and we've never had that before,'" Hafen recollects.

The water color showed that soil from the embankment or the reservoir bottom was escaping. Floodlights on top of the dike did not reveal any vortices in the dark reservoir, which was 35 to 40 ft deep, Hafen says.

Workers gave up repair efforts when the leak swelled to 600 gpm around 11 p.m. Soon afterward the base of the dike "just punched out" around the leak, says Stoker.

Stoker arrived about an hour after the collapse. "The gap was about 120 ft long" in the embankment, he says. By the next day the breach, near the left abutment, had about doubled, and the reservoir was still draining. Two or three hours after the dike failed, the outflow was "10 to 15% over the 100-year flood on the Virgin River, or in the neighborhood of 60,000 cfs at its peak," says Stoker.

A 48-in. discharge pipe had been the reservoir's only outlet. A worker was able to open its valve only part way before the collapse. Why it would not open to its 150-cfs capacity had not been determined last week.

Watched closely. The embankments were designed by Salt Lake City consultant Rollins, Brown & Gunnell, while St. George-based Creamer & Noble supervised the project. S. J. Groves & Sons Co., Minneapolis, built the $7-million embankment as part of a $23.5-million project.

The project includes the 9-1/2-mile pipeline, 48 to 66 in. in diameter, from the diversion dam upstream on the Virgin River. That line also drives two small hydroelectric units. A water treatment plant is nearing completion below the dike. The reservoir also supplied irrigation water.

The main dam and saddle dike were designed essentially the same. They have silty sand cores covered with clay in cutoff trenches that were swept clean but not grouted. Other zones include sand, gravel and random fill.

Quail Creek is classified as a high-hazard reservoir requiring annual inspection because it sits above populated areas. It was last officially inspected by Utah dam safety engineers last March, according to Stoker. But since then, it has had three unofficial inspections — the most recent last October — following the grouting of individual leaks in the dike.

Foundation suspected. Stoker has closely followed the project's construction and the attempts to halt its constant leaks over the past four years. He does not believe that construction methods contributed to the failure. "I can't see that it was anything but foundation problems," he says. "We felt good about compaction in all of the zoned material." Piezometers in the dike showed "nothing out of the ordinary" before the collapse, he says.

State Engineer Robert Morgan, who heads the DNR dam safety office, says, "there were serious concerns" about gypsum lenses revealed during tests prior to building the project. "We and the owner and the engineer would anticipate seepage problems. The owner thought they could be overcome by monitoring and staying on top of the seepage. There was an ongoing grouting program."

State officials ordered WCD to stop filling the reservoir in 1986 because of leakage, principally from the main dam. A wet spot had appeared on its downstream face, but Stoker says that problem was cured with placement of a blanket on the face.

At the same time, WCD drew down the reservoir to dig a $1.5-million cutoff trench just upstream from the dike, then blanketed exposed pervious formations with clay. Other areas were grouted from the crest. "We did discover a large number of voids and fracture systems," says Stoker. "We had some holes with tremendous takes [of grout]." But he believes the leakage, which had been as great as 14 cfs, was successfully controlled.

Seepage was still flowing through sandstone at the main dam's right abutment when the dike collapsed. "There was more water coming through those formations than we ever had at the dike," says Stoker. "But we were comfortable with it."

No one with either of the engineering firms would comment on the collapse. Morgan has assembled an independent panel to study the failure.

By David Ellingson at Quail Creek

WASHOUT BLAMED ON SEEPAGE[1]

An earth dike at Quail Creek Reservoir in Utah failed on New Year's Eve primarily "because embankment materials placed on the foundation, including overburden left in place, were not protected from seepage erosion," says a report by an independent review team.

The report appears to fault design and exonerate Minneapolis-based contractor S. J. Groves & Sons Co., finding "no indication that seepage through the dike embankment [the firm placed] or the quality of its construction contributed to the failure."

The off-stream reservoir, created by an earth dam and the failed dike on Quail Creek, was filled with Virgin River water sent through a tunnel from a small concrete dam upstream. The dike, 1,980 ft long and up to 70 ft high, had been plagued by leaks since the reservoir was first filled in 1985. Hours of attempts to stem major piping on December 31 led to warnings that prevented deaths when the dike burst, releasing 25,000 acre-ft of water in the middle of the night (ENR 1/12 p. 10).

Earthfill dike that burst had history of leakage ever since its reservoir was first filled in 1985.

Salt Lake City consultant Rollins, Brown & Gunnell designed the embankments. President Ralph Rollins said, "I don't believe we ought to make a statement off the cuff." His firm is writing a response.

Creamer & Noble, in nearby St. George, was project engineer for the $23.5-million project for the Washington County Water Conservancy District. A spokeswoman for the firm said only, "We did not design the dike."

Challenging. Conditions in the dike's foundation "were extremely challenging and deserved special consideration in design," says the report by the five-member review team. "Fractures in the form of three major near-vertical joint sets were present in

[1] Reprinted from ENR, March 16, 1989, copyright, McGraw-Hill, Inc., All rights reserved.

the foundation and permitted significant seepage flow; foundation exploration was not designed or complete enough to fully detect seepage problems associated with these joints."

The report says the assumption that there would be little seepage below the dike's shallow cutoff trench "was not valid," adding, "Highly fractured, pervious rock and erodible overburden was left in place upstream and downstream of the cutoff, permitting seepage along the foundation contact."

There was speculation that soluble gypsum in the rock foundation contributed to the failure. That "was not the primary cause of failure," the investigators say. "However, as time passed, the solutioning of the gypsum allowed increased volume and velocity of seepage near the contact, thus hastening the erosion process."

Relearned. The panel's chairman is Robert L. James, an independent geotechnical engineering consultant from Lancaster, Texas. Other members are Alan L. O'Neill, a consulting engineering geologist from San Francisco; Richard B. Catanach, the principal with Tierra Engineering Consultants, Inc., Santa Fe, N.M.; J. Lawrence Von Thun, head of analysis in the Bureau of Reclamation's embankment dam section in Denver; and Bruce C. Barrett, a project engineer in BuRec's southwest Wyoming field office.

They were not impressed by continued grouting that the Quail Creek owner used to try to stem leaks. It was not a long-term solution, the report says, adding that there is "evidence that remedial grouting restricted downstream drainage channels in the rock foundation, increasing hydraulic pressure against the embankment/foundation contact, enhancing conditions for piping at the contact."

The investigators' report to Utah Gov. Norman H. Bangerter and the state Dept. of Natural Resources says most of the lessons learned "should be more appropriately termed 'relearned and reinforced.'"

By Dave Ellingson in Las Vegas

AN IMPORTANT STEP IN SOIL-APPLIED HERBICIDE APPLICATIONS

by Victor S. Miyahara[1]

The directions on the label of a good soil-applied herbicide contain a section on fixing the herbicide in the soil soon after application by watering the area up to the point of runoff. After completing the 1987 and 1988 studies on posttreatment methods in soil-applied herbicide application, this section on the label cannot be stressed enough for safety when this type of herbicide is used in controlling all vegetation. Not only will fixing the herbicide in the soil keep the herbicide in the treated area, but the concentration of herbicide in the upper layer of the treated soil will stay high enough to control all vegetation over a longer duration. Fixing the soil-applied herbicide is accomplished simply by sprinkling the treated area with water up to the point of runoff. However, at times this part of the application method is omitted in the specifications to the contractor and will not be completed. The studies conducted the past 2 years show that once the soil-applied herbicide is fixed in the soil-aggregate soil used in Bureau of Reclamation power switchyards, it will stay in the treated area. There will be a similar study conducted in 1989, but on a much larger scale.

The results from earlier studies conducted with soil-applied herbicides indicate there are good herbicides that will inhibit all vegetative growth in power switchyards and irrigation rights-of-way for several years (reported in the Water Operation and Maintenance Bulletin No. 142, December 1987). There are two herbicides tested in this study still providing excellent control of all vegetation with very little leaching from the test plot 6 years following application. However, there were a few reported instances of soil-applied herbicides moving from the treated areas, and clearing all vegetation from areas surrounding the irrigation rights-of-way and power switchyards. This is such a concern that treatments with soil-applied herbicides on switchyards and irrigation rights-of-way are being omitted in several areas, substituting more frequent applications of a less persistent herbicide.

The studies conducted the past 2 years were set up to determine the reason for the movement of soil-applied herbicides and how it can be prevented. The applicators will have to be assured that the herbicide will stay in the treated area before they will start using this type of herbicide.

The test site for these studies is a fenced-in area on the west side of the Denver Federal Center.

Each year, three 3- by 3-foot plots were set up with a 3-foot undisturbed area between each plot. Approximately 5-1/2 ft^3 of soil was removed from each plot.

A wooden frame was used to border each of the 1987 plots. A compacted soil-aggregate replaced the soil in each plot to simulate a switchyard area (see photograph). The soil-aggregate material used in the studies was made up to meet the standard specifications used by the Bureau of Reclamation. The herbicide used in the study contained 1.86 percent prometon (2-methoxy-4,6-bis isopropylamino triazine). This herbicide was applied with a garden sprinkler can at a rate of 22.76 pounds per acre active ingredient.

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[1] Victor S. Miyahara is a botanist employed by the Bureau of Reclamation, Denver, Colorado.

The posttreatment procedures in 1987 and 1988:

Plot No. 1. — No posttreatment.

Plot No. 2. — This plot was watered down up to the point of runoff right after treatment and again 3 hours after treatment.

Plot No. 3. — Three hours after treatment, this plot was watered to the point where the water ran off treated soil aggregate.

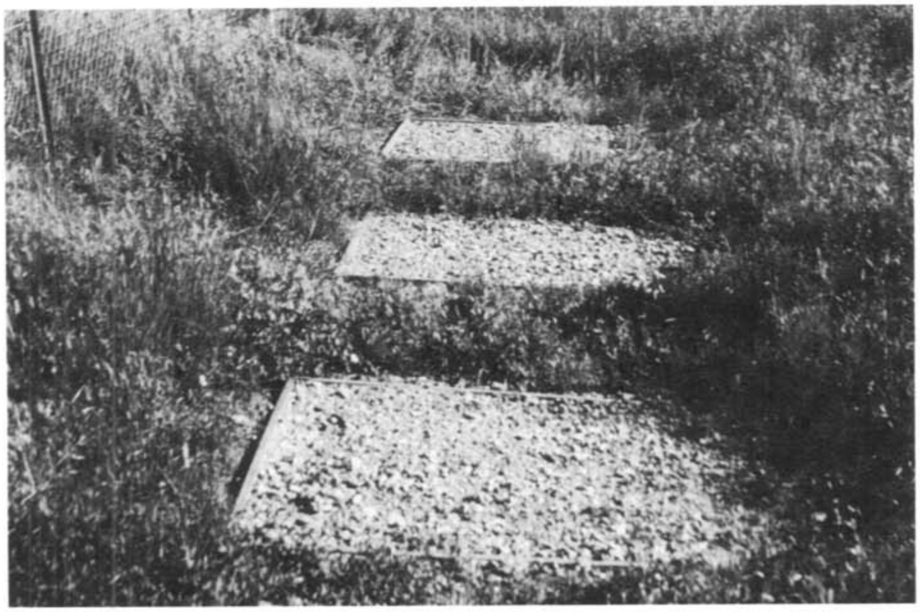
The plots were observed every 2 to 3 days for the first month, once a week the next month, and monthly for the remainder of the season.

A week after the treatments in 1987 and 1988, there were indications of movement of herbicide out of plot No. 3 with injury of all vegetation to the lower edge of the plot. On this date, there was no injury to vegetation outside the treated areas of plots No. 1 and 2. In 1987, there were two major rainstorms 2 weeks after treatment; and in 1988, there was a major rainstorm 10 days after treatment. A few days after the rainstorms, the vegetation showed some injury at the lower edge of plot No. 1. There were no indications that the herbicide had leached from plot No. 2, with healthy vegetation growing around this plot.

After initial runoff, the soil-applied herbicide seemed to be fixed in the soil with no further movement out of plots No. 1 and 3. During the latter part of the season, bindweed started to grow around all plots. However, the plants turned brown and died a few weeks later at the lower edges of plots No. 1 and 3.

Bindweed also grew in the 1987 plot No. 3, but turned brown and died, probably due to the initial leaching of herbicide in the runoff soon after treatment.

Two years of testing showed that if the soil-applied herbicide is not fixed in the soil, part of the herbicide remains on the surface ready to be washed away with the first heavy rainstorm or runoff from snowstorms. This will happen even if the storms happen a month after application. Once a soil-applied herbicide leaches with the initial runoff, there is very little or no further movement from the treated area. Often a light rain or snowstorm will fix the herbicide in the soil of a treated area. However, an applicator should never take a chance that this will happen before a major storm. A simple process of watering down the treated area up to runoff soon after treatment will take care of most of the leaching problems.



Picture showing the three plots in the 1987 study

SPOTLIGHT ON SHASTA DAM

Central Valley Project

California

Shasta Dam

Shasta Dam, on the Sacramento River 9 miles northwest of Redding, California, serves to control floodwater and store surplus winter runoff for irrigation use in the Sacramento and San Joaquin Valleys, and to provide maintenance of navigation flows and conservation of fish in the Sacramento River, protection of the Sacramento-San Joaquin Delta from intrusion of saline ocean water, water for municipal and industrial use, and generation of hydroelectric energy. Completed in 1945, the dam is a curved concrete gravity structure 602 feet high with a crest length of 3,460 feet. Shasta Lake, with a capacity of 4,552,000 acre-feet, provides abundant recreation, including boating, fishing, swimming, water skiing, camping, hunting, and houseboating. Many summer homesites have been developed along the shore, some accessible only by boat. Many resorts cater to the needs of the visitors to the Shasta Lake recreation area.

Shasta Powerplant

Shasta Powerplant is located just below Shasta Dam. Water from the dam is released through five 15-foot penstocks leading to the five main generating units and two station service units. Total capacity of these units is 539,000 kilowatts.

Early History

Agriculture in the Central Valley Basin has developed through three overlapping stages: the cattle ranching of the early days, followed by dry farming of small grains, and finally the specialized and intensified irrigation farming of today.

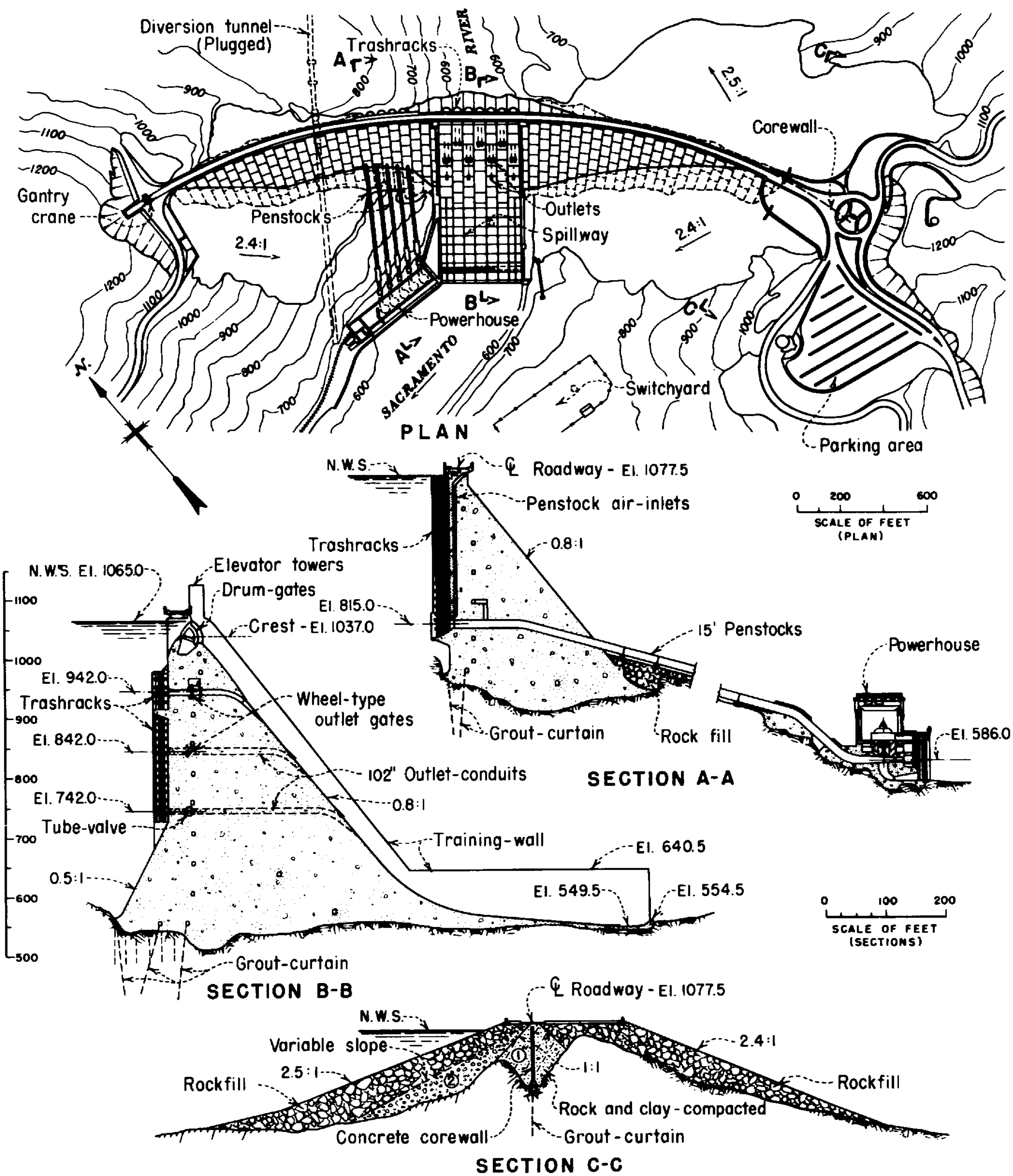
Although there were earlier settlements in the Central Valley, the real development of the area began in 1849 after the discovery of gold, as people came to the mining regions of the Sierra Nevada. The demand for food and fiber occasioned by this influx gave impetus to the great agricultural development of the valley.

Cattle raising as a major activity was brought to a sudden end by the disastrous drought of 1863-64 which resulted in the loss of practically all the cattle in California. This factor, plus growth of population, increased cost of land, and development of the railroads after 1869 made grain production first in agricultural importance. Dry farming of wheat and barley continued to expand until the latter part of the century, then declined as other grain regions were developed. Meanwhile, irrigation farming developed to the dominant position it now occupies.

Construction of the initial units of the Central Valley Project began in October 1937 with the Contra Costa Canal. The entire canal was completed in 1948. First delivery of water was made on August 16, 1940. A contract for the construction of Shasta Dam, keystone of the Project, was awarded July 6, 1938. Work started in 1938 and was essentially complete in 1945. Storage of water began in January 1944, and the first power was delivered in June1944.

Irrigation.–Each year, between 3 and 4 million acre-feet of water are delivered through the Project for irrigation use on nearly 2 million acres of fertile land. This land produces more than $1 billion in crops annually. The principal crops are cotton, barley, rice, alfalfa hay, grapes, citrus and other fruits, and nuts.

Municipal and industrial water.–Approximately 320,000 acre-feet of the water produced by the Project is furnished to communities for municipal and industrial use in a normal year. It is also used by the steel, oil, rubber, paper, and chemical industries of the area and supplements the supply of an existing private water utility.



Shasta Dam, Plan and Sections

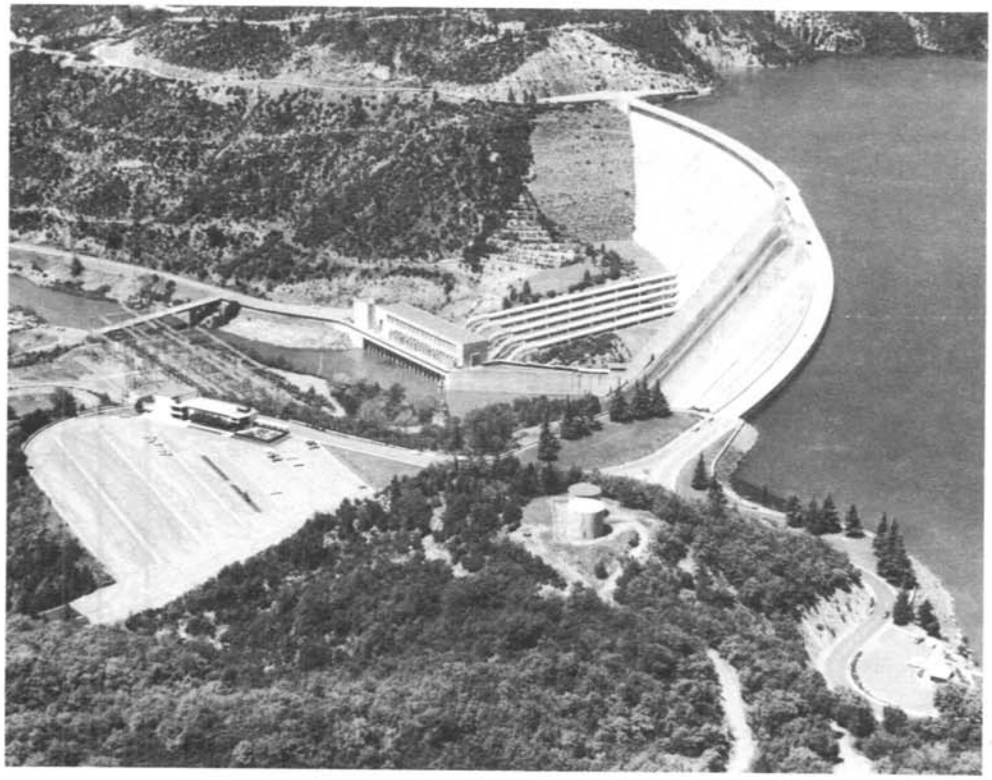


Photo 1. - Aerial view showing profile of Shasta Dam on Sacramento River - 5/7/75

Photo 2. - Aerial view of Shasta Dam showing spillway gates operating — 7/18/51

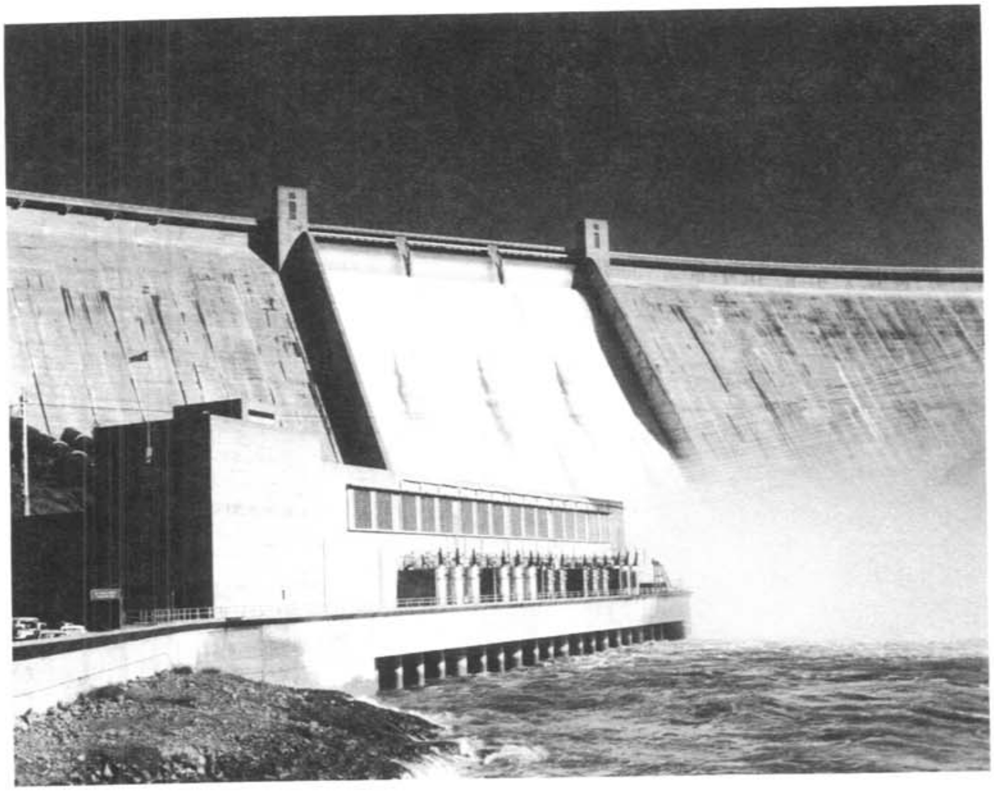


Photo 3. – Shasta powerplant and spillway - 1/28/70

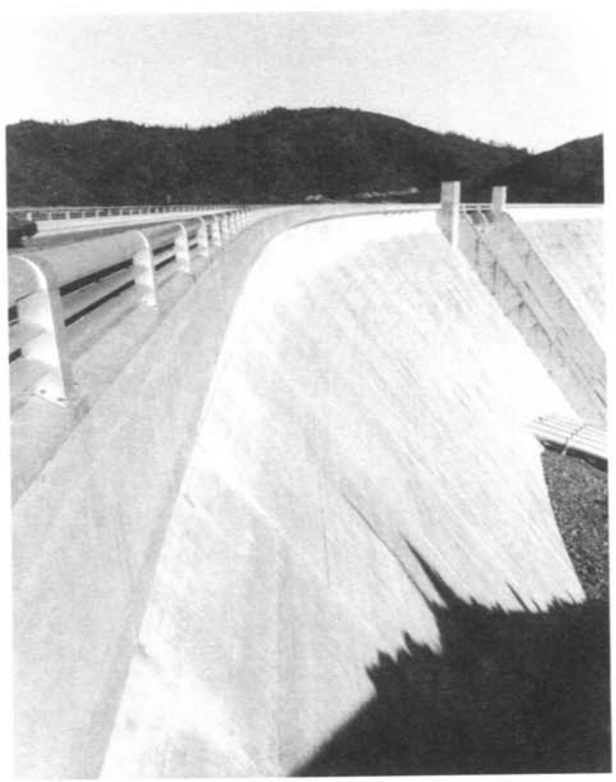


Photo 4. – Closeup view of downstream face of Shasta Dam - 2/17/70

GPO 859-973

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 regional office.