WATER OPERATION AND MAINTENANCE

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IN THIS ISSUE

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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 operation and maintenance information. It is hoped that the reports herein concerning laborsaving devices and less costly equipment and procedures will result in improved efficiency and reduced costs of the systems for those operators adapting these ideas to their needs.

To assure proper recognition of those individuals whose suggestions are published in the bulletins, the suggestion number as well as the person's name is given. All Bureau offices are reminded to notify their Suggestions Award Committee when a suggestion is adopted.

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Cover photograph:

Yesterday's revolutionary new irrigation products often appear clumsy and quaint in comparison to current standards, but they cannot be slighted for durability.

ATTENTION

CLARIFICATION

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Bulletin No. 137, September 1986 Issue

"A Programmed Approach to Chemical Weed Control"

The September 1986 Water Operation and Maintenance Bulletin No. 137, included an article titled "A Programmed Approach to Chemical Weed Control," which appeared on page 19. Although not intended, it could be inferrred that two herbicides (ammate and Krenite) are being used in a manner for which they are not approved. The use of "ammate" (ammonium sulfamate) and "Krenite" (posamine) in irrigation canals is inconsistent with EPA (Environmental Protection Agency) registration of these materials and the instructions on the product labels.

Irrigation systems are for multiple use with water being supplied for crops, livestock, and municipal purposes. These herbicides ARE NOT SPECIFICALLY REGISTERED FOR USE IN IRRIGATION DITCHES. Therefore, any person applying the pesticide must assume it is UNSAFE for such use.

Both CIVIL AND CRIMINAL PENALTIES FOR MISUSE of pesticides can be applied under the Federal Insecticide, Fungicide, and Rodenticide Act.

INTRODUCTION

Water Operation and Maintenance Bulletin

No. 137

Irrigation dates as far back as 3000 B.C. The article beginning on page 1 traces irrigation from its crudest and most ancient forms through the use of space-age computer circuitry and highly refined hardware.

See the article beginning on page 9 for information on underground storage tanks which can leak and pose a costly environmental hazard.

The article on page 12 gives some examples which illustrate the types of canal linings being designed and installed by the Bureau of Reclamation in recent years.

Maintaining control of weeds along canal banks can be a formidable task. See the article beginning on page 19 to find out how one manager has been doing it for years.

The article on page 21 describes how well screen design can increase flow and reduce the cost of irrigation pumping.

A digest statement describing the spillway deterioration at Big Sandy Dam starts on page 23.

Page 26 is the Water Systems Operation and Maintenance Cost Index.

IRRIGATION

Necessity and Imagination Transform An Ancient Task

If you watered any crops or fruit trees today, you owe thanks to a group of historic pioneers. Like most pioneer endeavors, modernization has taken over.

The ancient task of supplying life-giving water to plants is now performed through highly specialized applications of man-made materials and advanced technology.

Space-age computer circuitry and highly refined hardware dominate a field once reliant on oxen lifting water from a well and on "zaneros," or ditch tenders, maintaining irrigation ditches.

Irrigation dates back to ancient Egypt in about 5000 B.C., the Tigris-Euphrates Valley in about 3500 B.C., and India and China in about 3000 B.C.

The crudest and most ancient form of irrigation was in the form of flood waters that flowed over river banks into valley bottoms and delta lands. Relying on nature to provide adequate water when needed proved impactical at best. Necessity being the mother of invention, man turned his efforts to developing artificial methods of bringing water to the fields.

Some natural flooding, or inundation, was controlled by constructing dikes to hold water in artificial basins and natural depressions. Irrigated areas were later extended by digging inundation canals. This method of distribution is still practiced today in large parts of the Middle and Far East.

The practice of "baling up" water was first found along the Nile River. Simple equipment was used to draw water from wells fed by natural seepage of the river, such as a pole with a bucket at one end of a cross-beam counterbalanced with a weight called a "shadoof."

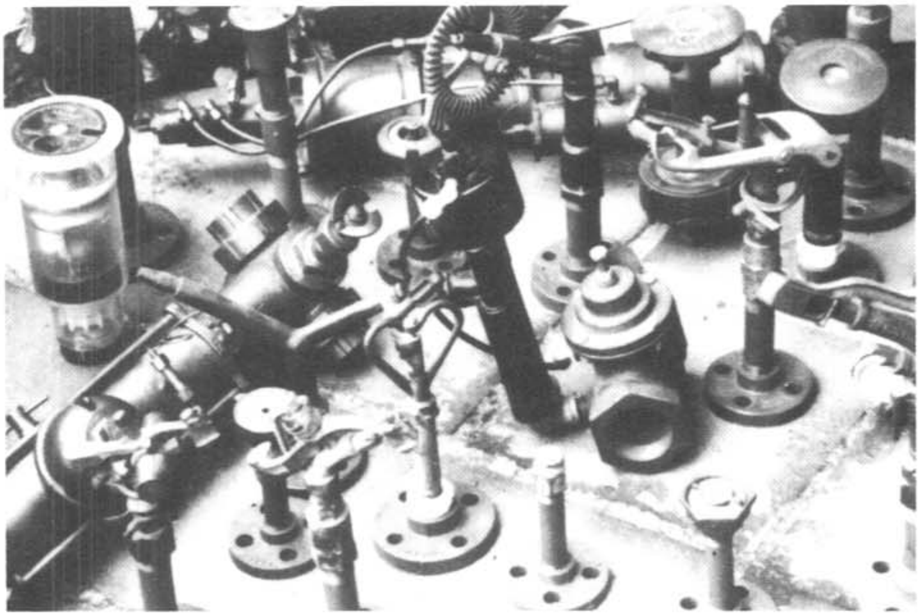
Later, a water wheel with a chain of earthen pots, called a "sakya," was developed. Oxen were able to raise water as high as 18 feet and keep 5 to 12 acres irrigated with one such device.

Irrigation was carried out by Pueblo Indians in New Mexico and Colorado as far back as 800 A.D. Hohokan Indians developed what were then considered extensive irrigation systems in Arizona.

Spaniards who came to America were well versed in irrigation from their Moorish ancestry. They are credited with teaching the Indians to build dams and reservoirs.

Reprinted, with permission from the Editor, from the January/February 1986 issue of the Irrigation Journal.

Irrigation in Texas was initiated by Spanish emigrants and missionaries from Mexico in 1598. Early California mission settlements were irrigated by padres and local Indians using these same ageless methods.



Yesterday's revolutionary new irrigation products often appear clumsy and quaint in comparison to current standards, but they cannot be slighted for durability.

In 1847, Brigham Young and the Mormon settlers in Utah built the first irrigation system established by white farmers in the West. In 2 years they were able to place a total of 16,000 acres of arid and previously useless land under irrigation.

The discovery of gold in California further pushed the "great expansion." Ditches dug for gold panning proved invaluable in later years for use as irrigation channels.

In 1862, a drought set in which killed thousands of longhorn cattle; they were the economic basis of California's Spanish heritage. The resulting loss of land gave rise to a massive agricultural industry when, in the 1860's and 1870's, the cattle barons were forced to sell off their mortgage-plagued ranches.

Enterprising farm families began to fill the area, and the need for adequate water supplies became more and more imperative. Irrigation as a private enterprise began to grow rapidly during this period.

In the 17 Western States, which account for the majority of irrigated land in the United States, more than 3,600,000 acres were under irrigation by 1890. The first federal irrigation project was begun in 1868, to irrigate land on the Mohave Indian reservation in Arizona.

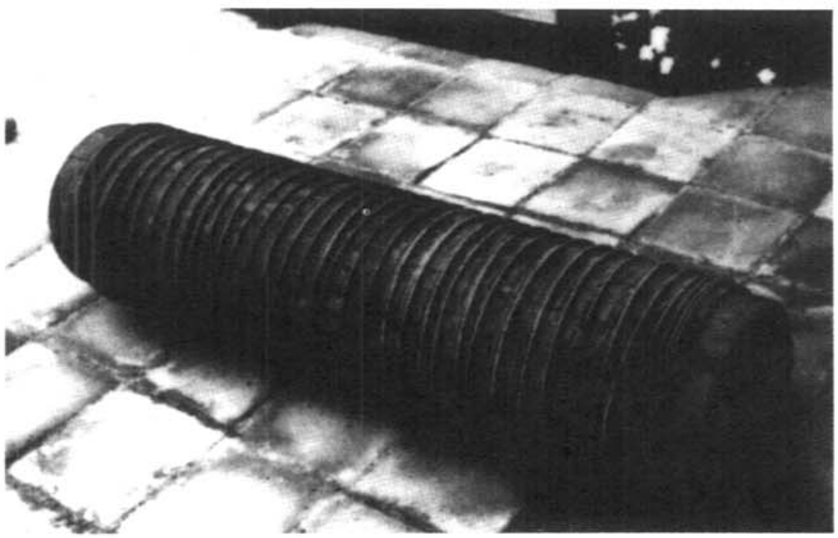
In 1897, Congress adopted the Carey Act, which granted land to states and territories that would build irrigation systems. Few states took advantage of the act at that time.

In 1902, the Federal Reclamation Act was adopted, giving the Department of the Interior power to construct irrigation systems from monies received through the sale of land.

By 1923, when the Reclamation Service became the Bureau of Reclamation, the amount of land under irrigation had increased to 8,900,000 acres, and 25 years later to more than 30 million acres.

Through the years, various materials have been used for irrigation, including wooden pipe in many West Coast areas. Pine and redwood pipes were used in fabricating many early pipelines and water ditches.

However, they rotted and contaminated the water supply, so they had to be discontinued.



Redwood pipe such as this, constructed in a manner similar to barrel staves, was used in many West Coast water supply and irrigation systems in the early part of the century.

Early Los Angeles history details a wooden pipeline used as a city water mainline, but leakage presented such a problem that horses and buggies actually sank into the streets.

Ancient history mentions the use of bamboo poles to convey water to the fields in China. However, the fabric used to connect the poles leaked and forced abandonment of the system.

Brass was used for piping when it was relatively low in cost, and it proved to be highly durable and corrosion free.

Prior to the metal shortage during World War II, experiments with different types of metals included the use of aluminum. However, it was easily corroded by minerals in the water. Copper was so high priced that it virtually eliminated itself. Galvanized pipe is still being used, especially in applications allowing straight-line designs.

The use of plastics in manufacturing for irrigation was not seen until the 1950's. Used in Europe as early as 1937, polyvinyl chloride (PVC) was not introduced to the American market until 1952.

Although low in cost, early PVC was unreliable from a performance standpoint. In the late 1950's and early 1960's, new standards for PVC were set by the American Society for Testing and Materials (ASTM). Due to its long life, ease of installation and flexibility, plastic pipes and fittings are now used in most irrigation projects.

As far back as could be traced, the earliest sprinkler irrigation system equipment was the brainchild of an Ohio farmer in 1897.

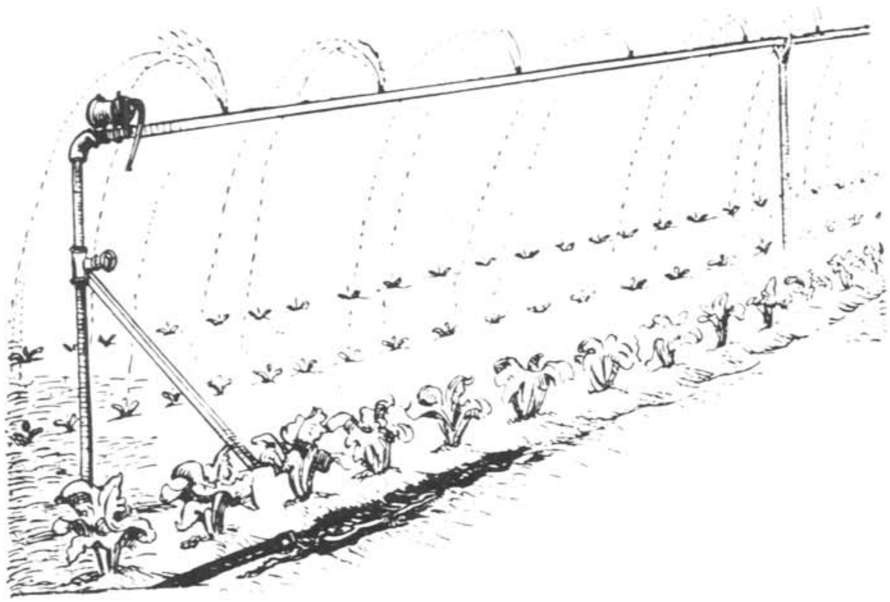
Farmer Skinner would probably not have called himself an entrepreneur in the irrigation industry. However, providing supplemental water to crops in Troy, Ohio in 1897 was quite a problem. Highly inventive by nature, Skinner began experimenting, seeking a way to provide water for his farm crops.

Borrowing a steel drill from his local dentist, he took a length of galvanized steel pipe, the kind still used in irrigation systems today, and made holes in it at 3-foot intervals. Resting the pipe 6-feet overhead in a Y-shaped piece of pipe set in the ground, he attached a garden hose and turned on the faucet. Crude, but it worked.

Later he designed and patented an oscillator operated by water pressure to rotate the pipe 180 degrees. He also designed rudimentary nozzles.

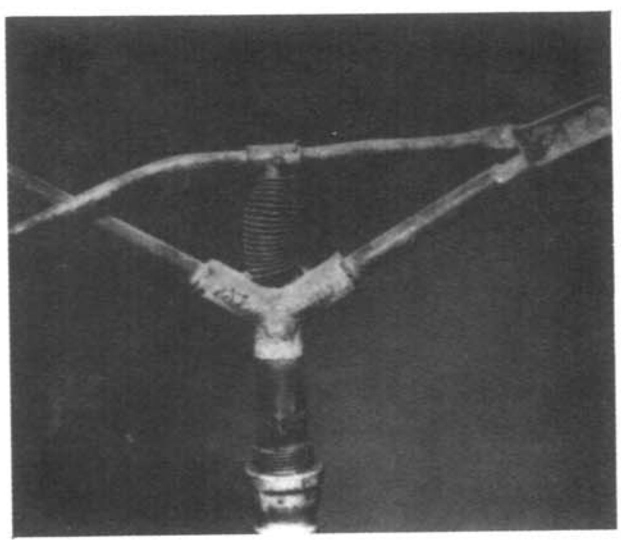
Before his death, Skinner greatly improved his designs and held patents for nearly 80 different types of nozzles. In conjunction with Walt Coles, to whom he sold his small business in 1907, the first designs for pop-up, stationary, and revolving sprinklers were patented.

Skinner Irrigation Company became a leader in the industry and was based in Cincinnati, Ohio. It installed pioneer systems in such famous places as Czar Nicholas' palace in Russia, West Point, Mount Vernon, Pinehurst Golf Course, Burning Tree Golf Course, the United Nations building, Vassar College, and innumerable city parks and facilities across the nation and in Canada. Skinner Irrigation Company was later purchased by Weather-Tec, Fresno, California.



The horizonal pipe of a stationary overhead system is usually supported upon gas-pipe posts with roller fittings at the top, so that the pipe can easily rotate.

Rain Bird Sprinkler Manufacturing Corporation also had a colorful beginning. In 1933 Orton Englehardt, a citrus rancher in Glendora, California, developed the first impact- or pulsating-head sprinkler by directing a stream of water onto a spring-loaded arm. When hit by a blast of water, the arm was forced away from it, and when hit again it continued its rotating movement.



Original impulse sprinkler manufactured by Rain Bird.

Rain Bird originally made and sold about two sprinklers a day from a barn-loft manufacturing "plant." Employing his family as a sales team and high school students as helpers in assembling the sprinklers, Englehardt produced and sold sprinklers on a very limited basis at first.

Rain Bird was purchased in 1935 by Clem LaFetra and his wife, Mary. Today their son, Tony, is president of the company. Rain Bird Sprinkler Manufacturing Corporation maintains its headquarters in Glendora, the city of its inception.

The company now includes global sales offices and distribution plants. It employs some 1,500 people and produces more than 100 types of sprinklers, in addition to spray guns, valves, bearings, controllers, and equipment parts.

W.A. Buckner, a Santa Fe Railroad dispatcher in Fresno, California, was much like Skinner. He thought there must be a better method of irrigation and set about to bring his ideas into existence.

Shortly thereafter, the hobbyist's dream came to fruition when he was awarded the contract for irrigation of California's Pebble Beach Golf Course.

In 1926 Buckner Irrigation purchased another Fresno-based firm, Febco, a manufacturer of anti-siphon or backflow prevention valves. Combining their efforts, the alliance contributed many products to the developing irrigation business. Febco was later sold.

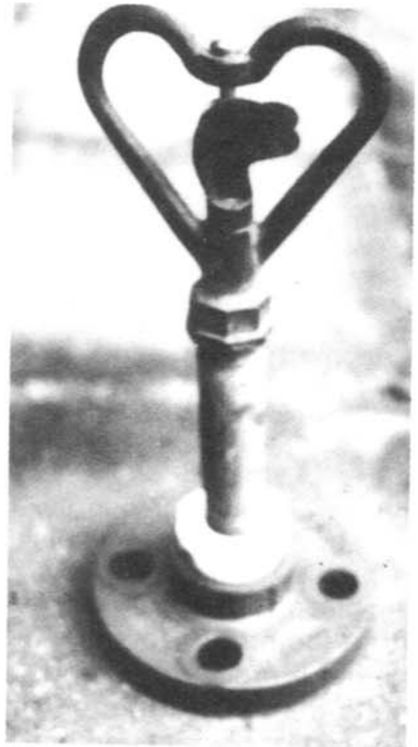
Johns-Manville entered the irrigation field with the purchase of Buckner's irrigation company in 1971. Then, years later, Royal Coach–also of Fresno–bought the firm's name and assets and became known as Royal Coach/Buckner.

The company now employs more than 500 people and markets over 130 different types of sprinklers, valves, controllers, and other equipment.

Another major supplier in the irrigation market is Toro Manufacturing, which launched its operations in Minnesota in 1914, producing farm tractor motors.

In 1962, with the purchase of Moist-o-Matic in Riverside, California, the brainchild of Ed Hunter, Toro began making and selling irrigation products. Hunter, who until recently designed for the Toro Irrigation Division, is credited with revolutionizing Toro's manufacturing approach through his design of exclusively plastic parts.

Moody Irrigation was begun in 1923 by George Moody, an irrigation installer. In that year he invented the first automatic irrigation controller for commercial irrigation. According to a company spokesman, his model is still in operation today, along with two others built the same year.



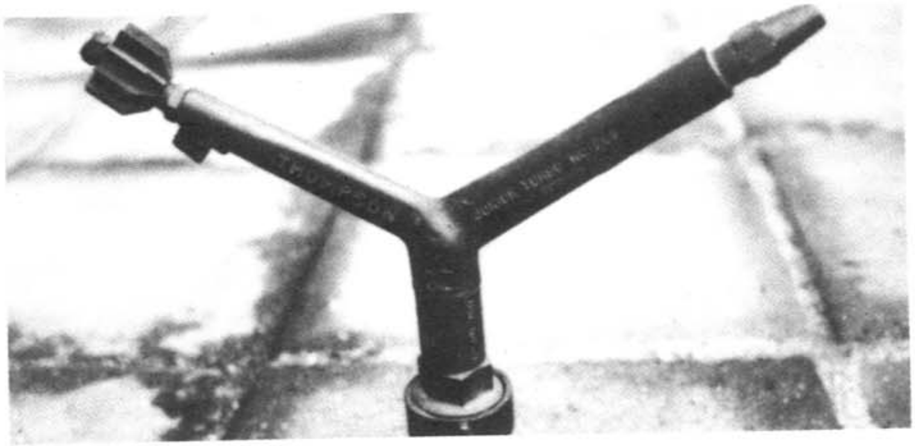
The curve in the nozzle caused the water stream to strike the "wings" of this Moody Butterfly shrub type sprinkler, causing them to spin and break up the stream into droplets.

The former offices of the Shah of Iran and the Los Angeles County Arboretum are only two of Moody Irrigation Company's installations around the world.

Until 6 years ago, Moody Irrigation Company was based in Costa Mesa, California. It was then acquired by L. R. Nelson Company, Peoria, Illinois. Nelson later announced that Fresno-based Weather-Tec had acquired the large turf portion of the business.

Thompson Manufacturing, Los Angeles, California, also rates alongside the oldtimers in irrigation history. It was established in a garage in Pasadena, California, in 1907 by Van E. Thompson, who moved his company only once. It has been in its present location for more than 70 years.

As the self-proclaimed "Cadillac of the sprinkler industry," Thompson claims to have pioneered the field of gear-driven rotor sprinklers in 1918. Thompson also held the first patent for the baffle spray head used extensively in nurseries. The company now manufacturers several basic types of sprinklers.



Thompson impact sprinkler, manufactured in the 1930's, featured a fluted end to cause the head to spin and water the inner circle.

Lasco Industries of Anaheim, California, one of the largest manufacturers of plastic fittings, entered the business in 1957 with a factory in Downey, California. Raw materials were unreliable and experienced personnel were hard to find. Four years passed before the company could turn 50 percent of its manufacturing to irrigation products made of PVC, ABS (high-temperature and high-pressure plastic) and polyethylene.

There are now scores of manufacturers of irrigation equipment and accessories in the country. The industry is centered in the West, where modern irrigation techniques were originally developed, but plants and offices are located throughout the nation.

Because water is rising in price and dwindling in reserves, the need for efficient irrigation techniques has never been greater.

Both the agricultural and landscape ornamentals irrigation industries have felt the need in recent years for a voice in the nation's capital. The Irrigation Association, based in Arlington, Virginia, has not only set performance standards in equipment, design, and manufacturing, it has also represented a vital American industry in Government corridors.

Today's irrigation industry continues on the march. New documentation, programming, and testing procedures have been introduced to create uniform standards. These new methods will not only help improve manufacturing techniques and quality, but will contribute computer accuracy to water conservation. A link has thus been established between space-age technology and the ancient practice of irrigation.

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LEAKING UNDERGROUND STORAGE TANKS POSE COSTLY ENVIRONMENTAL HAZARD

by

Robert L. Haney

Underground storage tanks have long been used by all kinds of businesses to store bulk fuel and other liquids. In recent years, many thousands of these aging tanks have been found to be leaking gasoline, diesel fuel, and other chemicals into the environment, according to Dr. Kirk Brown, soil physicist with the Texas Agricultural Experiment Station, located in College Station, Texas.

Brown is a nationally recognized authority on problems associated with the movement of toxic wastes in the soil.

He says there are presently estimated to be over 2 million underground storage tanks in the United States, with an average useful life of about 15 years.

Some officials estimate that as many as 70,000 underground storage tanks are already leaking. They warn that some 350,000 additional tanks could be leaking within 5 years.

The main cause of leaks is metal corrosion. It not only eats through the tanks but also destroys the pipes that connect the tanks to pumps and other equipment.

The corrosion rate, Brown says, depends on the completeness of the coating and the mineralogy of the soil, as well as the moisture, pH and salinity condition, the presence of other metals in the soil, and the condition of the cathodic protection system, if one was installed.

All metal tanks will eventually corrode in the soil. As the many tanks installed in the 1950's and 1960's age, it is no wonder that the number of leaking tanks is expected to increase radically.

If not immediately detected, even a small leak can result in the loss of thousands of gallons of liquid, according to Brown. However, the loss of the liquid is not the only problem.

The leaking liquids often pollute the ground water or find their way into adjacent streams, sewers, or basements. They may cause contamination of our water resources, explosions, or fires. It often requires millions of dollars to clean up.

"My measurements indicate that some of the components of gasoline can move at the rate of 4 feet per hour in unsaturated soils," says Brown. "Our studies also indicate that concentrated organic solvents and petroleum products can cause clays to shrink

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Reprinted, with permission, from the January/February 1986 issue of Irrigation Journal. Mr. Robert L. Haney is a science writer for the Texas Agricultural Experiment Station.

and crack, thus allowing the chemicals to move through these soils 100 to 1,000 times faster than water moves."

Once the liquids reach the water table, they often float in an expanding puddle on the surface, while the vapors are released in the air-filled pores in the soil and may migrate in any direction.

Well water is polluted when the chemicals are drawn toward the well, while explosion hazard occurs when the fumes that accumulate in an enclosed area are ignited by pilot lights or electrical switches.

Underground spills are often first detected in wells used for drinking water, or when fumes accumulate in basements or sewers, rather than by inventory controls.

Brown warns, "The cost of cleanup of such spills can be staggering. Underground leaks often migrate hundreds and, in some cases, thousands of yards. The responsible party may need to install an alternate water-supply system for those affected."

To clean up a simple underground spill, the cost may run between $50,000 and $100,000. More complicated and extensive cleanup operations have been known to run well over $1 million, even when every effort is made to minimize the cost.

Brown says there has been some success with introducing nutrients and sources of oxygen into contaminated aquifers to stimulate microbial degradation of dissolved hydrocarbons, "and our research indicates that drawing air through unsaturated soils can rapidly clean up chemicals". Even with more economical procedures, however, cleanup is never cheap.

In recognition of this problem, the Environmental Protection Agency has initiated a program to regulate the millions of underground storage tanks.

The first phase of the program requires that the owners of all tanks having a capacity of 1,100 gallons or more must report their existence to the state Hazardous Waste Regulatory Agency by May of this year.

According to Public Law 98-616, enacted in November 1984, all tanks now in use and all tanks that were taken out of service after January 1, 1974 but are still in the ground must be reported.

Only on-farm tanks are exempted at this time. Regulations, which will likely require leak testing and some means of certification of financial responsibility, are to be issued in May 1987.

Brown notes, "It is important that all tank owners realize, however, that even if a tank is smaller than 1,100 gallons or located on a farm, and thus exempted from present regulations, this does not mean that your tank will not leak or that you are exempted from the responsibility for the damage that may result."

The technology of leak detection is improving rapidly, and it is likely that the regulations being developed will require improved inventory records and periodic tank testing, as well as monitoring systems in the soil to demonstrate that the tank is not leaking.

"Our research indicates that pan samplers, which intercept the flowing liquids, or ceramic cups to which a vacuum is applied through a vapor filter, may be required," says Brown.

Ground-water wells or vapor-detection systems may also be monitoring requirements, he notes; however, more work will be needed to develop appropriate leak-detection techniques.

"If you are faced with installing a new tank," he continues, "what can you do to minimize your future liabilities? One obvious solution is to put the tank above ground. Such tanks are rightly exempted from regulations, since leaks can often be seen before they become catastrophic."

All new underground tanks for petroleum products or hazardous substances will need to be constructed of non-corrosive materials, cathodically protected, steel-clad with a non-corrosive material, or designed to prevent release of stored substances, Brown points out.

"Violations of this stipulation are subject to civil penalties up to $10,000 per day. New codes and regulations will develop to further guide the future installation of tanks and plumbing systems," he predicts.

"While these programs will increase installation and management costs, the net result will minimize the probability of future cleanup and thus save money in the long run," Brown concludes.

* * * * *

USBR CANAL LINING EXPERIENCE

by

Jerome M. Schaack

The U.S. Bureau of Reclamation has been constructing irrigation water distribution systems since the early 1900's in the 17 Western United States. The advent of this construction soon necessitated a means for preventing excessive seepage from some canals or portions thereof. Numerous types of linings have been installed including concrete, asphalt, masonry, buried plastic membrane, exposed membrane, compacted earth, etc., with varying degrees of success. The three most commonly used at the present are concrete, buried plastic membrane, and compacted earth. Although not a type of lining, buried pipelines are also used extensively and among other advantages they reduce seepage losses very significantly.

The following discussion will describe the USBR's experience in the design, construction, operation, and maintenance of concrete, buried plastic membrane, and compacted earth canal linings. There are many factors which affect the selection of an optimum lining and there is no "one" type which will best suit all conditions. The policy of the Bureau is to install the type of lining which is determined to be best for the specific conditions encountered, based on a technical evaluation of all anticipated conditions.

There has been a gradual trend toward the installation of plastic membrane or heavy compacted earth (clay, bentonite, etc.) lining in recent years.

This trend is probably the result of viable alternative options to concrete lining; i.e., technological advances in plastic development, new techniques, new pipe types, etc. From an O&M viewpoint, experience has shown some significant advantages to certain types of lining as will be discussed below. This experience is based primarily on experiences in the 17 Western States and conditions in other areas may vary considerably from these and should be taken into consideration.

Following are some examples which illustrate the types of linings being designed and installed by the Bureau in recent years:

- Perhaps the largest concrete lining contract the Bureau has awarded has been the 190-mile long Granite Reef Aqueduct, which is the supply canal for the Central Arizona Project.

  Cracking has been experienced in this lining due to very high temperatures and the canal not being filled with water until several years after construction. Elastomeric joint sealants have also not been successful, presumably for the same reason.

Jerome M. Schaack is Chief, Special Projects Office, in the Division of Water and Land Technical Services, Bureau of Reclamation, E&R Center, Denver, Colorado, March 1986.

•About 27 miles of PVC lining have been used on canals and laterals for the Riverton (Wyoming) Rehabilitation and Betterment Project. Concrete lining was also used on this project, but with little success. (This is a freeze-thaw climate.) The PVC lining has been quite successful to date (Schaack 1986).

•Three contracts have been awarded to line 29 miles with buried membrane lining on the San Luis Valley (Colorado) and a remaining 11 miles will be similarly lined in 1986 (Starbuck and Morrison 1986).

•About 50 percent of the canals and laterals on the Garrison Diversion Project will be unlined; of the remainder, about 30 percent will be earth lined and 20 percent membrane lined.

•The rehabilitation and betterment work being done on Bureau projects consists of a diversity of lining types, including pipe. There is a definite trend toward the installation of pipelines where it is feasible to do so. As discussed later, pipelines have definite advantages despite their relative high initial cost. Buried membrane lining has also become more popular and is a viable alternative for other lining types in many cases (USBR 1984).

Following are some of the conditions we have experienced in the Bureau which will affect the type of lining installed. These dicusssions are general in nature and obviously there will be exceptions. Many of the conclusions drawn are subjective and based on experience rather than on statistically defensible data (which are often not available for specific facilities).

1. General–Concrete linings are inherently rigid in nature which requires that they have a well designed and constructed bedding to prevent differential movement. Any action that leads to differential movement over a length of 5 to 10 feet will cause cracking and seepage. If the cracked area is not repoured or the cracks sealed, eventual deterioration of the lining will usually occur in the affected reaches of the canal.

Leaks through cracks in concrete lining are usually limited to a rather small cross-sectional area which intensifies the seepage, sometimes causing piping and settling which in turn leads to further lining damage usually requiring replacement. This is particularly true for fill areas. These cracks present significant maintenance problems. Sealants used have a short, useful life (5-10 years) and are labor intensive to maintain. We have also found upon investigation that concrete linings often have numerous voids which if not filled will create bigger problems. This is also an expensive maintenance item (USBR 1985).

Buried membrane linings, by nature, are flexible and will allow reasonable movement of the earth embankment without rupture, particularly the 20-mil membrane which we are now specifying. This flexibility provides assurance in many cases that the lining will maintain its integrity over a wider range of unfavorable conditions (USBR 1984 and 1985). It is important that buried membrane linings have a suitable protective soil and gravel cover (USBR 1981). One of the disadvantages of membrane lining as opposed to concrete lining is that care must be taken when cleaning these canals or the lining may be damaged. The same is true for earth lining.

Membrane and earth linings are also susceptible to damage from large animals in the canal. If enough cover is available in membrane-lined canals, this damage may be minimal. It is not a good practice to allow large animals in canals, but this is not always feasible. One alternative is to establish areas in the canals where animals can access and drink from canals. The animals are restricted to entering the canal only in these areas.

Burrowing animals are a problem in many areas and they should be controlled. They can cause failure in all lined and unlined canals, although concrete is the least susceptible.

Although pipelines usually have a higher first cost, the O&M costs for these facilities are very low over a relatively long period of time. We have found underground pipelines to be economically feasible for some smaller flows and/or when favorable slopes are existent. Many of our recent rehabilitation projects have included conversions from open channels to underground pipelines because of the advantages of these facilities such as reduced O&M and right-of-way costs, safety, and other operational problems.

Concrete lining is quite susceptible to damage if it is overtopped for a period of time, thus allowing an accumulation of water behind the lining. This may result in sufficient pressure on the lining to cause damage and/or failure. Overtopping may also occur when meeting high peak demands, when a channel is underdesigned, or when sedimentation is allowed to accumulate in the channel.

Very high temperatures can have an adverse effect on concrete lining unless water is kept in the channel to alleviate this problem. In continuous operation, this may not be a problem (except above water line), but can be for seasonal operation.

Weed control may be less costly in concrete-lined canals if other maintenance is carried out properly; i.e., sediment is removed periodically. Aquatic weeds will, however, proliferate in any lining environment. Chemical control of weeds is usually the most economical and this practice is used extensively in the U.S. When this is not feasible, mechanical or other means of control must be used (Hansen, Oliver, and Otto 1983).

2. Freeze-Thaw Conditions–Significant concrete lining deterioration has been experienced under freeze-thaw conditions. Problems are caused both from the freeze-thaw cycle as well as frost heaving. Once these actions start, they usually get progressively worse over a relatively short period of time. Under freeze-thaw conditions, strong consideration should be given to using other types of lining, if feasible.

Membrane and earth lining and pipelines are obviously not as susceptible to damage from freeze-thaw as concrete because of their flexibility and protective underground environment.

3. High Water Tables.–High water tables have a very detrimental effect on concrete lining. Rapid lowering of the water level in a concrete-lined canal with water behind the panels will frequently result in collapse or floating of the lining and a drainage system is sometimes required to protect the lining. Repairs of this type are very expensive, as they usually require reshaping of the canal prism and replacing the lining. Some success has been experienced with concrete lining by elevating the canal above ground level, thus eliminating the ground-water problem. This may, however, increase compaction requirements and potential for settling. Other types of lining (earth, membrane, etc.) may also show detrimental effects from high water tables, but usually not nearly to the degree of concrete. Heavy compacted earth lining is the most resistant to damage from back pressure behind the lining.

4. High Temperature.–Deterioration of concrete lining which has high exposure to direct sunshine has been observed. This is more prevalent on the north bank (south exposure) of concrete-lined canals above the water line.

5. Safety.–Because of their slippery nature when wet, concrete-lined canals present a hazardous condition for people and animals. Assistance is usually needed to exit a sizeable concrete-lined canal which is flowing water. This situation is extremely hazardous in urban areas where people exposure is high and presents a potential liability to the owner and/or operator. Other types of lining (earth, buried membrane, etc.), while still dangerous, will often allow escape by animals and/or people. A reinforced, concrete-lined canal can, however, provide structural strength to prevent a rapid canal breach, which is very desirable particularly if located above populated areas (Latham and Verzuh 1971).

6. Costs.

Contruction.–Capital costs for concrete, membrane, and earth linings are in the same general range in the U.S., with concrete tending to be slightly lower than the other two. Costs, of course, depend a great deal on local conditions and prices and particularly on availability of materials. Concrete lining requires a smaller cross-sectional channel area, which reduces excavation and soil-moving costs. Right-of-way costs will also be slightly lower for concrete-lined canals because of the smaller cross-sectional prism area.

O&M Costs.–Figure 1 illustrates annual costs for concrete, unlined and earth lined canals, and pipelines. We believe O&M costs for buried membrane-lined canals are similar to or possibly lower than unlined and earth-lined canals. For practical purposes, similar costs can be used. These data are somewhat subjective, particularly at lower flows, since records are not typically kept on specific canals and laterals. Although these curves are based on limited data; they generally illustrate what we believe to be typical costs for these linings particularly on a relative basis. The higher set of curves (less than ideal condition) typify the problems and costs encountered when conditions are detrimental to certain lining types; i.e., freeze-thaw conditions in concrete-lined canals. Under less than ideal conditions, problems and costs are usually more pronounced with concrete-lined canals than other types.

The most consistent aspect of these O&M costs is that pipeline O&M costs are significantly and consistently less than concrete, compacted earth, and buried membrane lining. A significant part of this cost is a minimal or no cleaning requirement and aquatic weed problems. The environmental advantages are also significant with pipelines; i.e., minimal chemical control, esthetics, health, etc. Pipelines also provide a safety advantage and a more desirable field layout, especially with sprinkler irrigation.

7. Life Expectancy.–Generally, Bureau canal linings and pipelines are designed to have a life of 50 years. Most factors indicate, however, that buried plastic membrane lining, if installed and operated and maintained properly, may have a longer useful life than 50 years. Since plastic has not been in use for this time, obviously experience or evidence is not available to verify this. Life expectancy is based on the assumptions of proper design, construction, and O&M.

Summary–There is no one best lining to meet all conditions. However, recent developments and technology advancements in plastics have made this method more viable and competitive than it has been in the past. Earth lining is very competitive if proper soil is available in the area of construction. As pointed out in our discussion above, concrete is still a viable lining; however, our experience has shown that due to its inherent characteristics, significant O&M problems can and do arise with its use, especially under certain conditions.

When the need for lining is identified either in initial construction or in rehabilitating or modernizing a system, all lining types, including pipe, should be evaluated, as suiting the type lining to the conditions onsite is especially critical in dealing with this matter.

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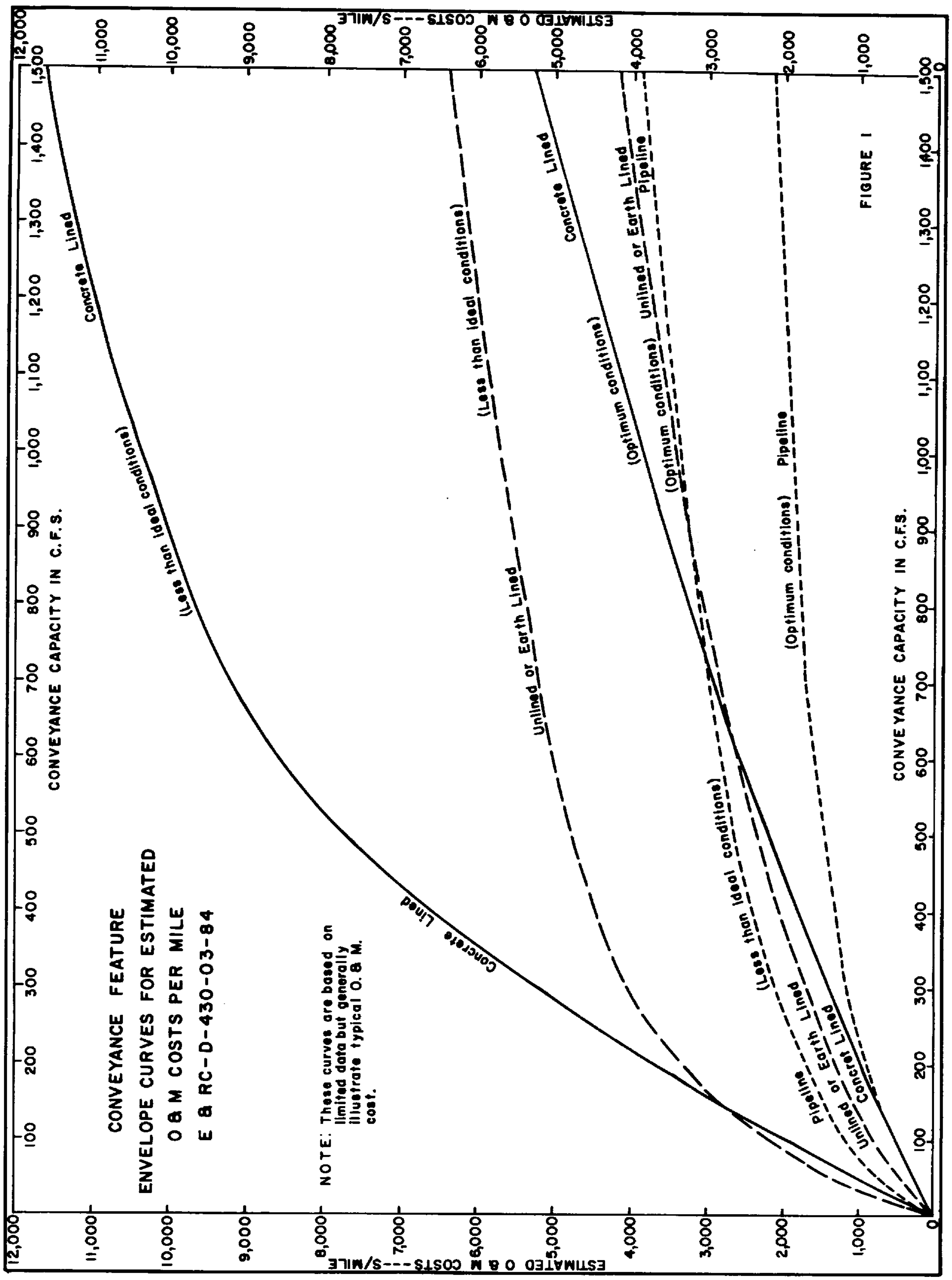
CONVEYANCE FEATURE
ENVELOPE CURVES FOR ESTIMATED
O & M COSTS PER MILE
E & RC-D-430-03-84
NOTE: These curves are based on limited data but generally illustrate typical O. & M. cost.
CONVEYANCE CAPACITY IN C.F.S.
ESTIMATED O & M COSTS---$/MILE
Concrete Lined
(Less than ideal conditions)
Unlined or Earth Lined
(Optimum conditions)
Pipeline
FIGURE I
0
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
1,300
1,400
1,500
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
12,000

FIGURE 1

A PROGRAMMED APPROACH TO CHEMICAL WEED CONTROL

As manager of the Canal Division of the Brazos River Authority in Texas, Gene Shannon has the primary responsibility for overseeing the development and maintenance of 130 miles of canals that provide water for rice farms and industry. He's been doing it for years.

Times have changed, however, and so has the nature of Shannon's job. Because of rapid residential growth along the canals, he finds himself spending an increasing amount of time educating the public about the purpose of the authority's canal system–and answering residents' complaints.

"There is now a lot of public concern about weed growth along the canals," says Shannon. "This was not the case in the early years, before urban development spread into the areas where the canals are located. They were out in the middle of nowhere, and no matter how many weeds and bushes grew up, no one said anything.

"Now there are many houses right on the banks of the canals. Residents are quick to pick up the phone and complain about that nasty canal system behind their house. They ask what I'm going to do about the weeds, rats and snakes which thrive naturally in that environment."

However, Shannon says the decision to clean up the canal banks was based on the requirements of canal operations and the need for efficiency. Naturally, he was also glad to please the public.

Cleanup involved getting rid of any vegetation that interrupts the flow of water for farming and industry or potable water for municipalities. It also means regularly controlling vegetation on canal banks to clear the way for repair equipment, instead of spending an inordinate amount of man hours uprooting trees, for example, to reach a trouble spot.

"The public in general is now aware of the operational and economic benefits of our vegetation management program," Shannon points out. "They view our efforts as a beautification program, and assume we're cleaning up the canal banks because it looks good."

Shannon admits that maintaining canals in three counties is a formidable task that commands all the manpower and resources his division can muster. Preventing dumping and eliminating troublesome vegetation are time-consuming tasks–as is the control of water rodents known as nutria, which are much in demand for fur coats but cause nothing but trouble in the canals.

One of the thorniest problems, in fact, has been getting rid of the nutria. Shannon explains that the beaver-like rodent with webbed feet was willingly imported to the Southwest

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in the late 1950's to consume the vegetation that was then clogging waterways. However, the prolific creature spread westward to Texas and did more than eat vegetation. It bored through canal banks, causing erosion and washing out the canals.

"It was then that we established a systematic program to eliminate canal vegetation," Shannon said. "In addition to solving the other problems caused by extensive weed growth, we knew that the nutria wouldn't last long without vegetation to feed on and tree roots to den up in."

The canal division initially relied on hand labor for weed elimination. For example, Shannon's crews subdued infestations of water lettuce, which clogs intake areas at pumping stations, by manually scooping up the weeds with fine-meshed nets. However, manual labor proved too expensive and time-consuming, so the division began using a backhoe for mechanical vegetation control.

Customized with screen-type buckets, the backhoe was temporarily effective in removing alligatorweed, considered "an extreme problem" by Shannon. However, it did not prevent alligatorweed return and regrowth.

To achieve more permanent weed control, Shannon integrated chemicals into his vegetation management program. After researching a large number of herbicides, he decided to ammate. He soon discovered, however, that while ammate burned back persistent weeds such as Chinese tallow, it did not prevent rapid regrowth. He found himself with the same problem as before: short-lived weed control.

He then tried Krenite and obtained excellent control on the Chinese tallow. As part of a comprehensive chemical program, Shannon also relies heavily on Rodeo herbicide. Foliar-applied and non-residual, Rodeo translocated down to the roots of a plant, providing both above- and below-surface control without regrowth.

Today Shannon says, "While mechanical weed control is still an important part of my vegetation management program, chemicals like Rodeo provide long-term control and save time and labor."

He first used Rodeo in 1983, when he sprayed 51 miles of canal bank with a 2 percent solution of the herbicide, using a specially designed sprayer that allowed workers to target their applications at specific areas from platforms extending over the water. The authority manager found the results so satisfactory that he has expanded spraying operations over the past 2 years.

"I intend to continue using Rodeo and Krenite," says Shannon, "although I probably won't need as much, because the chemicals have effectively controlled the weeds and prevented extensive regrowth. However, because weeds grow at such an amazing rate in our hot, humid climate, it's nice to know we can rely on these effective chemicals for complete vegetation control."

* * * * *

SCREEN DESIGN INCREASES FLOW, REDUCES COST OF IRRIGATION PUMPING

Well efficiency is a subject that is being talked about but one few people fully understand.

There is a certain "mystique" about water moving through the earth, yet there's nothing mystical about it.

Water moves in the path of least resistance and always downhill, and it moves in sand and gravel, and in crevised areas of rock or limestone. When water is encountered in sand and gravel, a screening device of some sort is needed to support the formation and allow some flow of water into the casing to be pumped to the surface.

This screen device is the most important portion of a well and serves two purposes:

- It should permit unobstructed entry of water into the well.
- And, it should allow direct access to the wall of the formation for back-washing to develop out silt samage or mud damage caused by the drilling operation.

To serve these purposes, the screen should have the largest possible open area consistent with strength requirements, the openings should be uniformly arranged so that water flowing through the horizontal lenses of the formation can enter the screen directly, and the entire formation can be reached during development.

Traditionally, casing that was torch cut, mill slotted, bridge slot (punched), louver slot (punched) has been used because of initial low costs. However, these do not fulfill the criteria of a good screening device.

If the screen has limited open area as in slotted pipe (2 to 5 percent), there is a tremendous head loss with water trying to move into the screen. The action from any development method is also reduced because 95 to 98 percent of the screen is blank pipe. Therefore, most of the aquifer remains untouched by the development process.

Bridge slot or louver screens have more open area than slotted pipe. However, the slot configuration diverts the flow of incoming water (causing greater losses through the screen) and again restricts the development of the formation because it doesn't allow direct access to the wall of the formation for development.

Continuous slot, V-shaped wire screens permit water to enter the well along the entire screen and allow maximum access to the water bearing formation so that proper development can take place. Low head losses through the screen and proper development guarantee the owner that the maximum amount of water can flow as freely as possible into the well. That allows less drawdown in the well to reduce your pumping cost at any given rate and the capability to pump more water.

This article is reprinted, with permission from the editor, from the November 1985 issue of Irrigation Age.

Several farmers have already seen the advantages to having a more efficient well. Paul and Janet Heinrich, Paxton, Nebraska, have struggled with present irrigation costs of approximately $80 per acre.

"I wanted to irrigate another field with a new well but I couldn't afford to operate at that same cost. I talked with the driller and told him if I couldn't cut my irrigation costs I couldn't afford to drill the new well," he said.

The driller suggested the use of a Johnson screen and design a proper well to assure maximum flow of water into the well. The new well was designed, drilled, and put into service by Haggard Drilling Inc. in Ogallala, Nebraska.

It was test pumped at over 1,540 gpm with a pumping level of 259 feet (86 feet of drawdown) and that's less drawdown than in the old well pumping 800 gpm.

The new well is now in service at 800 gpm and pumping from 217 feet (42 feet of drawdown).

Heinrich estimates his irrigation costs at approximately $35 per acre, which doesn't include the difference in the purchase price of the pumps.

Looking at just the difference in drawdown in the well, Heinrich is saving $1,370 per 1,000 hours of pumping, using $.85 per gallon diesel fuel costs and assuming both units were operating with a 65 PSI irrigation system.

His real operating savings amount to over $2,700 per 1,000 hours of pumping because he went to a low pressure (30 psi) system. His savings didn't stop there.

"My present well has a 125 HP unit with 330 feet of pump column and an 8 stage 12-inch bowl assembly," Heinrich said. "My new well operates with a 90 HP unit with 260 feet of pump column and a 6 stage 12-inch bowl assembly (list price is approximately $16,000). That's quite a saving."

* * * * *

DIGEST STATEMENT

Dam: BIG SANDY
State: Wyoming
Type: Zoned earthfill
Completed: 1952
Hydraulic height: 69 feet
Active capacity: 38,300 acre-feet

Project: Eden Project
Function(s): Irrigation, recreation
Crest length: 2,350 feet
Surface area: 2,510 acres

SPILLWAY DETERIORATION

Design characteristics: The spillway, located on the right abutment of Big Sandy Dam, is a free overflow uncontrolled structure, having a crest elevation of 6757.5 feet and a designed discharge of 7,350 ft^3/s at maximum water surface elevation. The structure consists of a side channel ogee weir with a crest length of 170 feet and a bottom width of 15 feet. The bottom width then varies from 13 feet to 50 feet within the stilling basin which has an elevation of 6679 feet.

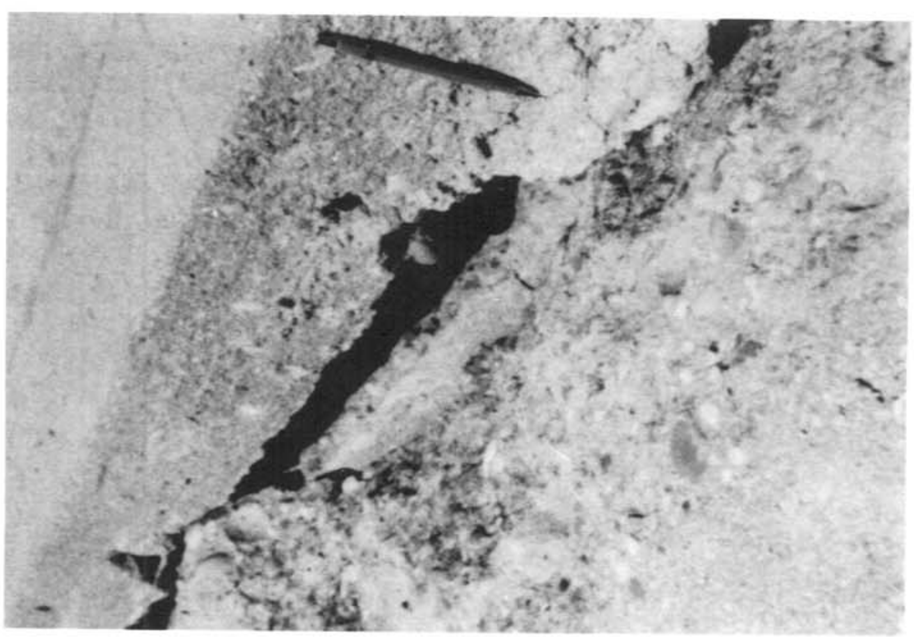
Evidence: Serious cracking was evident in the lower portions of the right side panels of the inclined chute and stilling basin. Another area of distress was located at the spillway intake along the left side. This consisted of slab movement and associated heavy spalling at the toe of the crest structure along the horizontal contraction joint. Additionally, in 1983, the first full floor slab above the water level in the basin failed and had raised as much as 8 inches near the left wall. A large longitudinal crack occurred along the centerline of the slab between the adjacent contraction joints.

Incident: Significant cracking and floor slab failure within the spillway structure made the spillway unsafe to operate.

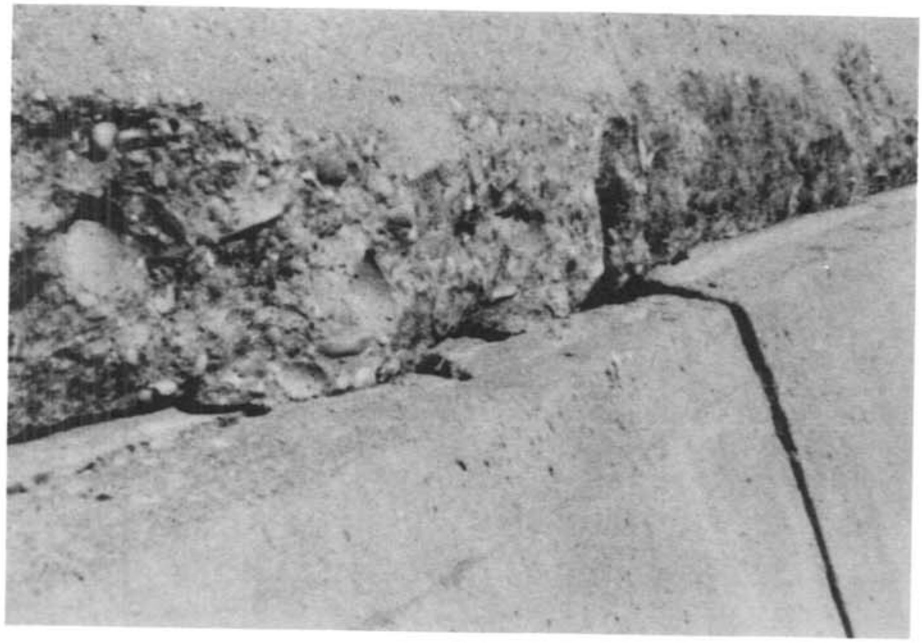
Causes: Environmental elements to which the structure is subjected, excessive seepage and insufficient drainage adjacent and beneath the structure, and underdesigned portions of the structure in distressed areas of frost action (expansion and heaving).

Remedy: Restrict reservoir elevation, construct a temporary cofferdam, and rehabilitate spillway structure. In 1985, construction efforts were completed which included grouting into the right abutment and a portion of the foundation under the spillway chute, replacing damaged concrete side linings and a floor slab, constructing a new chute and stilling basin, and installing new drains under various portions of the structure.

Big Sandy Dam–Cracks in stilling basin right wall. 10/8/80



Big Sandy Dam–Differential movement in spillway wall. 10/8/80



Big Sandy Dam–Spalled concrete and differential movement of spillway wall. 10/8/80

BUREAU OF RECLAMATION

WATER SYSTEMS OPERATION AND MAINTENANCE COST INDEX

1977* = 1.00

YEAR	INDEX
1979	1.125
1980	1.282
1981	1.444
1982	1.532
1983	1.640
1984	1.651
1985	1.812

* 1976-78 Bureau-wide average ($13.32 per irrigated acre)

This O&M Cost Index has been developed to measure the trends in O&M costs on Reclamation projects over a period of years.

The three basic uses of the O&M Cost Index are:

1. to adjust to a common year price level the annual O&M costs reported during a given year;

2. to adjust to the current price level values obtained from O&M cost estimating guides;

3. to adjust to the current price level an O&M cost estimate based on some past level.

The method for calculating this O&M Cost Index has been revised since the last index was published. Previously, the index was developed from O&M costs per irrigated acre on a number of selected projects which did not exceed set variances for acres and costs during a 3-year period. Under the new system, all Reclamation projects receiving full or supplemental water service for which operation, maintenance, and replacement costs and irrigated acres are reported in the annual Crop Production and Water Utilization Report are used to compute the index. Both Bureau and water user costs are included. Also, the base year has been changed from 1956 to "1977" (1976-78 average cost per acre).

GPO 851-899