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Cover photograph:

Calamus Dam and Reservoir, North Loup Division, Pick-Sloan Missouri Basin Program, is the spotlight of this issue.

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BURIED IRRIGATION PIPE
AT CARRINGTON IRRIGATION STATION
Carrington, North Dakota[1]

Introduction

Pipe materials and pipeline designs for irrigation water distribution systems vary depending upon application. Pipes used for open ditch replacement usually have only low head requirements, but pipe used for sprinkler systems are designed to withstand relatively high heads. Structurally, all buried pipe must be capable of withstanding external load forces imposed by the soil envelope as well as internal pressure from the contained water. Material from which the pipe is made must be resistant to corrosive effects of the soil and/or the soil solution with which it comes in contact.

Cold temperatures during the winter months in the north central states require the placement of waterlines 6 to 7 feet below the surface to protect them from winter freezeup. An alternative for waterlines used only during the warm temperature season is shallow burial within the frost zone but laid to grade to allow drainage of water before freezeup. Cost differences between 7- and 3-foot burial suggest that only shallow placement is economically feasible for irrigation pipes in North Dakota. Placement at this depth in milder climates has been commonplace for many years, but there was little evidence of similar application in the northern states where the pipeline would normally be frozen into the soil profile for several months of the year. The desire to gain experience with this kind of installation prompted the initiation of the buried pipeline studies on the Carrington Irrigation Station in North Dakota.

Conclusions

Approximately 15,000 feet of concrete, asbestos-cement, and polyvinyl chloride (PVC) irrigation pipe have been buried within the frost zone with 30 to 36 inches of cover on the Carrington Irrigation Station at Carrington, North Dakota. All pipelines have been laid to grade to permit drainage of water before freezeup. The pipeline distribution system has been in use for periods ranging from 16 to 20 years.

Vertical control was established and monitored periodically to identify any changes in elevation that may result from freezing and thawing of the soil profile. Changes in elevation were very small, usually less than 0.05 foot for the last 10 years of the study.

Head loss measurements were made in several sections of pipe, first in 1969 shortly after installation and then in 1974 and 1984, to identify any changes that may have taken place to alter the discharge capacity of the pipelines. All changes were minimal with the exception of the concrete pipeline.

All installations have performed satisfactorily. Little or no maintenance has been required except for occasional repairs to hydrant covers due to damage caused by farm implements.

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[1] Prepared under contract by North Dakota State University, November 1987, for the Open and Closed Conduit System (OCCS) Committee, Bureau of Reclamation, Denver, Colorado.

Application

Pipe buried within the frost zone is feasible in the north central states for irrigation water distribution. Pipe must be placed to grade to allow for drainage before winter freezeup.

Testing

Testing of the various types of buried pipeline covered four areas: (1) deflections for differing installation techniques and surface loading, (2) vertical control for monitoring frost heave, (3) frost heave and pipe strain over a simulated high water table, and (4) pipeline friction versus time. The various types of pipe used in the study are shown in table 1.

Table 1. - Pipe materials used

Materials	Feet	Diameter (inches)	Rating (lb/in^2)	Year installed	Coupler
Nonreinforced concrete	1,775	12	11	1964	roll gasket in bell
Asbestos-cement class 5	4,200	12, 10, 8	22	1966	gasket in sleeve
PVC plastic	1,000	12, 10	22	1968	solvent weld
PVC Plastic	3,000	8	100	1970	gasket bell
PVC Plastic	600	6	80	1968	solvent weld
PVC Plastic	600	6	125	1968	gasket bell
PVC Plastic	360	8	100	1968	solvent weld
PVC Plastic	300	6	160	1969	solvent weld*
PVC Plastic	300	6	160	1969	gasket bell*
Vinyl-clad aluminum	600	6	125	1969	buckle joint*
Vinyl-clad aluminum	600	8	125	1969	buckle joint*

* Abandoned with redesign of sprinkler irrigation system.

Low Head Pipe Deflection

The use of flexible "low-head" PVC for irrigation pipe is comparatively recent. It is a relatively inexpensive material designed to withstand operating pressures of not more than 22 lb/in^2. It is light in weight and easy to install; hence, its potential for irrigation application is apparent. However, it has a thin wall which offers minimal resistance to external forces that may be imposed by backfilling soil over the pipe and/or mobile farm equipment passing over the buried pipe. Resistance to vertical loading is supported by the outward movement of the sidewalls. Thus, the method of backfilling and degree of compaction achieved have a marked influence on the ability of a pipe section to hold its circular configuration and resist collapse. The latter is essential if it is to have general application in the field.

To make some determination on the type of installation required for use of this material, trenches 19 inches wide and 36 and 48 inches deep were prepared for installation of 20-foot-long sections of low-head 12-inch-diameter PVC. A series of seven tests were conducted as shown in table 2. Results of these tests relate the pipe deflection to the method of backfilling and amount of loading imposed on the pipe. The surface load was imposed from the rear duals of a farm-size truck loaded with 250 bushels of wheat.

Table 2. – Effect of backfill method on vertical deflection of 12-inch low-head PVC pipe

Test No.		Percent deflection by load* Soil	Vehicle	Total percent deflection
	48-inch depth test trench No. 1			
1	First 6-inch backfill hand placed, remainder dumped**	2.5	10.1	12.6
2	Backfill dumped then ponded with water	14.2	2.0	16.2
3	Same as No. 2 except pipe filled with water at 3-foot head then backfilled	15.1	1.0	16.1
4	U.S. Soil Conservation Service recommended procedures	5.3	4.6	9.9
	36-inch depth test trench No. 2			
5	Backfill completely dumped	3.8	11.4	15.2
6	Soil compacted to 1/2 diameter of pipe, backfill dumped	-3.7***	5.0	1.3
7	Two-inch cradle formed in trench, backfill dumped	3.2	10.5	13.7

* Deflection expressed as percentage of original pipe diameter.
** Fill crowded into trench with front-end loader.
*** Minus sign indicates elongation of vertical diameter as a result of soil compaction on sides.

Further deflection tests on low-head PVC were initiated on 12- and 10-inch pipe used in the field as service distribution lines for irrigation. Different backfill methods were imposed on sections when the pipe was installed. Replicated references were established for measuring top and bottom elevations. First readings were made in 1969 after allowing the backfill to consolidate for 1 full year. Elevation readings have continued since then. In table 3, the 1969 and 1974 readings are summarized.

Frost Heave Effects

Effects of frost action on pipe were measured using vertical reference points established on several pipelines in use on the station. Elevation measurements have been made periodically at these reference points since pipe placement. It has been presumed that changes in elevations after the initial settlement may be due to frost action. An abbreviated summary of these data is given in table 4. It suggests little, if any, frost action has occurred to cause vertical displacement of the pipe. Elevation readings taken before, during, and after winter freezeup have been essentially the same.

Table 3. - Vertical deflection of buried 12- and 10-inch low-head PVC pipe

Site	Backfill	Pipe vertical diameter (inches) 1969	Pipe vertical diameter (inches) 1974	Percent deflection* 1969	Percent deflection* 1974
	12-inch diameter				
A	Machine backfill, 48 in. fill 20 in. wide	9.28	8.68	22.7	27.7
B	Hand compacted, 36 in. fill by 20 in. wide to 1/2 diameter of pipe	11.94	11.24	0.5	6.3
C	Water packed, 36 in. fill by 20 in. wide, trench filled and puddled	10.53	10.04	12.2	16.3
	10-inch diameter				
D	Machine backfilled, 36 in. fill, 24 in. trench	8.79	7.88	12.1	21.2
E	Machine backfilled, 36 in. fill, 14 in. trench	8.88	7.88	11.2	21.2
F	Water packed, 36 in. fill, 14 in. trench	8.83	7.88	11.7	21.2
G	Water packed, 36 in. fill, 24 in. trench	8.82	8.12	11.8	18.8

* Deflection expressed as percentage of original pipe diameter.

Table 4. - Mean elevations recorded at intervals for vertical control points on pipelines placed within the frost zone at Carrington Irrigation Station

Kind of pipe	Number of control points	Mean elevation in feet by year 1969	1974	1984
12-inch PVC low-head pipe	6	95.09	95.11	95.07
10-inch PVC low-head pipe	2	95.25	95.27	95.22
12-inch concrete low-head pipe	20	92.06	91.92	91.91

An artificial water table was created using a trench 6 feet wide, 8 feet deep, and 70 feet long, excavated directly under the project centerline of a 10-inch PVC low-head pipe to be installed later. The trench was lined with 6-mil polyvinyl sheeting, backfilled with an 8-inch layer of coarse sand on the bottom, then filled with the excavated material. Backfill was compacted to the original density. A drainpipe was installed between the sand layer and the surface to permit charging of the water table. After backfilling, a wheel trencher was used to cut a 14-inch-wide trench 42 inches deep for placement of the 10-inch low-head PVC pipe. Vertical control points were established on the line, and 1 year later, strain gauges were attached in replicate to the pipe at several locations. The purpose of the strain gauges was to measure internal stress that may be occurring in the pipe as a result of temperature changes and/or realignment of the pipe due to frost heave.

Difficulties were encountered in maintaining an artificial water table after the first year. Apparently, as backfill settled, the polyvinyl membrane was ruptured which allowed water to slowly escape. Conditions did not permit recharging during the months of freezing temperature; hence, it was not possible to maintain the original test conditions. Nevertheless, an above-normal soil-moisture condition was created for at least two seasons during which some data were collected.

Change in vertical elevation of the buried pipe within the artificial water table was little different from that measured in sections of the adjacent 10-inch pipe outside the water table area. Elevation data show that the net change in pipe elevations during the 4-year period from 1970 to 1974 was only 0.07 foot over the water table and 0.04 foot in the adjacent section. These changes are insignificant. Though the data are not shown, there was also very little change in elevation between the frozen and unfrozen periods of each year.

Strain gauge readings taken at intervals over a 2-year period did identify changes in stress in the pipe material, but they were relatively small. The maximum recorded was approximately 1,400 lb/in^2 which occurred one December about the time the soil around the pipe froze. This stress is about 14 percent of the yield point for the pipe material and, therefore, well within the elastic limits.

Hydraulic Characteristics

In an attempt to measure the total effect of all changes in a pipe system that may occur with use and time, head loss measurements were initiated on the newly installed buried pipe at Carrington in 1969. In 1974 and 1984, measurements were repeated on the same sections of pipe to identify any changes that may have taken place in the 5- and 10-year intervals.

Before taking head loss measurements, two procedures were used to help reduce erroneous readings. The first procedure involved checking the flow rates by the use of a Hall Flowmeter. The second involved releasing air trapped in the pipe. It consisted of opening hydrant covers along the pipeline and gradually filling, allowing trapped air to flow out. After a period of time, the hydrant covers were closed and the test performed. A simple procedure was used to measure head loss. Piezometric taps were installed at intervals in the pipeline to measure total head loss at a given point. The measured head losses between successive points along a pipeline were averaged on the basis of loss per unit of length. The Hazen-Williams equation was then used to calculate the coefficient of roughness. These were calculated over a range of flow rates and then averaged to obtain a mean value. These values are summarized in table 5 for low-head PVC plastic, asbestos-cement, and nonreinforced concrete pipe as measured in 1969, 1974, and 1984.

Discussion

The deflection data suggest that the least pipe deflection occurs when the initial backfill is hand placed and tamped to a depth of one-half of the pipe diameter, or if a shallow cradle of compacted soil is formed to support the pipe. The U.S. Soil Conservation Service recommendation of backfilling 6 inches over the pipe and puddling with water is also effective. Greatest deflection occurred when the entire trench was backfilled and then puddled with water.

Table 5. – Summary of the Hazen-Williams coefficients calculated from head loss measurements made on various irrigation pipelines at the Carrington Irrigation Station in 1969, 1974, and 1984

Pipe material	Diameter (inches)	Roughness coefficient*		
		1969	1974	1984
PVC plastic low head	12	122	123	120
Asbestos-cement Class 5	10	139	139	137
Asbestos-Cement Class 5	12	132	138	141
Nonreinforced concrete	12	127	138	87

* Roughness coefficient (C) as calculated from the Hazen-Williams equation is expressed as follows:

$$Q = 1.32\, C \times R(0.63) \times S(0.54) \times A = \text{flow rate in ft}^3/\text{s}$$

R, hydraulic radius = D/4 for round pipe
S, slope of energy line (head loss/length)
A, cross-sectional area of pipe
C, roughness coefficient

Deflection resulting from truck loading over the pipe was greatest when backfill was dumped and uncompacted over the pipe. The deflection expressed as a percentage of the original vertical dimension was an additional 10 to 11 percent to that resulting from backfill placement. The sum of deflection due to soil loading and imposed load was well within the proposed 20 percent maximum allowable which has been suggested as a potential failure limit for light gauge steel [1][2]. Those working with plastic draintile found failure to occur at 40 percent deflection [2].

Trench depth (36 inches versus 48 inches) appears to have had little influence on the percent deflection resulting from either the backfill or the imposed load. Though hand compaction of backfill on either side of the pipe up to one-half of the pipe diameter may assure the most stable configuration of the pipe section, it is not likely to be practiced in the field due to the labor required. An alternative that appears equally effective as the hand backfilling is test No. 7 which employs a 2-inch cradle. This can be accomplished by either a wheel or chain trencher and does suggest an advantage in using one of these machines for excavation. Filling the pipe with water under 3 feet of head during backfilling did not reduce the amount of deflection.

For the pipelines in which changes in elevation were monitored, frost heave has been minimal and presents no engineering problems in the moderately well-drained loam soils on the Carrington Station. However, this should not suggest that problems will not be encountered in some irrigable soils which may have relatively high water tables during the cold temperature months.

[2] Numbers in brackets refer to references at end of paper.

There was little change over the 15-year term in the HazenWilliams roughness coefficient (C) in three of the four tests. The greatest change occurred in the concrete pipe. It decreased from 127 to 87 to suggest the inside surface of the pipe has become rougher. Another observation from table 5 shows that the (C) value for PVC is lower than the (C) value for asbestos-cement which is contrary to published literature. This suggests other conditions exist such as shape of the cross-sectional area, alignment, coupling, etc., to effect the coefficient of roughness (C).

Head loss versus flow rate curves were prepared for each pipe material tested for the years 1969, 1974, and 1984 and are shown in figures 1 through 4. In figure 1, the head loss versus flow rate curve is much higher in 1984 than in 1974 and 1969. This suggests that some change has occurred to produce a rougher surface inside the concrete pipe. It is speculated that over the years of use, the water may have had a corrosive or erosive effect on the inside wall of the concrete pipe to produce a rougher surface.

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1. Sangler, M. G. "Soil Engineering" Second Edition, Scranton International Textbook Company, 1969.

2. Meyers, V. J., R. J. Rektorik, and C. A. Wolfe, Jr., "Deflection Tests and Trench Conditions for Plastic Drain Pipe" Transactions of ASAE, 1967.

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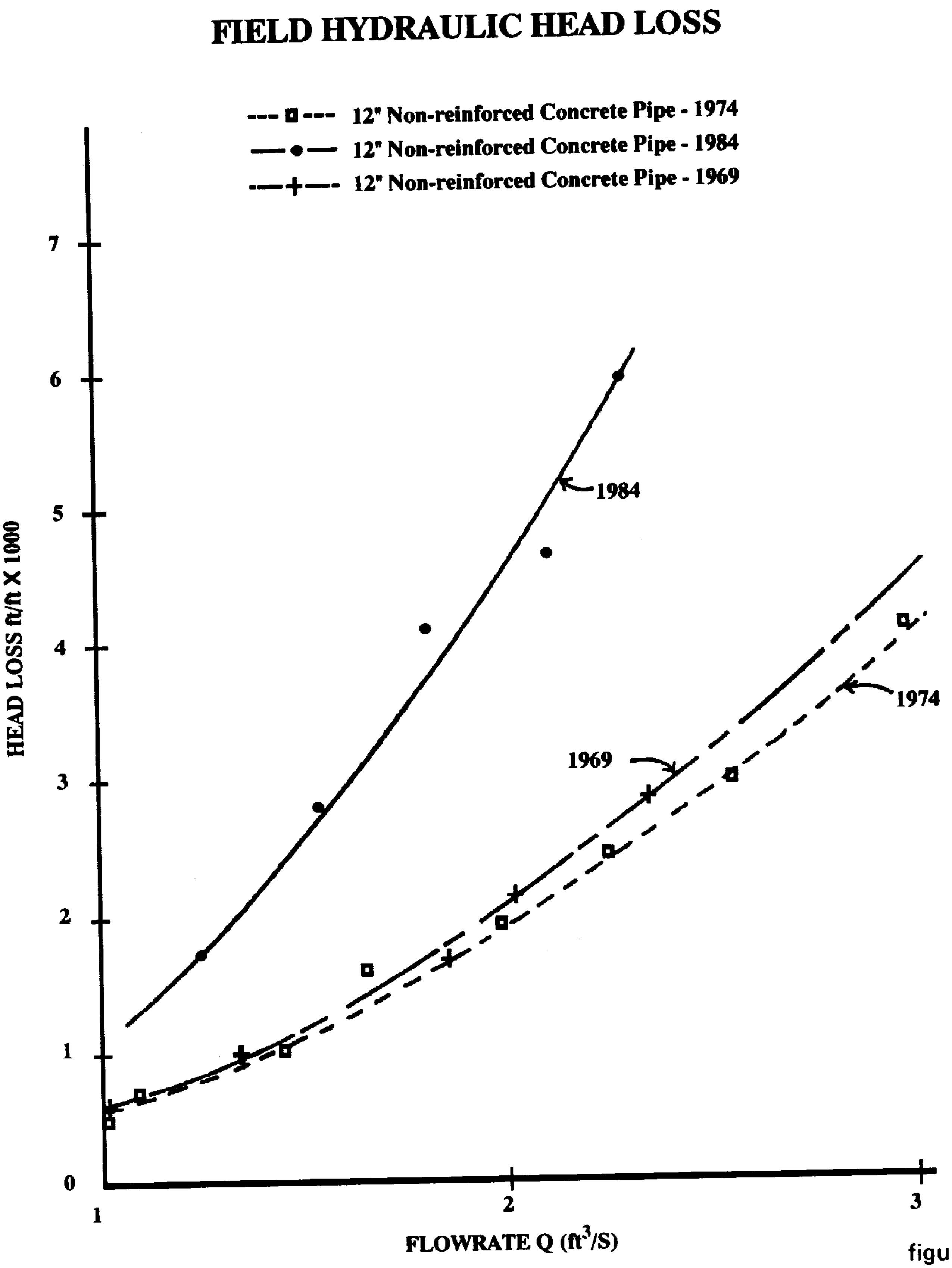
FIELD HYDRAULIC HEAD LOSS
12" Non-reinforced Concrete Pipe - 1974
12" Non-reinforced Concrete Pipe - 1984
12" Non-reinforced Concrete Pipe - 1969
1984
1974
1969
HEAD LOSS ft/ft X 1000
0
1
2
3
4
5
6
7
1
2
3
FLOWRATE Q (ft³/S)

figure 1

FIELD HYDRAULIC HEAD LOSS

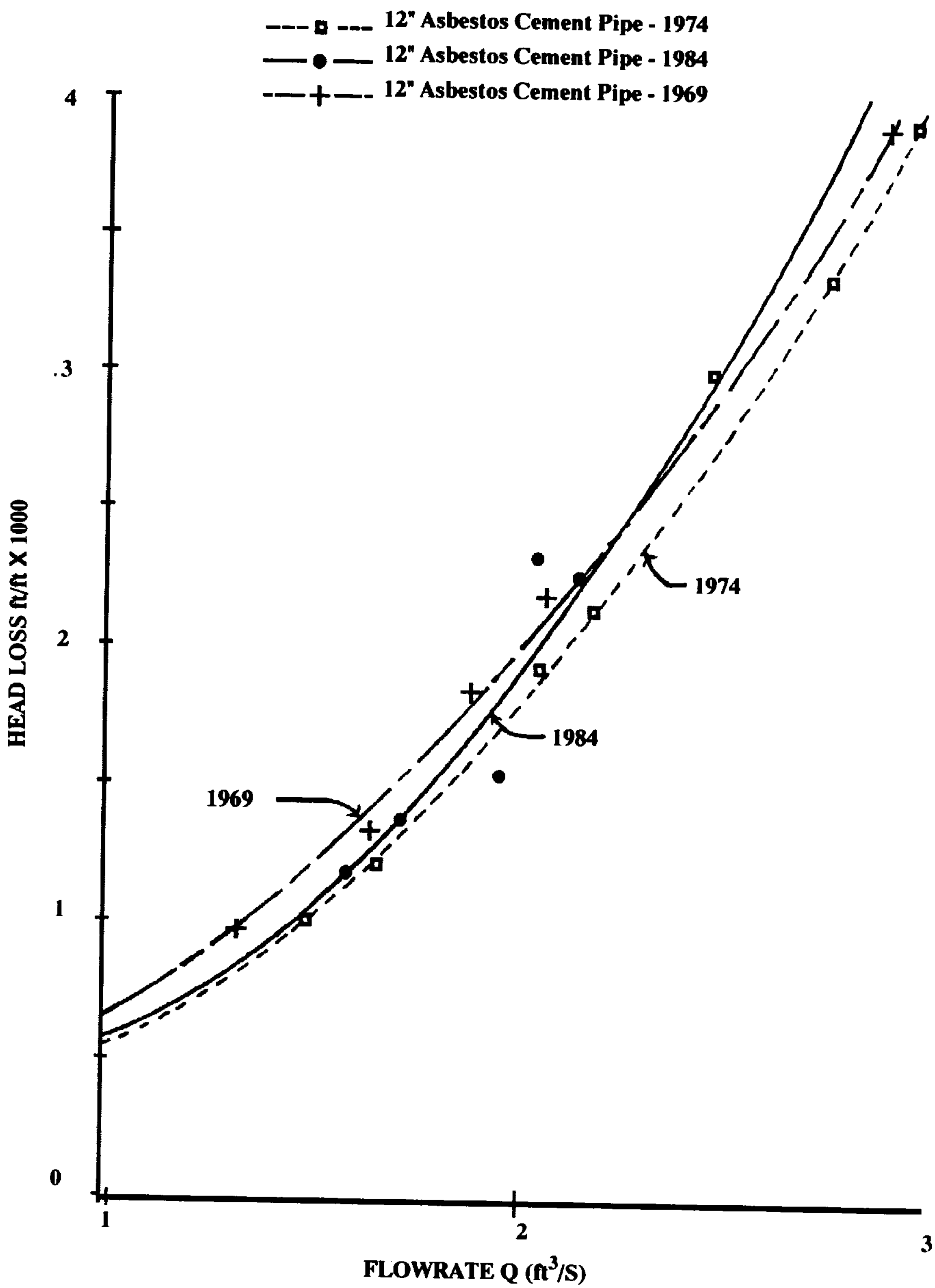

figure 2

FIELD HYDRAULIC HEAD LOSS

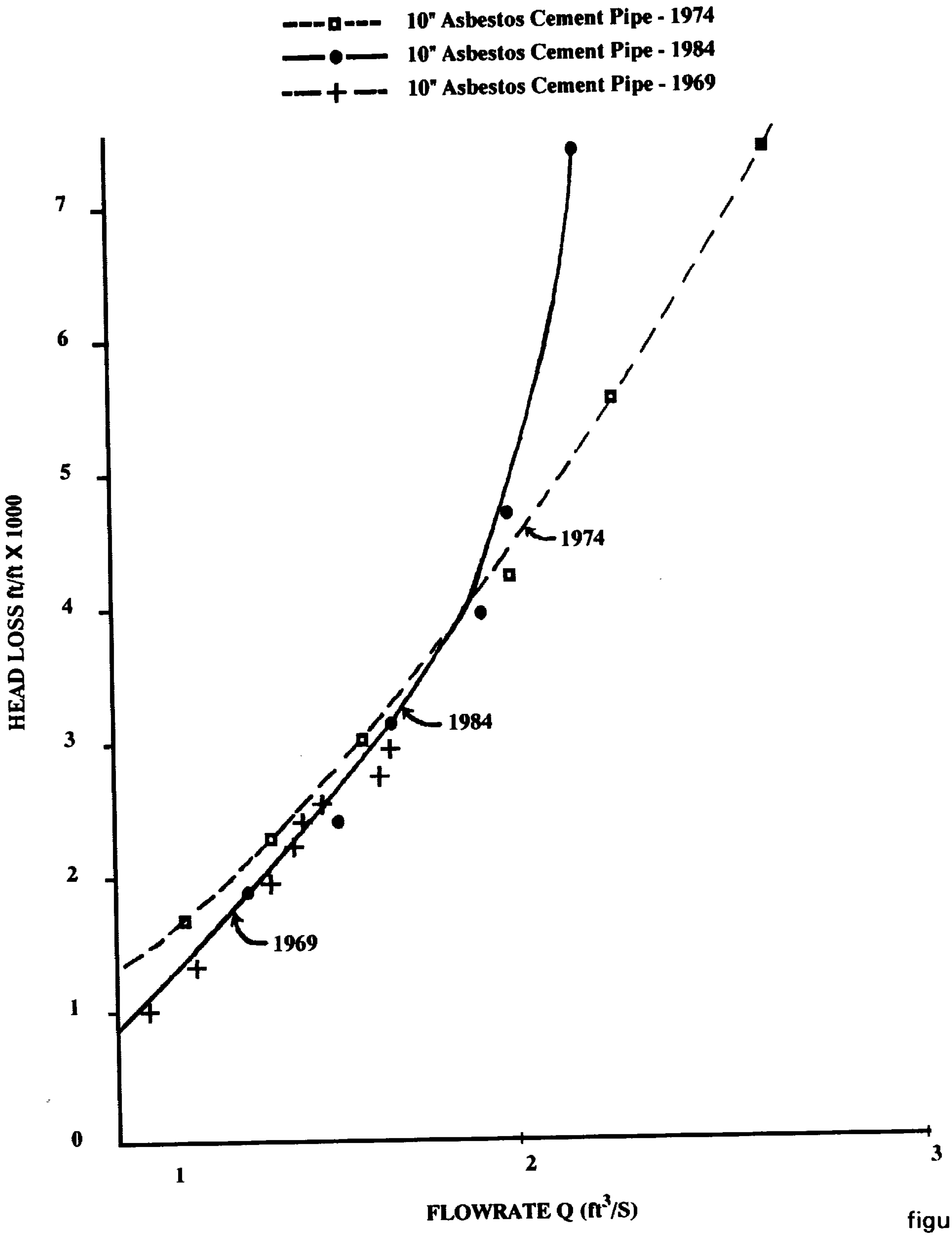

figure 3

FIELD HYDRAULIC HEAD LOSS

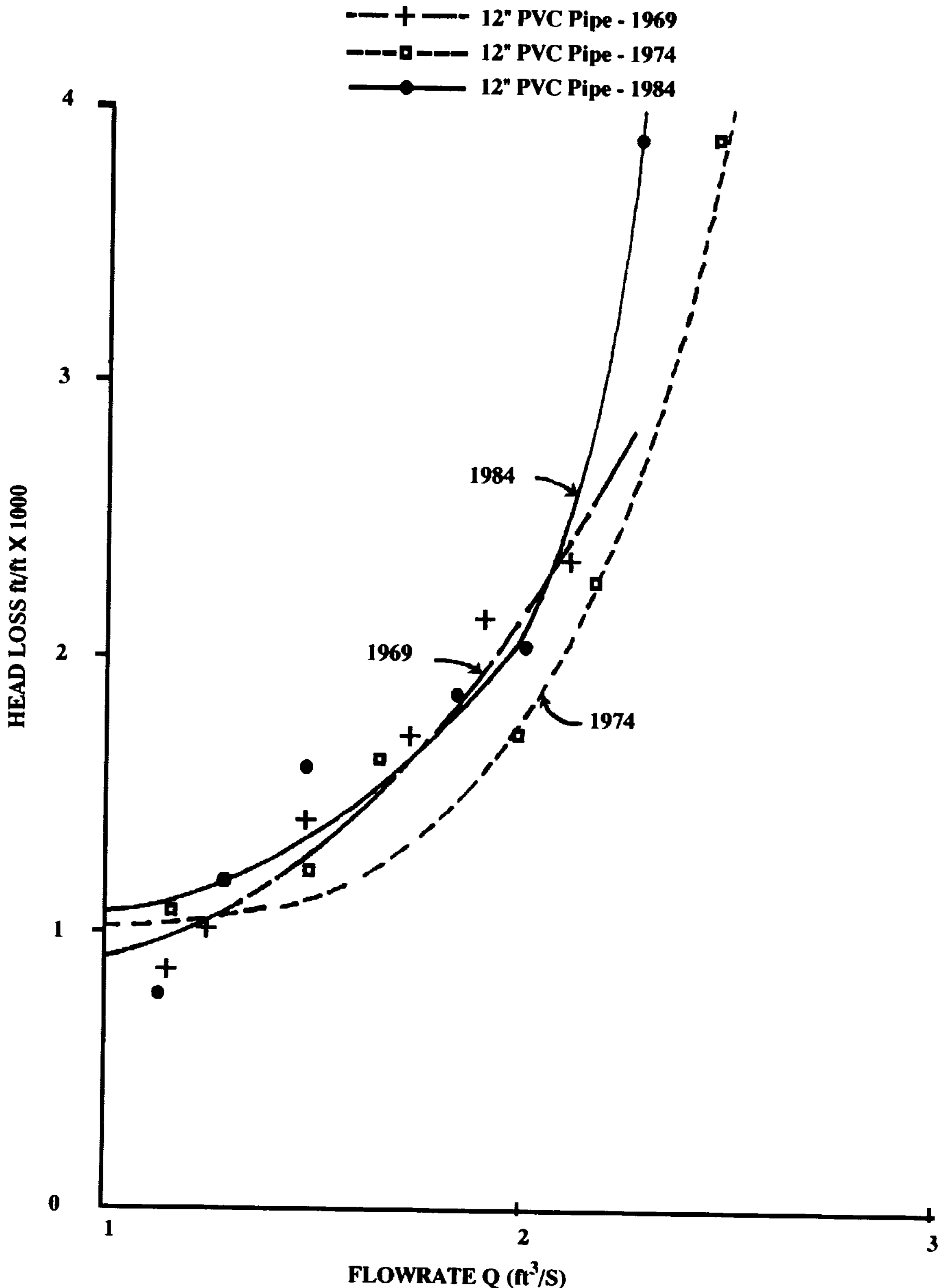

figure 4

FOUNDATION DRAIN MAINTENANCE METHODS[1]

by Robert A. Baumgarten[2] and James A. Lundeen[3]

Introduction

The Bureau of Reclamation operates and maintains many concrete gravity dams. Factors of safety utilized in the design of these dams consider continuous control of foundation uplift pressures and seepage. This report briefly explains the purpose of foundation drains and the importance of adequate maintenance to ensure reliable operation. This report describes the causes of the most typically encountered plugging problems and lists methods and equipment used for cleaning drain holes. The authors' intent is not to accept or reject any cleaning method but rather to document methods demonstrated on Bureau dams.

Background

Bureau dams are equipped with instrumentation (gauges and weirs) to monitor the performance of the foundation drains. Seepage flow rates and hydrostatic (uplift) pressures are compared over a period of time at the same reservoir water surface elevation. The flow rates from some of these drains have decreased while surrounding conditions have remained stable. One cause for this occurrence is partial blockage of the foundation drain holes due to encrustation. Should these holes become fully blocked, the uplift pressures would increase (varying from full reservoir pressure at the upstream face to zero or tailwater pressure at the downstream face).

Any increase in the uplift pressure will result in a decrease of the sliding and overturning stability of the dam. It is important, therefore, to keep these drains open to reduce the potential of pressure buildup.

Uplift due to hydrostatic water pressure has always been a concern in the design of structures when gravity is one of the stabilizing forces. In the design of concrete gravity dams, the effects of uplift pressures are always considered. Water pressure caused by reservoir water and tailwater occurs within the dam's foundation in pores, cracks, joints, and seams. This uplift pressure decreases the normal force occurring on potential sliding planes and reduces the foundation sliding and overturning stability of the dam. Foundation drains relieve this pressure; the pressure distribution is dependent on drain size, depth, location, and spacing. Current Bureau preliminary design practice assumes that drains in the foundation will reduce the potential uplift pressure to a value equal to the tailwater plus one-third the difference between the reservoir pressure and the tailwater pressure. The factor of safety utilized in the final design assumes that the drains are maintained continuously open to allow flow.

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[1] Condensed for bulletin. Information on complete report may be obtained by contacting one of the authors.

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The deposits most often found causing blockage in the foundation drain are calcium carbonate and bacterial obstruction. Calcium carbonate deposits are often noted at emergence of seepage water from foundation drains.

Calcium carbonate equilibrium includes the following important chemical species: aqueous calcium, carbonate, bicarbonate, carbonic acid, hydroxide, hydrogen ion, solid calcium carbonate, and water. Temperature of water, partial pressures of carbon dioxide, and ionic strengths will affect the presence and concentrations of the listed species.

Bacterial deposits result from life process activities of certain bacteria that obtain energy for their existence from conversion of sulfates to sulfides, ferrous to ferric oxides, and manganese to manganese oxides. Bacterial deposits are widely reported and occur under many conditions. Growth can occur at phenomenal rates and be difficult to control. Frequently, deposits are soft and easily removed; however, some can become mineralized and hard or viscous and thus prevent free flow of water. Bacterial growth can occur anaerobically (without oxygen) or aerobically (with oxygen). Energy sources can be organic materials or other carbon-containing substances. Bacteria require a continuous supply (such as in flowing water) of dissolved iron, manganese, or sulfate depending on the type of bacteria.

The buildup of calcium carbonate and bacterial obstructions, in general, will be called encrustations in this report unless specifically stated otherwise.

Various Methods of Cleaning Foundation Drains

The following is a list of various methods that were used to clean encrustation from foundation drains.

Rodding

Rodding is the process where a steel rod or similar device is used to break through the plugged encrustation deposits. In some cases, metal objects such as a star drill are attached to a line and dropped down the foundation drain to break the encrustation free.

This method of cleaning appears to be dependent on the thickness and hardness of the encrustation. Rodding may be acceptable where the majority of the blockage is near the surface of the foundation drain (in the concrete foundation) and where the seepage into the foundation drain is below the plugged area (in the rock foundation). Therefore, seepage is allowed to flow from the drain; and the encrustation buildup does not reduce the volume of flow.

Overcoring (Enlargement)

A drill rig is used to enlarge the original hole diameter by 1/8 to 1/4 inch. In some cases, new drains are drilled to replace the old ones.

Overcoring ensures that the encrustation is removed from the foundation drain, excluding any encrustation formed in cracks or veins deeper than 1/8 to 1/4 inch. Considerable cost of approximately $25 to $75 per foot and the time involved do not make this method a desirable alternative.

Rotary Interior Tube Cleaner

This method cleans the encrustation from the inside surfaces of the foundation drain, cleaning out to but not beyond the full original diameter. The Bureau has utilized the following types of rotary interior tube cleaners:

Wilson Tube Cleaner.–An air-driven device that turns the power head and is made primarily of a flexible hose and spring, which is attached to an SE holder used with a No. 64 cutter or a three-arm expandable head.

This device has been used since the late 1970's to clean foundation drains at Flaming Gorge Dam. The device appears to be doing an adequate job of cleaning the foundation drains.

Payne and Arnholtz.–An electric-driven (110-volt) flexible rod used with different types of carbide heads, which were designed and constructed by Payne and Arnholtz for the purpose of cleaning plugged foundation drains.

Evidence from the borehole camera video tapes showed that the contractor effectively cleaned the encrustation from the foundation drains. At present, there appears to be an increase of flow from the foundation drains at Yellowtail Dam of approximately 6 percent after cleaning. However, it is too early to state whether the drain cleaning was fully effective.

Goodway Reaming Tool.–An air-powered tube-cleaning machine capable of reaming to a depth of 125 feet. The Goodway AWT 100 is compact, portable (25-lbm drive unit), and has a simultaneous water flush that has the capability to carry deposits out of tubes. An automatic water valve turns water on only when the machine is running. This machine includes an adjustable tachometer and speed/torque control, which enables an operator to set shaft rotation at optimum speed for application. A flex hub centrifugally activates cutting tool blades to remove encrustation deposits. If necessary, a drill can be attached to the front of the flex hub. Other attachments are also available.

This reaming tool appeared to be very capable when used to clean foundation drains at Morrow Point Dam. The capability to clean to a depth of 125 feet adds to its assets as a portable cleaning device. The tool is a very economical alternative, in similar conditions as Morrow Point Dam, to the more expensive methods of cleaning.

Coleman.–This device runs on hydrostatic water pressure, which allows the head to oscillate back and forth. The oscillating head removes the encrustation from the sidewalls of the foundation drain. The water tip is attached to a hose with water pressures from 60 lbf/in^2 to over 200 lbf/in^2 (varying with gallery elevation) and greater with depth of the drain. The water allows the encrustation to be flushed from the drain.

This water tip appears to be effectively cleaning the foundation drains at Hungry Horse Dam. There is not a rapid buildup of encrustation if the drains are cleaned every 3 to 5 years. If the water tip is effective at cleaning the foundation drains, it is a very economical method for cleaning.

Roto-Rooter.–This is an electrically driven device that turns the cutting edges and consists of a flexible shaft (pipe snake) and a variety of cutting edges.

This method has proven to have the ability of cutting through plugged sections of foundation drains at Folsom Dam. Foundation drain 12.D.3 at Folsom Dam was opened to a final depth of 129 feet after cutting through solid plugs between depths of 16 to 25 feet and 40 to 50 feet. In approximately 6 to 7 hours, the drain was completely opened and cleaned to its entire depth at a cost of $500.

Foundation drain 12.D.3 was inspected with a borehole camera. The sidewall was virtually free of encrustation, excluding only small particles of encrustation noticed in crevices. The seepage increased from no flow previous to cleaning to 1.6 gal/h after cleaning. This method appeared to do an acceptable job of cleaning encrustation, both plugged and on the sidewall, from the drain. From this demonstration, it is difficult to conclude how economical this method would actually be for cleaning an entire gallery of foundation drains.

UHP (Ultra-High-Pressure) Water-Cleaning System

A typical UHP water-cleaning system delivers flows of 1 to 3 gal/min, at pressures between 20,000 and 50,000 lbf/in^2, with a pressure of 35,000 lbf/in^2 being the most practical in application where hoses are used. Because of the low flow rate, the UHP water system substantially reduces the danger of hydrofracturing and possible subsequent increase in seepage under the dam. A rotary head is recommended with the UHP water cleaning system. Two- or four-nozzle configurations produce balanced force on the head and are most common. The UHP nozzle was demonstrated to clean encrustation buildup on a gallery wall. Difficulties with grooving the sidewalls of a foundation drain are minimized by using a rotating head. Only one pass of the head per hole should be required to save labor and time. The only drawback to using a rotary head is that the diameter of the flexible lance assembly is increased, which decreases flexibility.

Calcium carbonate was cleaned from the gallery wall at Grand Coulee Dam. The test did prove it was feasible to clean a foundation drain in hard rock using a UHP water system. As shown from a borehole camera, the UHP method was effective in cleaning the encrustation deposits from the sidewalls of the drains.

The UHP equipment could only be moved to limited foundation drain locations without requiring major time-consuming disassembly and reassembly work. At these locations, there were no uplift pressure measurements or flow data from the foundation drains, and none of the drains cleaned were completely plugged with encrustations. More experience using the UHP water system is needed before determining if this technique is practical.

The UHP water-jet method met with little success at Folsom Dam. The foundation drains, which were used for the demonstration, were completely plugged. Many different nozzle configurations were tried at various water pressures with little success. The combination of 80° nozzle tip and 36,000 lbf/in^2 did manage to cut and satisfactorily clean approximately 6 feet of foundation drain as observed by a borehole camera. In general, the equipment used to clean the foundation drain was very bulky, hard to maneuver, and prone to break down. This method holds promise in the future, but modifications are necessary to adapt the UHP water-cleaning equipment to clean foundation drains economically and efficiently .

High-Pressure Water-Cleaning Devices

This method utilizes a lower pressure usually between 6,000 and 10,000 lbf/in^2 and a higher volume of flow between 5 and 20 gal/min.

Industrial Hydropower.–Industrial Hydropower demonstrated a high-pressure water-blasting system to clean 3-1/2-inch-diameter foundation drains.

Two foundation drain holes were cleaned. The results of cleaning the foundation drains were inconclusive. The equipment was capable of removing the harder carbonate deposits, which were located on the wall.

Donco Industries, Inc.–Donco designed a high-pressure water-blasting (referred to as hydroblasting) device that is most effective with a working pressure of 10,000 lbf/in^2 and a flow rate of 20 gal/min. Due to the diameter and length of hose, there was a loss of 150 lbf/in^2 per 50 feet of 1/2-inch-inside-diameter supply hose and a loss of 3,300 lbf/in^2 for 25 feet of nylon steel 1/4-inch-inside-diameter flexible lance hose. The heads available for use were:

a. A 7/16-inch flexible lance, with 25 feet of 1/4-inch-inside-diameter nylon steel hose, 1 hole straightforward, and 18 holes pointing forward 30°

b. A 1/2-inch molehead, with 5-foot-long, 1/2-inch-diameter steel shaft, one hole straightforward, three holes at 45° forward, and seven holes at 35° aft

c. A 2-inch molehead, with 5-foot-long, 1/2-inch-diameter steel shaft, consisting of various different nozzles that can be arranged as needed

d. A 2-1/2-inch rotating molehead, with 5-foot-long, 1/2-inch-diameter steel shaft, one hole straightforward, two holes at 45° forward, and two holes at 45° aft

e. A 3-inch-diameter carbide bit with high-pressure water jets protruding forward, adding 5-foot steel rigid shafts as necessary to reach required depths

A 1/2-inch, 30,000-lbf/in^2 capacity hose is used to carry the flow from the pumps. Also, as a safety feature, a dump-load device with a foot pedal is used to regulate pressure to the molehead or lance for cleaning.

The hydroblast equipment was easily assembled, and access to foundation drains was fairly easy to obtain by the use of high-pressure lines. Various cutting tips can easily be attached and changed when encountering different types of encrustation.

The 1/2-inch-diameter molehead was very proficient in cutting through the solid plugged encrustation. Using the different moleheads and a flexible lance, the encrustation was inconsistently removed from the sidewalls. A minor adjustment may be necessary either to the direction or number of jets in the moleheads and/or a centering device installed to ensure the device is centered. The hydroblast equipment is adequate and appears to be an economical alternative to cleaning encrustation deposits both plugged and on the sidewall of foundation drains.

Sulfamic Acid

Sulfamic acid is an ingredient that was field tested to chemically treat calcium carbonate to rehabilitate clogged foundation drains. Granular and pelletized forms of the acid are applied to clogged foundation drains in quantities equivalent to roughly 2 to 8 percent of the unobstructed drain volumes.

Sulfamic acid was used at Folsom Dam. On initial application of the granular form of acid, an immediate vigorous reaction was observed. An application of the pellets was designed to drop to the bottom of the hole and dissolve slowly, providing acidification at the point of encrustation over an extended time period.

On inspection of the plugged calcium carbonate foundation drains, there was no evidence of the foundation drains opening. After the acid treatment, an odor was detected in and around the area of the acid treatment. Because there was concern for the safety of the workers in this area, the acid treatments were discontinued. There are still possibilities of using the sulfamic acid to dissolve the calcium carbonate, but the problems of the gases generated by the sulfamic acid need to be studied further. The sulfamic acid treatment may be best utilized as a deterrent to calcium carbonate buildup on a preventative maintenance basis.

Conclusions

1. Over the past 40 years, several drain cleaning techniques have been successfully used by the Bureau.

2. The various methods reported have proven to be site specific. It is very difficult to compare procedures for cleaning foundation drains. The hardness or exact chemical makeup of the mineral deposits may vary with field conditions. The strength of mineral deposits to adhere to the sidewalls of foundation drains varies. Consequently, each drain system must be examined on a case-by-case basis to determine the most effective method for maintenance.

3. The instrumentation (uplift pressure and flow) presently in use may not be sufficient to determine that a problem exists with the foundation drains. The instrumentation also may not reveal if the foundation drains have been sufficiently cleaned.

4. The most beneficial foundation drain-cleaning effort is one that restores foundation drains to normal and acceptable flows and uplift pressures.

5. The cost of cleaning foundation drains may vary from as little as a few dollars per foot to as much as $25 or more per foot.

6. Due to space limitations and the different sizes of galleries and entrance ways, various methods are impractical for use.

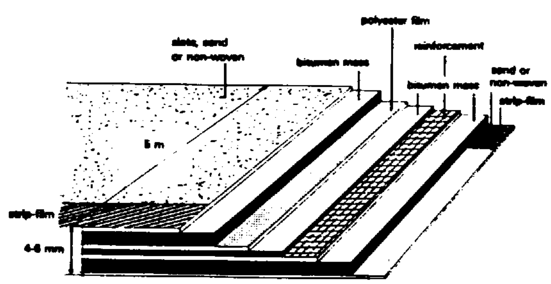
7. Concrete dams have been designed and constructed such that uplift pressures at the base of the dam are controlled by the presence of an open, freeflowing foundation drain system. Consequently, to ensure the stability of the dam as designed, the foundation drains need to be maintained in a freeflowing condition.

The long-term safety of concrete gravity dams is ensured by an ongoing program of foundation drain maintenance. Foundation drains have been kept open by use of various methods. This process has proven to be satisfactory. As more experience with existing methods is gained and new methods are developed, the effectiveness of cleaning and monitoring foundation drains will improve.

REINFORCED BITUMEN CANAL LINING

by Gary Weatherly[1]

In 1987, the Kennewick Irrigation District, Kennewick, Washington, began plans for installation of an exposed, reinforced, modified bitumen (rubberized asphalt) lining material at two sites on the District's canals. The liner offers the advantages of concrete for weed control and low friction yet is flexible and less costly. One project on the District's Main Canal lined 1,940 linear feet of a 500 ft^3/s canal and required 125,000 ft^2 of material while the second project lined 2,115 linear feet of a 45 ft^3/s lateral and required 41,000 ft^2 of material. Rolls of the material are 16.4 feet wide by 282 feet long and weigh roughly 4,000 pounds. This liner has been used extensively in Europe for the past 30 years and by several irrigation districts near Calgary, Alberta, over the last 4 years. The District's projects were the first use of this material in the United States. The material consists of modified bitumen, a woven nylon fabric for reinforcement, a polyester film to prohibit root penetration, and a granular slate cover to reduce ultraviolet degradation. Tensile strength of the material is 183 pounds per linear inch; and weather tests on material, without the slate cover, indicate a minimum life of 30 years. Although testing with rodents from our area has not been done, where the fabric has been used to line European sanitary landfills, rats and other rodents have left it alone. The bitumen is somewhat tacky and elastic which apparently keeps rodents from attacking it.



Composition of Hyvofors membranes

Lining material cross section

Over the past 5 years, the District has installed in excess of 1.25 million ft^2 of 20-mL PVC liner to control seepage and reduce the potential for canal failure. The PVC liner has succeeded in stopping seepage and canal failures but maintenance problems have increased. Weeds rooting in the cover material will eventually have to be removed resulting in removal and/or damage to the cover material. The possibility exists that areas of cover material will slide into the canal bottom during the cleaning process. The problem is compounded because of the inaccessibility of the canal to equipment because the cover material in the canal bottom remains saturated during the off-season. The District has also experienced problems with seasonal runoff from hills behind the canal flowing overland into the canal and washing the cover material into the canal bottom.

The exposed bitumen liner stops all weed growth so future weed removal is unnecessary, as is the application of herbicides. Overland flow entering the bitumen lined sections of canal can be handled without a problem.

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The 45 ft^3/s lateral lined with the material is located in a rocky area where overexcavation necessary for the installation of PVC liner would have been difficult. Earth and gravel cover materials were also not convenient to the site. The Hypofor lining Mannings "n" value of 0.016 allowed the canal cross section to be reduced thereby avoiding any rock excavation. This low "n" value also makes the liner suitable for rehabilitation of concrete-lined canals where the concrete lining is acceptable as a subgrade but no longer satisfactory as a liner.

Delivered in Kennewick, Washington, purchase price for the material was \$0.84 ft^2. The higher cost of the material (compared to PVC) is offset considerably by reduced excavation and no requirement to import and place earth and gravel cover material. There are also future savings in weed control and removal. Placement of the liner, sealing the seams, and backfill of the anchor trenches ran an additional \$0.20 ft^2. Canal preparation costs will vary depending on local conditions and the condition of the canal.

Installation of the liner is straightforward. District crews who were unfamiliar with the procedure were able to install 41,600 ft^2 of material and seal the seams in 4 days with the assistance of one technician. Preparation of the canal consists of clearing and grubbing, shaping the canal into the desired prism, removal of any sharp rock or other objects which could eventually damage the liner, and digging anchor trenches around the perimeter of the project. Side slopes for the two projects ranged from 1-1/2:1 to 2:1. The material is then laid out with 20-inch overlaps for joining the sheets. The size and weight of the rolls require that an excavator with a roll handler be used to install the liner. The combined weight of the roll and handler is 6,000 pounds. The roll handler is provided by the distributor. Once the seams are sealed, they are capable of sliding up to 3 inches and still remain watertight. Anchoring the liner, to prevent wind damage, before the seams are sealed and the anchor trenches backfilled is unnecessary because of the weight of the material.

The liner is a petroleum based product and therefore is susceptible to damage from other petroleum based products. It is resistant to Xylene in concentrations of less than 900 p/m and Magnacide H in concentrations of less than 30 p/m. These concentrations are well in excess of concentrations used by the District, so problems are not anticipated. Releases of herbicides are however made far enough upstream from lined sections to ensure complete dilution. The liner is noncombustible but can be damaged by fire which will melt the asphalt.

The joints are sealed by pouring hot roofing asphalt on the joint surfaces and applying pressure. The roofing asphalt provides a uniform heat source to melt the rubberized asphalt in the joint area of each sheet so they will adhere. A 20-inch joint area of the strip film on each edge of the liner is left free of slate to allow proper sealing of the seams. Early installations done in Canada used torches to heat the material and seal the seams. This procedure was found to be unreliable as some seams were not heated enough and the seams leaked, and in other areas the material was overheated and the rubber was burned out of the asphalt. We have found one minor problem with the installation. The bead of roofing asphalt poured over the edge of the seam following sealing of the joint tends to slough at high ambient temperatures, particularly on south facing slopes. In the future, the District will either eliminate the bead entirely or place it only as high as the waterline. The bead is installed for an added margin of safety

Placement of liner

but is not necessary to ensure the seam is watertight. The modified bitumen in the liner has withstood the heat without problems and the 20-inch overlap provides a secure seam. The sloughing roofing asphalt is mainly an esthetic problem.

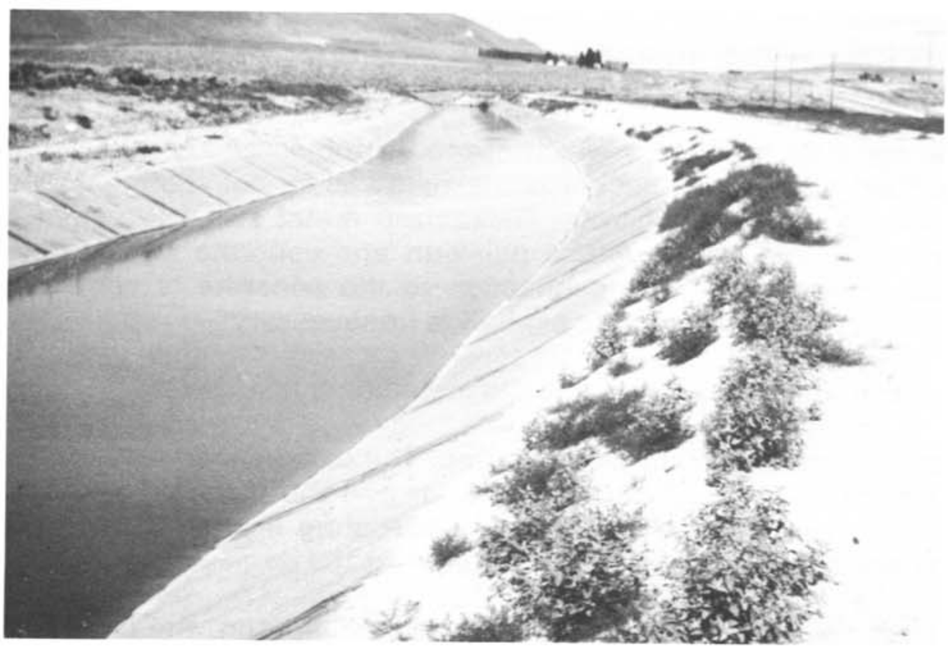
Connection to concrete structures which are to be submerged is made by first cleaning the concrete, then applying cutback asphalt, followed by hot roofing asphalt. The liner is then pressed against the concrete. Galvanized metal strips are then placed along the edges and anchored either with a nail gun and concrete nails or by drilling and installing wedge anchors. Where connection to the concrete is above waterline, the application of the cutback and roofing asphalt is unnecessary.

Anchor trenches are then backfilled and the installation is complete.

Repair of damaged areas is a simple operation. The damaged area of the liner is heated to the point where the slate sinks into the liner and the modified bitumen rises to the surface where it can adhere to the patch. Hot roofing asphalt is then poured on the damaged area and a piece of the liner is placed over the damaged section.

After having had the liner in place for one irrigation season, the District remains very pleased with the installation. The District will be monitoring the installations during the coming years and if the material performs as expected, plans call for installation of an additional 1.5 million ft^2 of material.

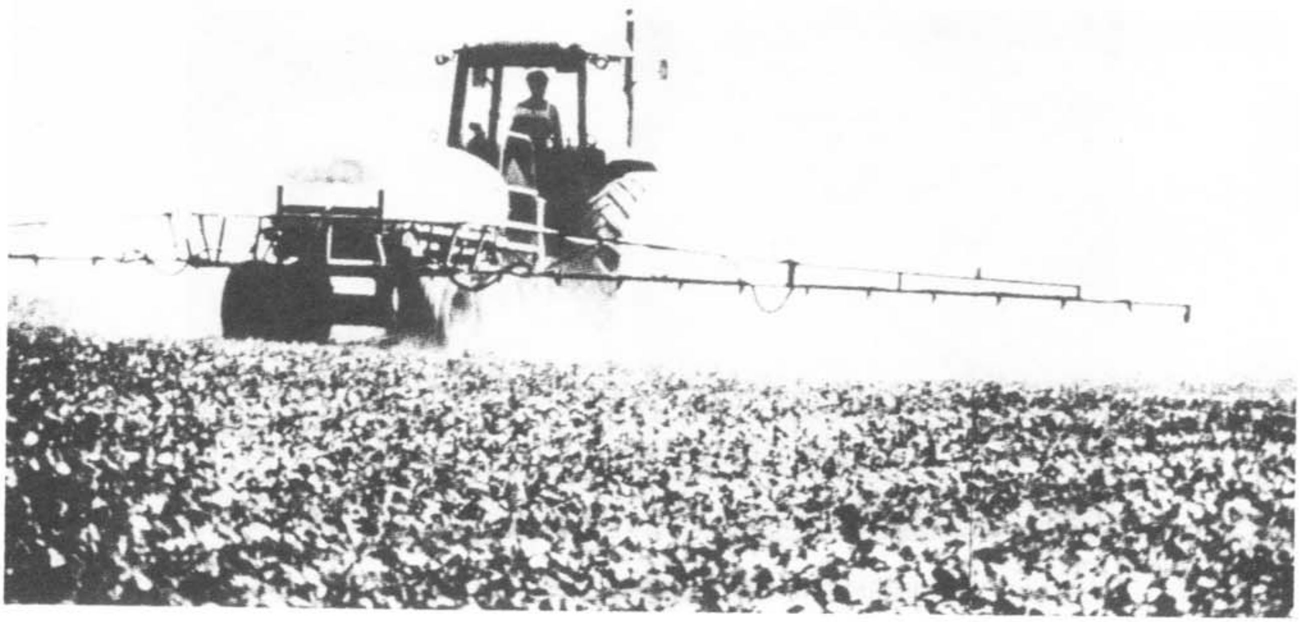
Joint sealing



Completed project, Main Canal

Completed Project, Badger East Lateral

SOME GOOD TIPS ON SPRAY TIPS[1]



Postemergence herbicide being applied on soybeans

Widespread use of conservation tillage and increased pressure to reduce crop costs have spawned a variety of spray rigs - from traditional boom units, pulled behind tractors, to rigs where spray nozzles are mounted directly on tillage or planting equipment.

Walk into a farm-implement dealer's to inquire about the new features available on a custom-made sprayer, and you will find just about any option you can think of, plus some others you never knew existed.

It's no wonder that there has been some confusion about nozzle fittings: Modern spray-rig design and construction are about as predictable as the scope of a designer's imagination - which means you cannot tell what will happen next. With all those spray rigs, options, and nozzles crowding the marketplace, trying to decide on which way to go with which product can give any grower a king-sized headache.

Not only do you need to know the difference between a full cone tip and flat fan, you also need to know what size tips to purchase, then how to mount those tips - and finally, how to operate them for the best coverage.

If you're confused, help is at hand. Shake off that headache, clear your head of any dizziness, and read on. Herein are some tips on tips * * *

First of all, keep one thing in mind: Regardless of the many design possibilities, the single objective of all spray equipment, including both machines and attachments, is to get the chemical to the target — and get it there at the prescribed rate of application.

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[1] Reprinted with permission of the Editor, Irrigation Journal, March/April 1988 issue.

Herbicide application on irrigation ditch with adjustable boom

Simple, right? There's just one problem: Without the right spray-tip size or capacity, and without the correct setting, you aren't going to accomplish that simple goal. Either you'll miss your target, or you'll drown it in excess spray, or you'll leave it high and dry with no protection, or whatever it is you were spraying. That's why you need these tips on tips.

It's not that we claim to be experts, mind you - we just happen to know some experts.

To help you understand all the variables involved in the application of agricultural chemicals, we've turned to two leading authorities on spray equipment: Dr. Robert Grisso, who's an agricultural engineer at the University of Nebraska, and Tom Reed, agricultural marketing manager for Spraying Systems Company in Wheaton, Illinois. His company makes TeeJet spray products - including, of course, spray tips.

TEEJET® VISIFLO® FLAT SPRAY TIPS

TIP COLOR VisiFlo version	TIP NO. (Strainer Screen Size) 80" SERIES	110" SERIES	Liquid Pressure in PSI	Capacity 1 Nozzle in GPM	Capacity 1 Nozzle in oz/min	GALLONS PER ACRE 20" SPACING 5 MPH	6 MPH	7 MPH	8 MPH	GALLONS PER ACRE 30" SPACING 5 MPH	6 MPH	7 MPH	8 MPH
ORANGE	8001VS (100 Mesh)	11001VS (100 Mesh)	30	.09	11	5.1	4.3	3.7	3.2	3.4	2.9	2.5	2.1
			35	.09	12	5.6	4.6	4.0	3.5	3.7	3.1	2.6	2.3
			40	.10	13	5.9	5.0	4.2	3.7	4.0	3.3	2.8	2.5
			45	.11	14	6.3	5.3	4.5	3.9	4.2	3.5	3.0	2.6
			60	.12	15	7.3	6.1	5.2	4.6	4.9	4.0	3.5	3.0
GREEN	80015VS (100 Mesh)	110015VS (100 Mesh)	30	.13	17	7.7	6.4	5.5	4.8	5.1	4.3	3.7	3.2
			35	.14	18	8.3	6.9	6.0	5.2	5.6	4.6	4.0	3.5
			40	.15	19	8.9	7.4	6.4	5.6	5.9	5.0	4.2	3.7
			45	.16	20	9.5	7.9	6.8	5.9	6.3	5.3	4.5	3.9
			60	.18	23	10.9	9.1	7.8	6.8	7.3	6.1	5.2	4.6
YELLOW	8002VS (50 Mesh)	11002VS (50 Mesh)	30	.17	22	10.3	8.6	7.4	6.4	6.9	5.7	4.9	4.3
			35	.19	24	11.1	9.3	7.9	6.9	7.4	6.2	5.3	4.6
			40	.20	26	11.9	9.9	8.5	7.4	7.9	6.6	5.7	5.0
			45	.21	27	12.6	10.5	9.0	7.9	8.4	7.0	6.0	5.3
			60	.25	32	14.6	12.1	10.4	9.1	9.7	8.1	6.9	6.1

Chart taken from Spraying Systems Co. catalog, page 11

TeeJet® and VisiFlo® are registered trademarks of Spraying Systems Co., Wheaton, Illinois.

"The first thing you need to know about selecting the proper-size nozzle is the prescribed application rate on the chemical label," says Reed. That will be shown in GPA (gallons per acre). Secondly, you have to determine your spray-tip spacing for broadcast spraying, or your intended spray-band width for banding applications.

Another variable that affects the application rate, and your subsequent choice of nozzle size, is the actual travel speed.

Fluctuations in, or misjudgments of, travel speed can result in dramatic errors in the application rate. For example, let's say you intend to apply 20 GPA at a speed of 6 mph (miles per hour) — but actually you only travel at 5 mph when you get into the field. By going slower — even 1 mph slower — you risk a 20 percent overapplication.

So make sure that your speed remains constant during application — unless you have one of those advanced spray controllers just hitting the market that compensates for fluctuating land speed. But let's not go that high-tech for the purposes of our present discussion, or we'll just complicate things.

Most tip styles are available in several sizes or capacities. "Within each size, a spray tip is capable of supplying different flow rates over a range of spraying pressures," Reed explains.

"However," he adds, "for most tips — the extended-range flat spray tip is an exception — there is a narrow range of operating pressure that should be used in order to get the best possible coverage." Therefore, Reed recommends that you not try to make major rate adjustments by altering the operating pressure — the pounds per square inch, or psi.

Consider this scenario. You're spraying at a rate of 20 GPA, with an operating pressure of 30 psi when you decide to switch to a new chemical that has an application rate of 10 GPA. What's the best way to achieve the lower output? Chances are your first idea may be wrong.

A common tendency is to lower the operating pressure by the same ratio - in this case, to 15 psi. In reality, application of the new product would require a pressure of 7.5 psi. This is lower than the suggested operational range of the tip you were using to apply the original chemical.

"Because there is not a linear relationship between pressure and application rate, you end up over-applying pesticide, with the actual application rate being 14 GPA at 15 psi," says Dr. Grisso.

What's more, even if you try to compensate by lowering the pressure further, the application will likely be off the mark. At the substantially lower pressure required to obtain 10 GPA, the tip may not be capable of providing uniform coverage.

A better approach, Grisso explains, is to use a spray tip that's designed to produce a lower output in gallons per minute, or gpm, at the desired operating pressure. This can be easily accomplished by consulting the nozzle manufacturer's catalog, using the spray-tip charts or the gpm equation.

In the catalog distributed by Spraying Systems, we found the following information for each tip choice: the recommended spray angle, operating pressure, and capacity in gallons or ounces per minute. There is also a chart to show the tip's capability in terms of GPA at various nozzle spacings and operating speeds.

Under the heading for operating pressure, you'll see 3 to 5 psi levels, based on the pressure at which that particular style of tip is designed to perform best. For example, the ideal operating pressure of a TeeJet flat spray tip is between 30 and 60 psi.

Meanwhile, back at Irrigation Journal, refer to the sidebar article on "How to Select a Spray Tip" to determine whether or not the pressure and tip style will accommodate your particular application.

Next, look in the chart accompanying this article for the GPA you've determined you'll require. For example, say you want to spray 6 GPA at 7 mph, using 20-inch nozzle spacings. In the chart, you'll see that you should select an 80015 tip, which produces 0.14 gpm at approximately 35 psi.

Once you've chosen the proper tip, there's still an important step that you can't overlook: proper setting.

The two key adjustments in setting the spray tips are orientation and height. The orientation refers to the angle at which the spray penetrates the target.

"The key is to get the most uniform pattern possible," says Grisso. He suggests following the spray-tip manufacturer's catalog for angle recommendations. Though most tips are designed to be used in a downward position, a few types provide better coverage if tilted slightly.

The optimum height setting varies with individual booms, and normally it requires fine-tuning once the spray tips are mounted. If available, a spray table is ideal for checking the uniformity of the spray, which can be affected by height.

At proper height, the sprayer should provide an even amount of chemical across the full width of the boom

Otherwise, Grisso recommends checking height by driving the operating sprayer at normal working speed over a pad of hot concrete or asphalt. Then observe how the solution dries.

If there is streaking, where the overlapping areas dry faster than under the nozzle centers, the boom should be raised higher. If the area between nozzles is the slower-drying section, then the boom may be too high.

However, worn nozzles or incorrect pressures can make diagnosis difficult, if not impossible. At proper boom height, the sprayer should provide an even amount of chemical across the full width of the boom. Keep in mind that the sprayer boom may actually be lower in the field, due to wheel sinkage in the soil.

Modern chemicals are expensive, and they allow little margin for error. So you, the grower, must make sure you're using the application rates and practices that are best suited for a particular chemical. It's your money, and your crop.

By taking advantage of today's spraying-equipment technology — including proper nozzle sizing and setting — there's a better chance that you will achieve application accuracy. Then your headaches will be over. Besides, there's money in it.

HOW TO SELECT A SPRAY TIP[1]

The important thing to remember in selecting a spray tip is that no single tip is suitable for all types of applications. That advice comes from Tom Reed, agricultural marketing manager for Spraying Systems Company, makers of TeeJet spray products, who has provided this "crash course" in tip selection.

You should base your selection on two factors: desired droplet size and spray coverage.

For example, preplant incorporated and preemergence herbicides that rely on soil moisture for their activation can be applied with nozzles that create larger droplets to minimize drift.

On the other hand, postemergence contact herbicides require nozzles that create finer droplets, in order to ensure effective foliar coverage.

Several factors determine droplet size: spraying pressure, spray tip capacity (size), the shape of the tip orifice, and the spray angle. Generally speaking, the greater the pressure, the smaller the droplets. The larger the orifice, the larger the droplets will be; the wider the spray angle, the smaller the droplets will be - and vice versa. To help you in selecting tips, the chart in the previous article shows which tips are best for different applications of pre- and postemergence herbicides. In addition, the following paragraphs are descriptions of various tips that are currently available.

The *extended-range flat spray tip* is the only tip that offers the versatility of creating different flow rates and droplet sizes at various operating pressures, while maintaining uniform coverage along the boom.

Like a standard flat spray tip, its elliptical-orifice design produces a tapered spray pattern that overlaps adjoining sprays, for uniform distribution across the boom.

For preemerge soil-incorporated applications, this tip, due to its unique design, may be used at a low pressure (down to 15 psi) to form large droplets. However, when pressure is increased to 40-60 psi, the extended-range tip produces finer droplets, which can be used for broadcast spraying of postemergence contact herbicides.

This extended-range flat spray tip is ideal for use with spray controllers that adjust pressure to compensate for various ground speeds. Because the tip maintains a wider spray angle than the standard flat fan at various pressures, spray overlap is sufficient to minimize streaks that might occur at low pressures, or if the boom bounces or tilts at higher pressures.

Next let's consider the *standard flat spray tip*, which is the "granddaddy" of the tip family, dating back to the early years of chemical spraying. At 30 psi, this tip produces medium-size droplets for preemerge surface-applied herbicides.

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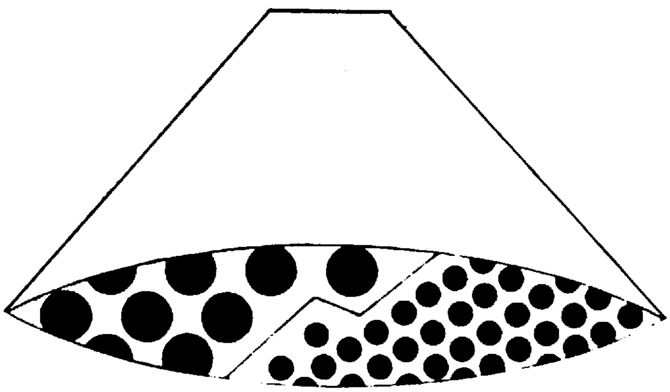
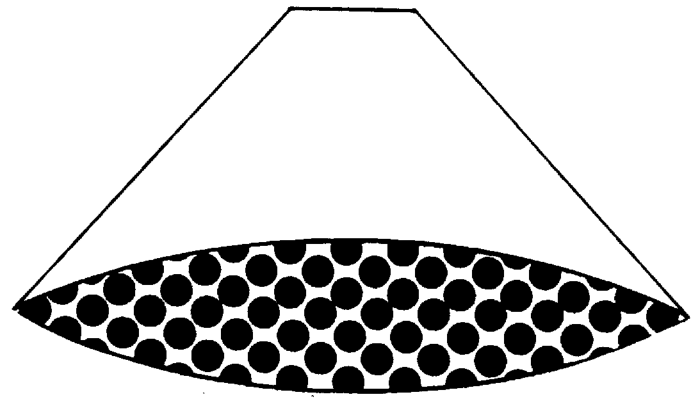
[1] Reprinted with permission of the Editor, Irrigation Journal, March/April 1988 issue.

In postemerge applications of contact herbicides at 40 psi and above, this standard flat spray tip provides good canopy penetration, with smaller droplets for effective foliar coverage.

However, at spraying pressures below 25 psi, the spray angle of the tip is dramatically reduced, and spray uniformity may suffer because of insufficient overlap.



Extended Range Flat Spray Tip



Standard Flat Spray Tip

The *even flat spray tip* is ideal for band spraying preemerge and postemerge systemic herbicides, thanks to its medium-sized droplets. This tip produces a fan-shaped pattern, but spray coverage is "even" without tapered edges created by the flat fan spray tip. This provides uniform distribution across the band.

Typical spraying pressures for the even flat spray tip are 30-40 psi. The band width can be controlled by spray-tip height, or by choosing one of the many spray angles available.

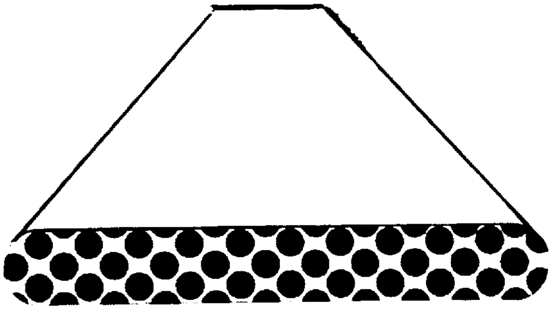
Next comes the *twin flat spray tip,* which produces two spray patterns — one angled 30° forward, and the other angled 30° backward.

Its spray angle and shape are similar to the flat fan, but with smaller droplets, due to the atomizing by two smaller orifices. The fore-and-aft spray directions and smaller droplets improve coverage and penetration when you are broadcast-spraying postemerge contact herbicides.

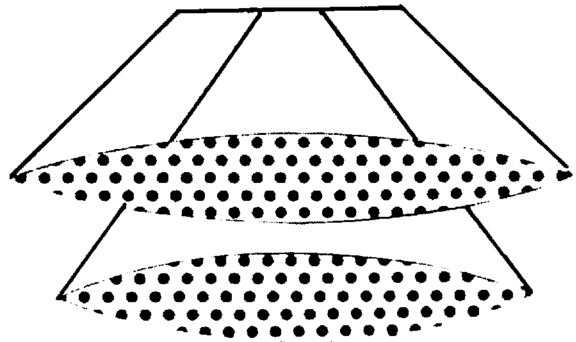
Typically, these spray tips are spaced 20 inches apart and are operated at 30-60 psi. The twin flat spray tip is also growing in popularity in the application of surface-applied herbicides, where coverage under crop residue is necessary.

When herbicides dictate using smaller droplets for banding applications, the *hollow-cone spray tip* is ideal. The hollow cone provides a circular pattern of small, uniform droplets. When banding postemerge contact herbicides over the row, three hollow-cone spray tips can be mounted on the boom to maximize chemical coverage. Typical operation pressures for this tip are 40-60 psi.

When drift is a concern, the *wide-angle full cone* is a good choice, because of its large droplet size. This tip is traditionally used at lower operating pressures (15-25 psi). It



Even Flat Spray Tip

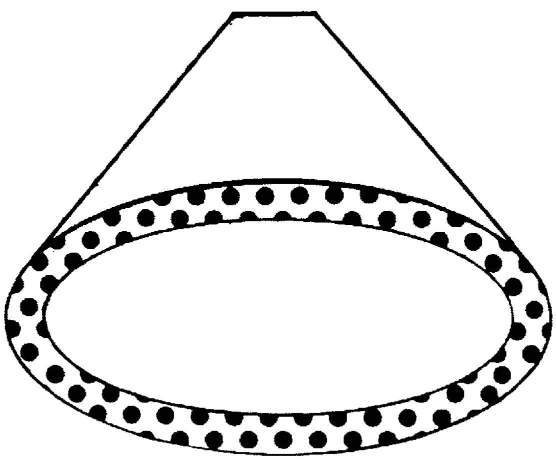


Twin Flat Spray Tip

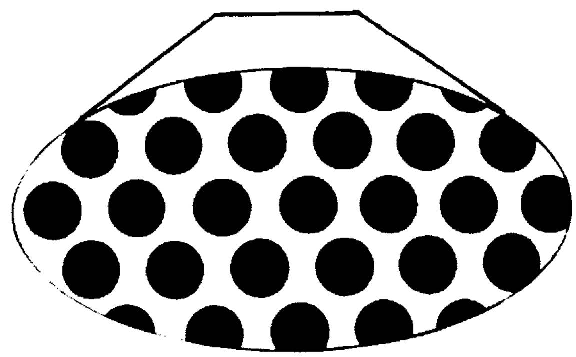
provides uniform coverage along the boom at spacings up to 40 inches apart. Optimum uniformity is achieved by angling the spray tips 30-45° and overlapping 30-50 percent on each side of the pattern.

The *flooding tip* is popular when clogging is a potential problem, such as when applying suspension fertilizer. This tip has a round orifice and produces large droplets at low pressures.

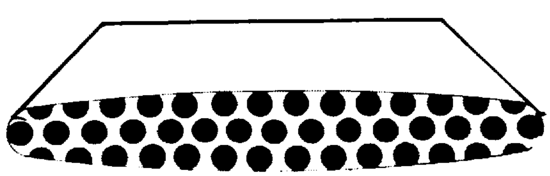
A disadvantage is the heavy edges produced on the outside of the spray pattern. These heavy edges of large droplets increase the possibility of streaks of over-applied material when overlap is not ideal. Because of the irregular nature of the patterns, a 100 percent (double) overlap between adjacent tips is suggested to optimize uniformity.



Hollow Cone Spray Tip



Wide-Angle Full Cone Spray Tip



Flooding Tip

Spray tips are a relatively minor investment. Nevertheless, matching the proper tip to specific types of chemical applications helps improve accuracy. That can pay dividends in maximizing the effectiveness of agricultural chemicals.

SPOTLIGHT ON CALAMUS DAM & RESERVOIR

North Loup Division
Pick-Sloan Missouri Basin Program, Nebraska

Early History of the Platte River Valley

The first settlers started arriving in the Platte River Valley by way of the Oregon Trail in 1832. However, the Loup River area remained unsettled until the late 1860's. From the beginning, the farmers were plagued with invasions of grasshoppers and other pests, but the greatest deterrents to stability in the agricultural economy were insufficient rainfall and recurring droughts. There were attempts to irrigate, with individuals devising and operating simple methods to bring water to the land. Several cooperative and district-type irrigation plans were conceived, and a few irrigation systems were built.

Some irrigation districts were eventually organized; the largest was the North Loup River Public Power and Irrigation District. Other irrigation development is generally limited to water being pumped from the river to irrigate adjacent lands. The Twin Loups Reclamation District, organized in 1954, and the Twin Loups Irrigation District, organized in 1958, were formed as legal entities of the State of Nebraska to operate the North Loup Division.

Investigations in the area were conducted by private engineering firms beginning in 1933. The Bureau of Reclamation made its first study in 1943 which resulted in recommendations for irrigation development in the Loup Valley. This plan received basic congressional approval and authorization by the Flood Control Acts of 1944 and 1946.

A more extensive investigation was undertaken late in 1944, and a preliminary report was completed for the Lower Platte River Basin in 1951. Plans for a North Loup Division were included in this broad basin plan.

The Division was authorized on October 20, 1972. Construction began on June 4, 1976, with execution of the first contract in connection with improvement of the county road for access to Calamus Dam site. This road improvement was completed June 16, 1977.

The North Loup Division is located within the Loup River drainage basin in central Nebraska. Diversion facilities are on the Calamus and North Loup Rivers. The plan provides for direct surface water service to 53,000 acres of land. Operation of the Division will provide a sustained ground-water supply for the development of an additional 17,000 acres by private investment. Of the 70,000 acres benefiting from project development, 43,500 are considered to be nonirrigated and 26,500 are considered to be irrigated. The Twin Loups Reclamation District and the Twin Loups Irrigation District will benefit from and pay for the irrigation facilities. The Division will provide a water supply to the area that can be served economically by gravity and private farm pumps.

In addition to irrigation, the Division will include recreation and fish and wildlife benefits. The Division will provide increased recreation opportunities, particularly those associated with water sports. Fish and wildlife resources will be benefited by the water development project. Principal benefits will be to fishing and hunting.

Calamus Dam

The dam embankment is a zoned, rolled, earthfill structure over 7,000 feet in length with a maximum height of approximately 89 feet above the bed of the Calamus River about 5.5 miles northwest of Burwell, Nebraska. The dam also includes a 10-foot-thick upstream impervious blanket and soil-cement on the upstream face of the embankment and on portions of the upstream blanket. The dam has a cutoff trench along the entire length that was excavated to designed depths, backfilled, and compacted with various zones of material. A slurry trench is located 300 feet upstream of the centerline crest of the dam and has a length of approximately 7,000 feet with depths ranging from 45 to 110 feet.

Calamus Dam Reservoir has a total storage capacity of 127,400 acre-feet with 5,123 surface acres at elevation 2244 feet. At the top of the conservation pool, elevation 2244 feet, the reservoir has an active conservation capacity of 102,754 acre-feet. From the dam, the reservoir extends upstream about 9 miles. The maximum width of the reservoir is about 1.5 miles.

The spillway consists of a glory-hole inlet structure, a 10-foot-diameter steel-lined encased conduit through the dam embankment, a concrete chute, and a stilling basin.

The river outlet works includes an intake structure, 10-foot-diameter steel-lined upstream conduit, gate chamber housing a 6-foot 6-inch by 10-foot high-pressure guard gate, 14-foot 6-inch horseshoe access conduit with a 9-foot-diameter steel outlet pipe, control structure with a bifurcation, an outlet to serve the Mirdan Canal branch, and a river outlet works branch. The river outlet-works branch consists of an emergency-generator house, a control house containing two 5- by 6-foot high-pressure regulating gates, a concrete chute, and a stilling basin.

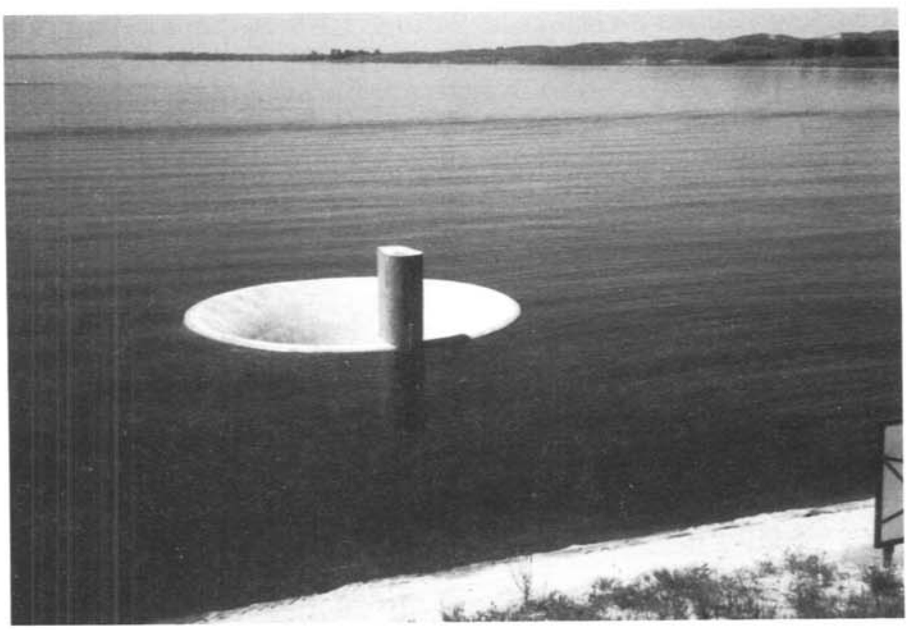
The Mirdan Canal branch consists of a 9-foot-diameter steel-lined conduit beginning at the bifurcation, gate house containing two 5- by 6-foot high-pressure regulating gates, chute, stilling basin, and a transition to the Mirdan Canal prism.

Seepage control includes filtered chimney and blanket drains in the embankment, toe drains, and relief wells along the toe of the embankment. Relief wells and filter zones are also installed at the spillway stilling basin, the river outlet works stilling basin, and the river outlet works outlet channel.

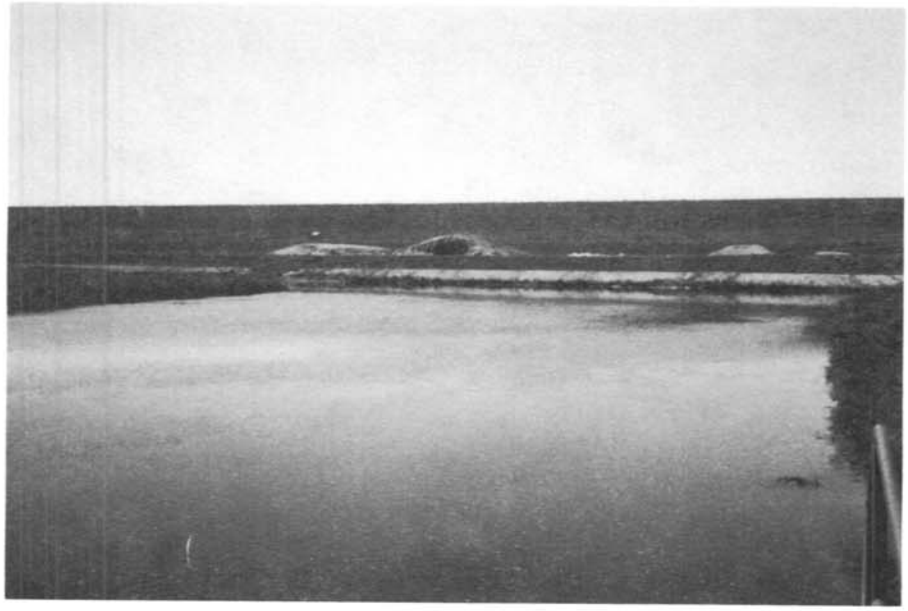
In the dam and reservoir rights-of-way, there are approximately 23 miles of paved road, 40 miles of barbed wire fence, a 30- by 80-foot concrete road bridge over the Calamus River, an embankment and corrugated-metal-pipe drop structure at Gracie Creek, and a 24- by 60-foot prefabricated metal building.

There were 242,815 visitors and 13,500 camp participants during the 1988 recreation season. The area has 4,400 registered campsites. In addition to four completed boat ramps, there exists the possibility that a marina and a swim beach may be built in a few years, but such plans are not definite.

Calamus Dam - Spillway discharge channel. 6/7/88



Calamus Dam - Spillway inlet structure. Reservoir elevation 224.92 feet. 6/7/88

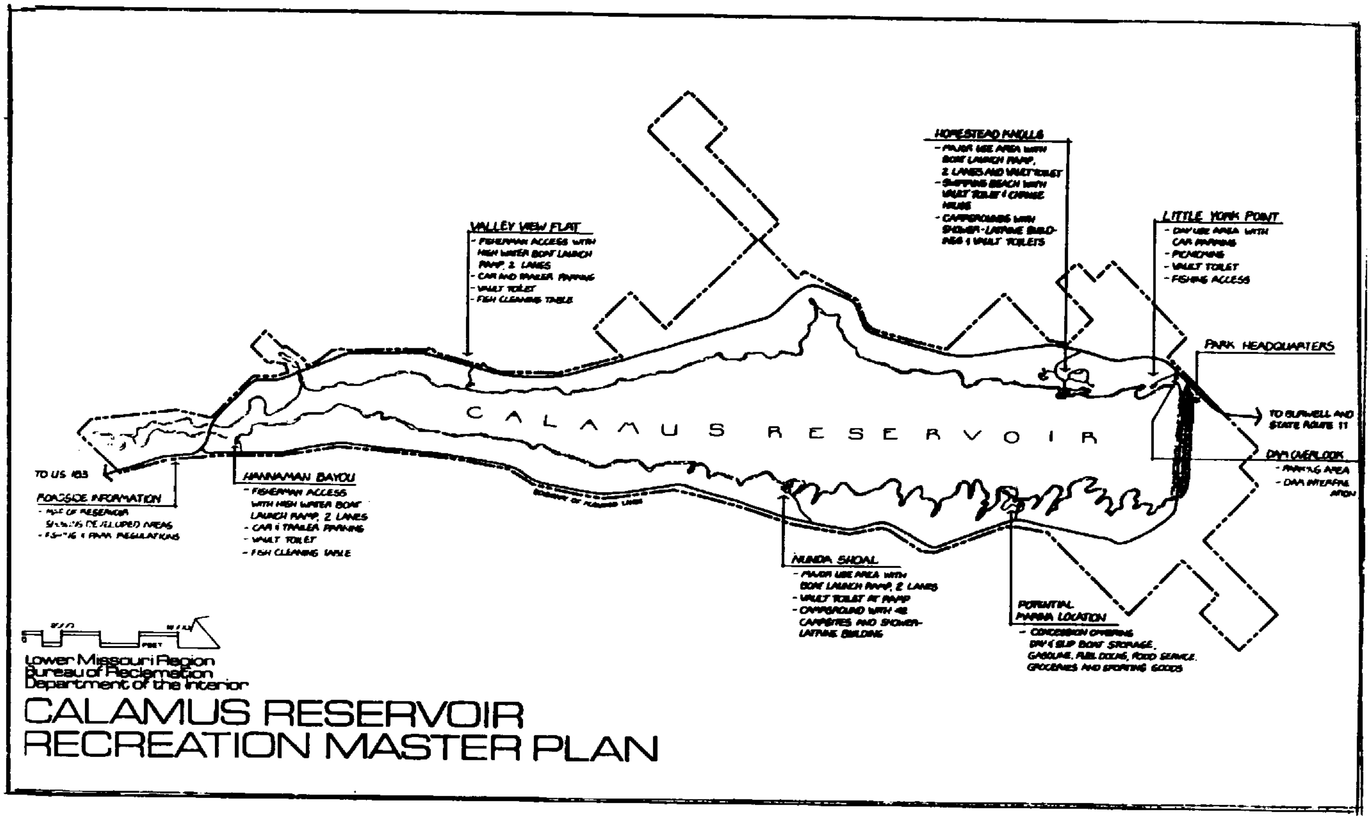


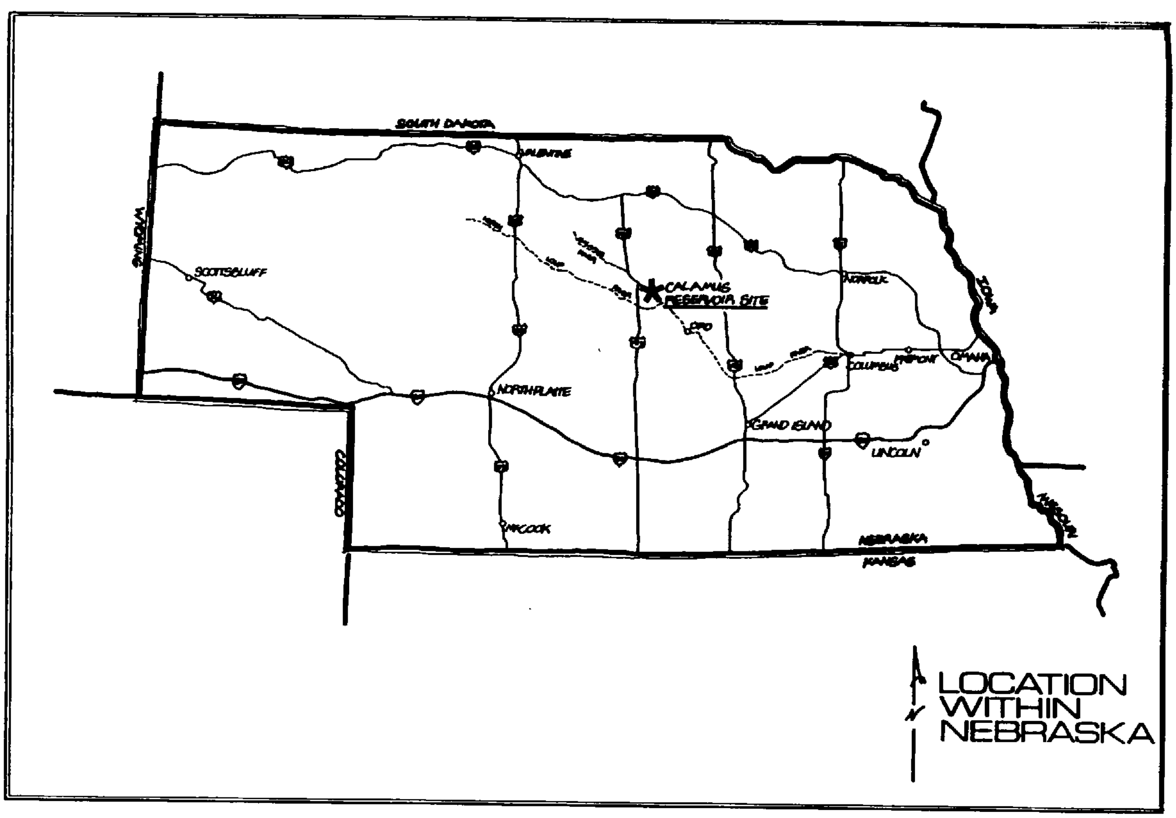
Calamus Dam - Junction of river outlet and spillway discharge channels from river drop structure. 6/7/88

Calamus Dam - River drop structure. 6/7/88

Calamus Dam - Soil-cement protection on upstream face of dam. 6/7/88

Calamus Dam - Calamus River downstream of river drop structure. 6/7/88


HOMESTEAD KNOLLS
- MAJOR USE AREA WITH BOAT LAUNCH RAMP, 2 LANES AND VAULT TOILET
- CAMPGROUNDS WITH SHOWER-LATRINE BUILDINGS & VAULT TOILETS
VALLEY VIEW FLAT
- FISHERMAN ACCESS WITH HIGH WATER BOAT LAUNCH RAMP, 2 LANES
- CAR AND TRAILER PARKING
- VAULT TOILET
- FISH CLEANING TABLE
LITTLE YORK POINT
- DAY USE AREA WITH CAR PARKING
- PICNICKING
- VAULT TOILET
- FISHING ACCESS
PARK HEADQUARTERS
CALAMUS RESERVOIR
TO BURWELL AND STATE ROUTE 11
TO US 183
DAM OVERLOOK
- PARKING AREA
ROADSIDE INFORMATION
HANNAMAN BAYOU
- FISHERMAN ACCESS WITH HIGH WATER BOAT LAUNCH RAMP, 2 LANES
- CAR & TRAILER PARKING
- VAULT TOILET
- FISH CLEANING TABLE
NUNDA SHOAL
- MAJOR USE AREA WITH BOAT LAUNCH RAMP, 2 LANES
- VAULT TOILET AT RAMP
- CAMPGROUND WITH 48 CAMPSITES AND SHOWER-LATRINE BUILDING
POTENTIAL MARINA LOCATION
- CONCESSION OFFERING DRY & SLIP BOAT STORAGE, GASOLINE, FUEL DOCKS, FOOD SERVICE, GROCERIES AND SPORTING GOODS
FEET
Lower Missouri Region
Bureau of Reclamation
Department of the Interior
CALAMUS RESERVOIR
RECREATION MASTER PLAN


SOUTH DAKOTA
VALENTINE
SCOTTSBLUFF
CALAMUS RESERVOIR SITE
NORFOLK
NORTH PLATTE
GRAND ISLAND
COLUMBUS
FREMONT
OMAHA
LINCOLN
McCOOK
NEBRASKA
KANSAS
IOWA
MISSOURI
LOCATION WITHIN NEBRASKA

GPO 859-285

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.