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IRRIGATION DITCH MANAGEMENT ON ARIZONA IRRIGATED FARMS

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ORGANIZATION

This study is a result of the joint efforts of the Department of Agricultural Economics, University of Arizona, the Salt River Valley Water Users' Association, the U.S. Department of Interior, Bureau of Reclamation, and the U.S. Department of Agriculture, Soil Conservation Service.

In addition a number of farmers within the Salt River Valley aided in supplying the cost data used in the analysis. Their co-operation is appreciated.

*On leave

All photographs are by Carl A. Wiese

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SUMMARY AND CONCLUSIONS

1. Water shortages and increased water and labor costs have necessitated improvements in irrigation systems in Arizona.
2. During the first six months of 1951, 175 miles of concrete-lined irrigation ditches and 31 miles of underground pipelines were installed in Arizona under the supervision of the Soil Conservation Service.
3. The cost of installing a concrete irrigation system has not increased as much during the past few years as the cost of the irrigation water and the agricultural labor saved by such an installation.
4. The principal sources of savings resulting from the installation of an improved irrigation system are:
   a. More profitable use of ditch area
   b. Decreased weed control costs
   c. Reduction in the amount of irrigator's labor required
   d. Decrease in the amount of water lost through seepage.
5. Under farm irrigating conditions, seepage losses were found in this study to vary from 3 per cent to 16 per cent of flow per ¼ mile in unlined ditches. The loss was greater during the first six to eight hours than during the remainder of the irrigation period.
6. The approximate 1950 cost of converting a ¼ mile section of unlined-unfenced ditch to each of the following systems was:
   a. Unlined-fenced $ 400
   b. Concrete-lined $1,050—$1,430
   c. Underground pipe $4,500
7. The installation of a concrete irrigation system is a water conserving measure eligible for government payments under the Agricultural Conservation Program. In some cases the payments amount to as much as 50 per cent of the installation cost.
8. No one system of irrigation is best under all conditions. The slope of the land, texture of the soil, crops grown, and personal likes and dislikes of the farmer are all factors in determining the system to be used.
9. Fencing the ditch and pasturing the ditch area is recommended on small farms where the amount of water lost through seepage with the existing ditches is small.
10. Lining the ditch with concrete is recommended where seepage losses are high, water costs are high and/or a large volume of water is carried in a ditch section.
11. The installation of an underground pipe system is recommended in areas where the agriculture is expected to be on a permanent basis, seepage losses are high, and the operator is financially able to make a long term investment.
12. The budget analysis presented in this report is a useful tool in determining which system of irrigation should be used under a given set of conditions.

IRRIGATION DITCH MANAGEMENT ON ARIZONA IRRIGATED FARMS

By Rex Rehnberg[1]

INTRODUCTION

During the first six months of 1951 about 175 miles of concrete-lined ditch and 31 miles of underground pipe were installed in Arizona under the supervision of the Soil Conservation Service. There are a number of reasons for the current interest in permanent irrigation systems, the main one being the changing relationship between the price of irrigation water, farm labor, and the cost of concrete irrigation systems.

A farmer who installs a permanent irrigation system now is, in effect, substituting concrete and construction labor at present prices for the water, labor, and other materials he hopes to save during the life of the system. The savings from the permanent installation are realized through decreased seepage losses, lower weed control and ditch maintenance costs and diminished irrigation labor requirements.

During the last ten years the cost of agricultural labor and water has risen much more rapidly than the cost of cement, (Fig. 1). An index of the cost of concrete structures is not available. If such an index were available it would probably have increased more rapidly than the cost of cement but less rapidly than the cost of labor as cement constitutes about 20 per cent of the total cost of concrete-lined ditches. Because the total cost of a permanent irrigation system has not risen as rapidly as the cost of the items which are saved, such installations are now justified in many cases where they were not twenty years ago.

Many farmers are now asking the question, "Can I afford to install a permanent irrigation system?" Lending institutions also would like to know under what conditions a loan to a farmer for irrigation ditch improvement would be justified. It was the purpose of this study to help answer these questions.

METHOD OF STUDY

During the calendar year 1950, cost records were kept on the ditch section of the irrigated area served from sixteen different water turnouts within the Salt River Project. The original intention was to keep records on four areas with each of the following ditch systems:

1. Open ditch, unlined and unfenced.
2. Open ditch, unlined but double fenced and pastured.
3. Concrete-lined open ditches.
4. Complete underground pipe system.

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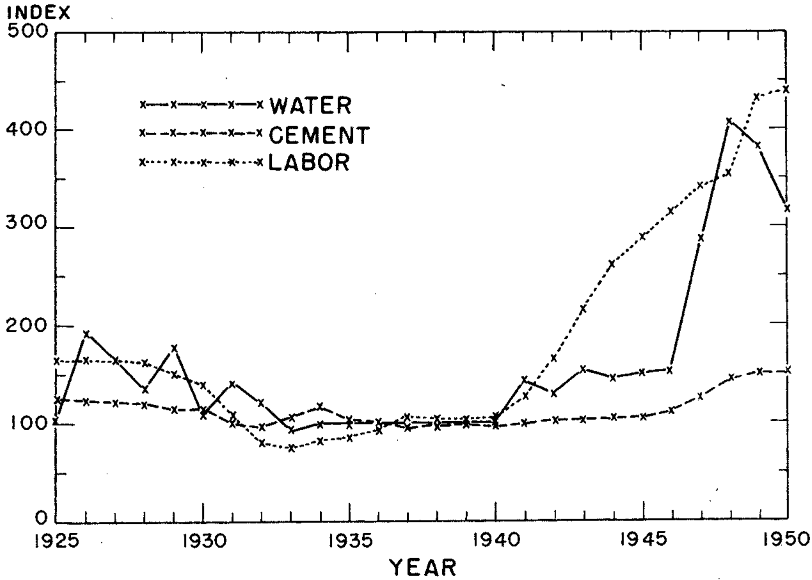

FIGURE 1.—Index of price of labor and cement in the United States and index of cost of 3 acre-feet of water in the Salt River Project, 1922-50 (1935-39=100).

Due to a change in operators on one of the farms with the underground system and a change in the method of irrigating another farm, three records were obtained on the first and fourth systems mentioned above and five records each on the other two.

Records were kept on the following cost items on these fields:

1. Maintenance and repairs of the ditch.
2. Weed control costs on the ditch area.
3. Amount of water delivered and hours of irrigator's labor required.

In addition, a number of seepage tests were run under actual irrigating conditions in order to determine how much water was lost between the Salt River Valley Water Users' turnout and the field that was irrigated. Both head ditches and conveyor ditches were included in the study.

It should be emphasized that this study was conducted within the Salt River Project and the figures presented have limited application outside that area. The method of analysis will apply equally well in a pump or gravity-flow area. In general the soils are heavier within the project and seepage losses are lower than in some of the other areas. The ditches are well established and have a vegetative cover in most cases. The Water Users' deliver the water to the high point on each quarter section. Most of the farm ditches within the project carry less than 320 acre-feet of water per year.

No one irrigation system is the best under all conditions. The slope of the land, texture of the soil, crops grown, and personal likes and dislikes of the farmer are all factors in determining the system to be used. On any one farm a combination of two or three of the systems listed above may be necessary to secure the most efficient water delivery. The analysis which follows is on the basis of ¼-mile ditch sections. This makes it possible to arrive at the system of ditch management that appears to be best adapted on each section of the ditch.

COST OF EACH SYSTEM

The greatest difference between the four systems is the capital invested in each. System 1, the *unlined, unfenced,* open earthen ditch is the most common in the Salt River Valley at the present time and represents the lowest capital investment (Plate I). System 2 is very similar to System 1 except that the ditch section is fenced on each side and the enclosed area pastured (Plate II). System 3 differs from System 1 in that the ditch is lined with concrete (Plate III). System 4 is the complete underground pipe system (Plate IV). In order to avoid needless repetition during the remainder of this report, System 1 will be referred to as *unlined-unfenced,* System 2 as *unlined-fenced,* System 3 as *lined,* and System 4 as *underground.*

Most farmers in the Salt River Valley project are not concerned with the initial cost of each type of installation as they already have some type of system on their irrigated land. They are concerned with the cost of converting their present system to one of the other types. Since most conversions will be made from the *unlined-unfenced* system, all costs will refer to the cost of converting it to the other types.

COST OF CONVERTING FROM UNLINED-UNFENCED TO AN UNLINED-FENCED SYSTEM

In converting from the *unlined-unfenced* to the *unlined-fenced* system all that is necessary is the addition of a fence on each side of the ditch. At prices prevailing in 1951 the total cost of double fencing ¼ mile of ditch was about $400.[2] This was the approximate cost of installation on the basis of a new fence on both sides of the ditch. In cases where a single fence already existed on the property line, the cost of adding the second fence would, of course, be about $200.

[2]Computation of fencing cost:

160 rods of 32-inch woven wire (12½ gauge)	$160.00
320 rods of barbed wire	30.00
160 steel posts	140.00
Cost of installation	70.00
	$400.00

PLATE I.—The Unlined-unfenced System. This system requires a low capital investment and was very common in Arizona in 1950.

PLATE II.—The Unlined-fenced system. Sheep or cattle are used to pasture off the weeds in the enclosed area.

COST OF CONVERTING FROM UNLINED-UNFENCED TO LINED SYSTEM

Several types of concrete lining can be installed in an open ditch. The cost of these linings varies with the type installed, the size required, and the amount of ditch bed preparation necessary before the lining can be installed. For purposes of comparison, let us assume that a farmer has a ditch section with an average fall of 1 foot per 1,000 feet. He desires a ditch that will carry about 300 miner's inches or 3,370 gallons per minute.

The ditch requiring the least capital outlay is a hand-plastered one installed by the farmer with his own crew during the season when other work is not pressing. The quality of such an installation will be greatly influenced by the skill of the farmer and his crew. A study of ditches of this nature during 1950 revealed that, although such installations are not as attractive as many built by contractors, they are about equal in the control of seepage losses. At the prices of labor and materials existing in early 1951, such a ditch could be constructed for about 80c per lineal foot or $1,050 per ¼ mile. This cost includes farm labor, skilled labor, and all materials.

Slip-form lining of a similar size costs about 85c per lineal foot or $1,100 per ¼ mile. In addition, there was a charge of $1.50 for every outlet installed.

A reinforced gunited concrete ditch cost about $1.10 per lineal foot or $1,430 per ¼ mile, exclusive of outlets.

In addition to the costs listed above, there was, in some cases, a charge for new outlets. However, because we are comparing a *lined* with an *unlined* ditch, the cost of any change in outlets was not included.

COST OF CONVERTING FROM UNLINED-UNFENCED TO UNDERGROUND SYSTEM

The underground pipe system is the most expensive to install. The cost of such a system varies with the installation difficulties encountered. At prices prevailing in early 1951 a 24-inch underground system with a 12-inch valve every 33 feet cost about $4,500 per ¼ mile. The capacity of a 24-inch system is comparable to the lined ditches mentioned above.

PRODUCTION AND MARKETING ADMINISTRATION PAYMENTS

The installation of a concrete irrigation system, lined or underground, is a water-conserving measure eligible for government assistance under the Agricultural Conservation Program. Under the 1951 program, the following payments can be secured:

1. $0.10 per cubic yard of earth moved.
2. $10 per cubic yard of concrete.
3. 50 per cent of the cost of the gates, pipe, and other materials.[3]

[3]For footnote, see Page 10.

PLATE III.—The Concrete-lined Ditch. The concrete lining reduces the amount of water lost through seepage.

There is, however, a limit of $2,500 per farm for the year 1951.

If a farmer receives these assistance payments, the cash cost of the system to him can be reduced. The exact amount of the payment will vary with the type of installation and the amount installed. Occasionally the payment schedule is revised from year to year. These possibilities should be investigated before making the final decision as to which type of irrigation system to install.

SOURCES OF SAVINGS

Although some land owners may install a concrete irrigation system because it makes the farm more attractive, most commercial farmers will not make such an investment unless they think it will increase their long-time net return from farming. In order to do this, the improved system must either decrease the costs or increase the gross returns from the farming operations. What, then, are the possible sources of savings from an improved irrigation system?

AREA OCCUPIED BY THE DITCH

In any irrigated area a part of the potentially productive land is occupied by ditches. Under most systems of ditch management, this area is not used for productive purposes but is a source of expense. It is, therefore, a charge against that system.

On the farms studied, the area occupied by the open dirt ditches averaged about 18 feet in width. This amounts to a little over ½ acre of land per ¼ mile of ditch. The ditch area where lining had been installed was smaller, averaging about 13 feet, occupying less than 0.4 acres per ¼ mile of ditch. The area kept out of cultivation by an underground pipe system is negligible. In most cases, the pipeline is installed to a depth sufficient to permit the use of most tillage equipment over it. The only land actually taken out of production is a small area surrounding each valve plus possibly 1 or 2 feet between the pipeline and the fence or property line.

WEED CONTROL

Controlling weeds in the ditch area, a common problem in all irrigated areas, is a large item of expense to many farmers. This problem is largely eliminated by the installation of underground pipe or by double-fencing the ditch area and pasturing it. Lining the ditch with concrete reduces the weed problem somewhat but is not as effective as either of the two methods listed above.

On the installations on which records were kept, the weed control costs were very small on the *unlined-fenced* and *underground* systems (Table 1). Lining the ditch with concrete did not greatly reduce the weed control costs. In most cases the ditch had been

[3]Agricultural Conservation Program for Arizona, Handbook for 1951, U.S. Department of Agriculture, Production and Marketing Administration, page 12.

PLATE IV.—The Undeground Pipe System. The entire system is underground except for the standpipes and the irrigation valves.

TABLE 1.—COST OF WEED CONTROL PER ¼ MILE OF DITCH SALT RIVER VALLEY—1950

Type of ditch	Number of cases	Cost per ¼ mile per year: Range	Cost per ¼ mile per year: Average	Saving over unlined-unfenced
Unlined-unfenced	5	\$13 - \$ 92	\$50	\$ 0
Unlined-fenced	3	3 - 21	12	38
Lined	5	21 - 101	46	4
Underground	3	0 - 10	3	47

lined within the last one or two years and expensive chemicals were being used to control the weed growth. It is possible that the weed control costs on lined ditches will decrease as the cumulative effects of the chemicals are realized.

IRRIGATOR'S LABOR

Few people will dispute the point that it is easier to irrigate from an *open-lined* ditch or *underground* system than it is from an open dirt ditch. The question of economic importance to the farm operator is "How much will an improved system decrease the cost of irrigator's labor on my farm?"

A tabulation of the irrigator's hours per acre-foot of water delivered on the farms studied did not reveal any relationship between irrigator's labor requirement and the type of ditch. This does not indicate that the installation of a concrete system will not make labor savings possible in some cases. It does indicate that many factors, other than the type of ditch installation, affect the irrigator's hours required per acre-foot of water delivered.

An important factor influencing the cost of distributing an acre-foot of water is the size of the head of water. For example, a head of water of 100 miner's inches (about 1125 G. P. M.) will yield an acre-foot of water in five hours. If water costs \$4 per acre-foot, and an irrigator costing 85c per hour is required to distribute the water, the labor cost is greater than the cost of the water. If 200 miner's inches could be handled by the same irrigator, the labor cost would be only about half the cost of the water.

On many of the larger operations, a regular irrigating crew is rotated from field to field in an irrigation schedule. Each field may have a different type of irrigation system. Under such an arrangement, the amount of work required may vary widely between fields but the labor cost to the operator will be nearly uniform. Many irrigators have expressed a definite preference for lined ditches. In times of an acute labor shortage an operator with lined ditches is likely to be more successful in hiring and retaining irrigators.

In arriving at the probable savings in irrigator's labor from installing a permanent irrigation system, consideration should be given to how the new system will fit into the over-all farm set up.

In some cases, the lining of a ditch or the installation of an underground system has greatly reduced the number of irrigator's hours required. In other cases, the labor requirement for irrigation has not been altered. It is, therefore, impossible to make generalizations about the potential savings in labor requirements without studying the individual operation.

PASTURE CREDIT

On ditches that are double-fenced and pastured, the plant growth in the area becomes a source of revenue rather than a weed control expense. On the three pastured ditches covered in this study, this return averaged about $50 per acre of ditch area per year. This figure was obtained by applying the 1950 pasture rental rate to the animal days of pasture realized from the ditch area.

SEEPAGE LOSSES

The diminishing water supply in the irrigated West has created serious concern over the amount of water lost through seepage in irrigation ditches. As water has become more costly, it has paid to install more expensive structures in order to reduce the water transmission losses.

Method of testing seepage losses: In order to determine how much water was being lost through seepage, a series of tests were conducted during 1950 on farm ditches in the Salt River Valley and surrounding areas. Fields were selected on which the water was conveyed through a ditch for some distance before reaching the field on which it was to be distributed. The length of the conveyor ditches varied from ¼ to 1 mile. A Sparling low-pressure line meter was installed on the upper end of the conveyor ditch, and a second meter was installed at the lower end. By comparing the amount of water that passed through the two meters, the total seepage loss was determined.

The inflow-outflow method was used for several reasons:

1. The meters could be installed without interrupting the normal irrigation schedule.
2. The conditions under which the losses were tested approximated normal irrigating conditions.
3. The meters automatically recorded the acre-feet of flow.
4. By taking a series of readings, the pattern of water loss throughout the irrigation period could be determined.

Results of seepage tests: Seepage losses can be expressed in several ways. One of the most common is to express losses as a percentage of flow. This has the advantage of being easy to compute and easy to understand. However, it means little unless the length of the section and the rate of flow are also specified.

Another method of expressing seepage losses is to express it as a loss in acre-feet per acre of wetted ditch area per twenty-four hours. This method is not as easily understood as the first, but has a number of advantages. By expressing water loss in terms of wetted area, the length of the ditch, the size of the ditch, and the rate of flow are considered, as they are the factors determining the wetted area. It is, therefore, possible to make direct comparisons between ditches of varying sizes and length and at varying rates of flow.

This method also calls attention to the factors which increase seepage losses. Any factor that increases the wetted area is likely to increase the amount of water lost through seepage. Any restrictions in the ditch such as irregular sides and bottoms or tall weeds will increase the wetted area, resulting in increased seepage losses. It is held by some that seepage losses are greater in wide, flat ditches than in semicircular ditches because of the larger wetted area. Other tests have shown that the rate of water penetration is greater on the sides of the ditch than on the bottom.[4] This would offset somewhat the disadvantage of the wide, flat ditch.

The amount of water lost through seepage varied widely among installations. The seepage loss is expressed both as percentage of inflow and as loss in acre-feet per acre of wetted area in twenty-four hours (Table 2). This table does not provide an exact means of determining the probable water loss in any ditch located on a similar soil type. However, it does provide the upper and lower limits within which most ditch losses within the Salt River Valley would fall.

The ditch on which Test 3 was conducted was selected because it had many features associated with a high loss ditch. The upper portion of the ditch passed through a very sandy ridge. The ditchbank had washed away on each side resulting in a wide, flat ditch. There was less than 1/10 of a foot fall in the first 500 feet of ditch. It was not surprising, therefore, to find that 16 per cent of the water flowing into this ditch was lost in the first ¼ mile.

Looking at it in another way, the ditch was 1,285 feet long with an average wetted perimeter of 8.34 feet. This results in a wetted area of 10,717 square feet, or approximately ¼ of an acre. Every twenty-four-hour period that this ditch is kept full about 6.96/4 or 1.74 acre-feet of water are lost (Table 2). If water is valued at $4 per acre-foot, about $7 worth of water is lost every day that this ditch is full.

Test 5 was conducted on a very similar ditch that had been lined with concrete. This reduced the seepage loss to 2.7 per cent of flow. Part of this indicated loss may be due to inaccura-

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[4]For a more detailed discussion see Rohwer, Carl and Oscar Van Pelt Stout, Seepage Losses from Irrigation Channels, Colorado Agriculture Experiment Station. Technical Bulletin 38, March, 1948.

cies in the measuring devices. Seepage tests conducted in other areas by measuring the drop in pools made by damming both ends of the section of canal have indicated that losses through properly constructed concrete linings are much less than indicated above.[5] Unless the ditches are cracked badly seepage losses in lined farm ditches will be less than 1 per cent of inflow per ¼ mile.

TABLE 2. — SEEPAGE MEASUREMENTS, SALT RIVER VALLEY, ARIZONA, 1950

Test number	Soil type	Average wetted perimeter of ditch	Average inflow*	Seepage loss: Per cent of inflow per ¼-mile†	Seepage loss: Per acre of wetted ditch area per twenty-four hours
		Feet	Miner's inches	Per cent	Acre-feet
1	Cajon Silty Clay Loam (Shallow phase)	4.21	196	6.5	4.98
2.	Cajon Silt Loam and Silty Clay Loam	7.00	227	5.7	3.C5
3.	Mohave Fine Sand and Sandy Loam	8.34	216	16.0	6.96
4.	Cajon Silty Clay Loam (Shallow phase)	5.15	168	6.0	3.30
5	Mohave Fine Sand (Concrete Lined)	7.08	173	2.7	1.10
6.	Mohave Sandy Loam	4.65	177	3.6	2 37
7.	McClellan Loam	6.44	302	3.0	2.28
8.	McClellan Loam	6.66	233	3.3	1.94
9.	Cajon Silty Loam and Cajon Fine Sandy Loam	8.02	478	3.0	2.95
10.	Cajon Silty Clay Loam	8.53	235	9.8	4.48

*To get gallons per minute multiply by 11.2; cubic feet per second, divide by 40.
†Losses were converted to ¼-mile equivalent on basis of straight line variation.

Seepage losses in six of the ten tests were within the range of 3 per cent to 6 per cent of inflow per ¼ mile (Table 2). Losses within this range are more common than the 9.8 per cent on Test 10 and the 16 per cent on Test 3.

At the time the total seepage loss was determined, the pattern of loss during the period of irrigation was also determined. This was done by computing the rate of inflow and outflow at 30-minute intervals during the test. On Test 3 the water loss was a little greater during the first five to six hours that the water was in the ditch (Fig. 2). Following this time the loss was nearly constant. A very similar pattern was found on Test 4 although the total loss was much less than on Test 3 (Fig. 3).

The patterns of loss on the ten tests indicate that the loss during the first few hours of the irrigation is slightly higher than during the remainder of the period. However, in all cases the seepage loss continued after the ditch had had time to become thoroughly wetted.

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[5]See footnote on previous page.

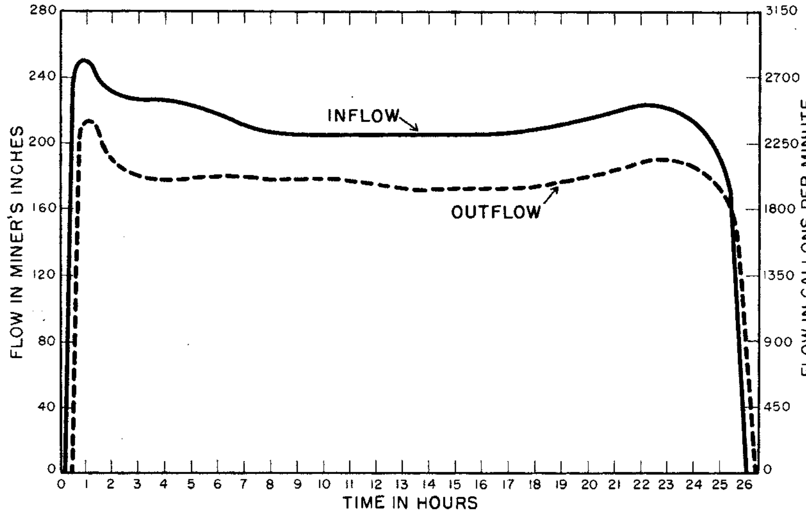

FIGURE 2.—Pattern of seepage loss on Test 3, unlined ditch, Mohave fine sand and sandy loam.

Methods of valuing water: There has been much discussion concerning the value of water lost through seepage. There are at least three methods of valuing water, and each is appropriate under a given set of conditions.

The valuing of water at cost is very common, and correct in those cases where the additional amount required can be purchased at that price. For example, if within a project an operator does not use his entire allotment, the water lost through seepage should be valued at the cost at which additional water could be purchased.

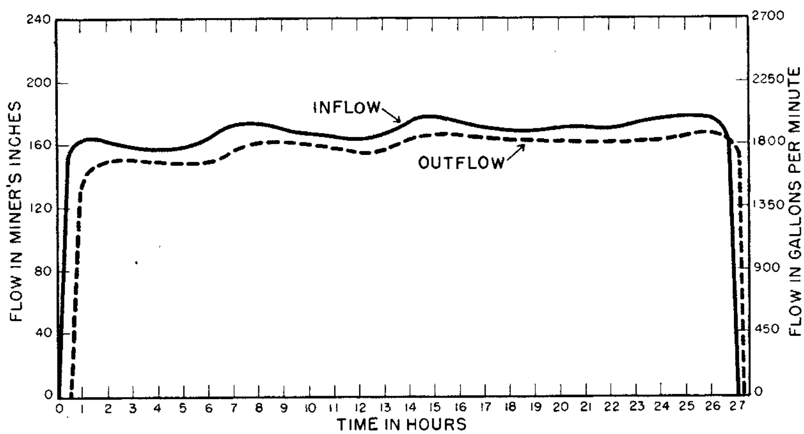

Figure 3.—Pattern of seepage loss on Test 4, unlined ditch, Cajon silty clay loam (shallow phase).

Another method of determining the value of water is to estimate the additional net return that would have been realized by the application of the water to the land. For example, the water lost through seepage may have been sufficient to increase hay yields by ¼ ton or grain yields by 500 pounds. The value of the water is, therefore, the market value of the additional produce minus the cost of harvesting and marketing it.

In some irrigated areas only a part of the potentially irrigable land is under cultivation because of a shortage of water. In such areas, the water lost through seepage would be valued at the net return it would have yielded if applied to the idle land.

It should be emphasized that *net return* referred to above is the value of the product produced on the land minus all of the costs of producing it except water.

COSTS AND SAVINGS BETWEEN SYSTEMS

The costs and savings of the various systems have been considered separately. In order to make a direct comparison, it is necessary to convert both the cost and the savings to an annual basis.

Accountants refer to the annual costs of ownership as the "DIRTI 5," namely, depreciation, interest, repairs, taxes, and insurance. Buildings, machinery, and some types of crops can be, and often are, insured against fire, theft, storms, etc. It is not the present practice to insure an irrigation system. Neither is it the present policy to increase property taxes because of an improvement in the system. The three remaining annual costs are depreciation, interest, and repairs.

One method of expressing the annual use-cost is to compute it as a percentage of the original investment. For example, if the estimated useful life is 25 years, then the depreciation rate will be 4 per cent per year. At current rates, interest on the investment would equal about 5 per cent of the average investment during the life of the system. Since the system depreciates from the original cost to practically zero during its useful lifetime, the average investment will equal approximately one-half the original investment. Interest can, therefore, be expressed as 5 per cent on one-half of the original investment or as 2½ per cent of the original investment. Repair costs can be expressed as a fixed sum per year or as a percentage of the original cost.

The annual use cost is an approximation of the benefits that must be realized from an improved system in order for it to be a sound investment. These requirements vary from about $30 per ¼ mile per year for the *unlined-fenced* system to $225 for the *underground* system (Table 3).

During the last five years many ditches have been lined in Arizona by the slip-form method. Although the slip-form is not a new development it has only been recently used as a method of lining farm ditches in Arizona. Farmers have rated these ditches

TABLE 3.—ANNUAL USE COST PER ¼ MILE FOR VARIOUS IRRIGATION SYSTEMS

Type	Cost of conversion	Estim't'd life year	Annual cost: Percentage of original cost: Dept. per cent	Int. per cent	Repairs per cent	Total per cent	Dollars Total
Unlined-fenced	$ 400	25	4.0	2.5	1.5	8.0	$ 32
Lined-Hand-plastered	1,050	33	3.3	2.5	0.5	6.3	66
Lined-Gunited concrete	1,430	33	3.3	2.5	0.5	6.3	90
Underground pipe	4,500	50	2.0	2.5	0.5	5.0	225

from very satisfactory to not acceptable. The cause of the failures, in those ditches that have failed, was found to be principally due to faulty construction. Proper construction is essential if a concrete-lined ditch is to have a long useful life.[6]

With a new development such as the slip-form ditches it is not possible to establish an estimated life based on farmer's experience. An individual contemplating such an installation should visit a number of slip-form ditches in his area and seek the advice of the owners. Recent improvements in construction may overcome the weaknesses in some of the earlier slip-form ditches.

The figures presented in this report are averages of a group of installations studied during 1950. On any particular installation the costs and savings may vary from these figures. They are presented as a general guide for those who do not have a more accurate estimate for their own situation. In recognition of the wide variation in these figures between installations, blank spaces have been provided in the proposed budgets that follow, in order that each operator can enter his own estimates.

UNLINED-UNFENCED VS. UNLINED-FENCED

On the basis of the average costs and returns on the farms studied in 1950, the decrease in annual weed control costs more than pays for the added annual cost of fencing the ditch area (Table 4). In addition there is a return from the pasture grazed from the ditch area. There is little evidence to indicate that seepage losses, irrigator's labor requirements, or the area occupied by the ditch are changed significantly by the addition of the fences.

The unlined-unfenced system seems best adapted on a farm with the following characteristics:

1. A heavy soil on which seepage losses are low.
2. A small operation where income from 1 or 2 additional acres is of importance to the operator.
3. An operator who has interest in, and the ability to care for, livestock, (preferably living on the farm).

[6]For more detail on concrete ditch construction see "Suggested Construction Methods and Specifications for Concrete Lined Farm Irrigation Ditiches," Arizona Agriculture Experiment Station. Report 106.

TABLE 4.—BUDGETED COSTS AND SAVINGS
CONVERSION FROM UNLINED-UNFENCED TO UNLINED-FENCED SYSTEM

1950 records			Individual estimate		
Cost of conversion			Cost of conversion		
Fencing ¼-mile ditch	$400		Fencing ¼-mile ditch	$..........	
Annual costs			Annual costs		
Interest ......(2.5%)	$ 10		Interest .... (......%)	$..........	
Depreciation (4.0%)	$ 16		Depreciation (......%)	$..........	
Repairs ....(1.5%)	$ 6		Repairs .... (......%)	$..........	
Total annual costs..		$32	Total annual costs....		$..........
Annual savings			Annual savings		
Land	$ 0		Land	$..........	
Weed control	$ 38		Weed control	$..........	
Irrigator's labor	$ 0		Irrigator's labor	$..........	
Pasture credit	$ 27		Pasture credit	$..........	
Total annual savings		$65	Total annual savings		$..........
Net gain or loss...........		+$33	Net gain or loss...........		$..........

4. An area in which weeds would be a serious pest if not properly controlled.

It is recognized that many large operators do not feel that these small savings are sufficient to compensate for the inconvenience of farming around fences and handling livestock. This viewpoint is justified where the farmer is primarily a crop farmer with holdings scattered over a wide area. It is likely that the cost of transporting the livestock from field to field and the death loss due to improper care of the animals would offset the benefits received.

UNLINED-UNFENCED VS. LINED

The savings in weed control costs, irrigator's labor, and the area occupied by the ditch did not equal the annual use-cost on a lined ditch on the farms studied. In order for ditch lining to be a profitable investment, there must be a decrease in the amount of water lost through seepage. An approximation of the savings required can be computed by working through a budget similar to the one presented in Table 4.

In Table 5 no credit was allowed for the agricultural conservation payments. In many cases these payments will amount to approximately one-third the cost of the installation. This greatly reduces the amount of water that must be saved before ditch lining becomes a sound investment.

After the annual dollars saving in water required is computed by the budget method, three factors become important in determining how far a farmer can economically go with ditch lining. They are:

1. The value of the irrigation water.
2. The amount of water lost through seepage.
3. The amount of water that annually flows through that section of the ditch.

The importance of these three factors can be shown with the following illustration. Suppose it were determined that $50 worth of water must be saved for every ¼ mile of ditch lining in order to pay the annual use-cost for lining. A farmer has a ditch 1 mile long out of which he irrigates on ¼ mile runs applying 4 acre-feet of water per acre measured at the source (Fig. 4). All of the water that was applied on the 160 acres (640 A. F.) would pass point A, 480 A. F. point B, 320 A. F. point C, 160 A. F. point D, and

TABLE 5.—BUDGETED COSTS AND SAVINGS CONVERSION FROM UNLINED-UNFENCED TO LINED SYSTEM

1950 records			Individual's estimate		
Additional cost			Additional cost		
¼-mile of ditch lining	$1,050		¼-mile of ditch lining	$........	
Less government payment	$		Less government payment	$........	
Net cost	$1,050		Net cost	$........	
Annual cost			Annual costs		
Interest (2.5%)	$26		Interest (......%)	$........	
Depreciation (3.3%)	$35		Depreciation (......%)	$........	
Repairs (0.5%)	$ 5		Repairs (......%)	$........	
Total annual cost		$66	Total annual cost		$........
Annual savings			Annual savings		
Land— 0. 1 A. @ $50 A.	$ 5		Land	$........	
Weed control	$ 4		Weed control	$........	
Irrigator's labor	$ 0		Irrigator's labor	$........	
Total annual savings (excluding water)		$ 9	Total annual savings (excluding water)		$........
Remaining cost (to be paid by savings in water)		$57	Remaining cost (to be paid by savings in water)		$........
Value of water $5 A.F.=11.4 A.F			Value of water $........A.F.=........A.F.		
Average annual flow through canal section		240 A.F.	Average annual flow through canal section		........A.F.
Seepage loss per ¼- mile required to equal 11.4 A.F. =4¾ per cent.			Seepage loss per ¼-mile required to equal ........A.F. = ...per cent.		

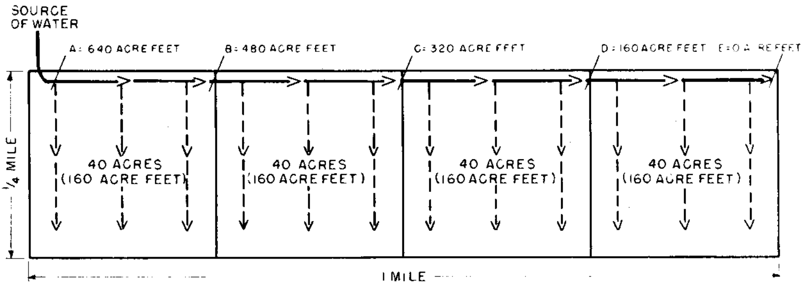

Figure 4.—Field layout and the amount of water carried in each section of the irrigation ditch where 160 acres are irrigated from 1 mile ditch.

O at points E. The average flow in the first ¼ mile of ditch would be 640 plus 480 divided by 2, equals 560 A. F., the second ¼ mile, 400 A.F., the third, 240, and the fourth, 80 A. F. If water is valued at $5 per acre-foot then a savings of 10 acre-feet per ¼ mile of ditch is required to yield the $50. This is equal to 1.8 per cent of flow on the first ¼ mile, 2.5 per cent of flow in the second, 4.2 per cent in the third, and 12.5 per cent in the last ¼ mile of ditch.

Under these conditions if 2 per cent of flow per ¼ mile could be saved by lining, it would be wise to line the first ¼ mile but not the second. If 10 per cent of flow per ¼ mile could be saved the first ¾ mile should be lined but not the last ¼ mile. This illustrates the importance of the rate of water loss through seepage and the volume of water carried in the ditch on the advisability of installing concrete ditch lining.

The importance of the value of irrigation water can be illustrated by assuming that water is valued at $10 per acre-foot instead of $5. A saving of 5 acre-feet per ¼ mile would then yield the desired return of $50. It would then become advisable to line the first ¼ mile if 0.9 per cent of flow could be saved, 1.3 per cent on the second ¼ mile, 2.1 per cent on the third ¼ mile, and 6.3 per cent on the last ¼ mile.

The ditch arrangement shown in Figure 4 is very common in pump areas. It is seldom found within the Salt River Project because of the Water Users' policy of delivering water to the high point of each ¼ section. Using the same assumptions as to field size and water-use presented in Figure 4, few farm ditches within the project will carry more than 320 acre-feet of water per year (Fig. 5). Under these conditions, there is not as much to be gained from ditch lining as there is in pump areas where water is conveyed greater distances and a given section of the ditch carries a larger volume of water per year.

The interrelationship of the rate of seepage, value of water and amount of water passing through a ditch section is shown graphically in Figure 6. This graph presents numerous combinations that result in a loss of $50 worth of water per year. A ¼-mile

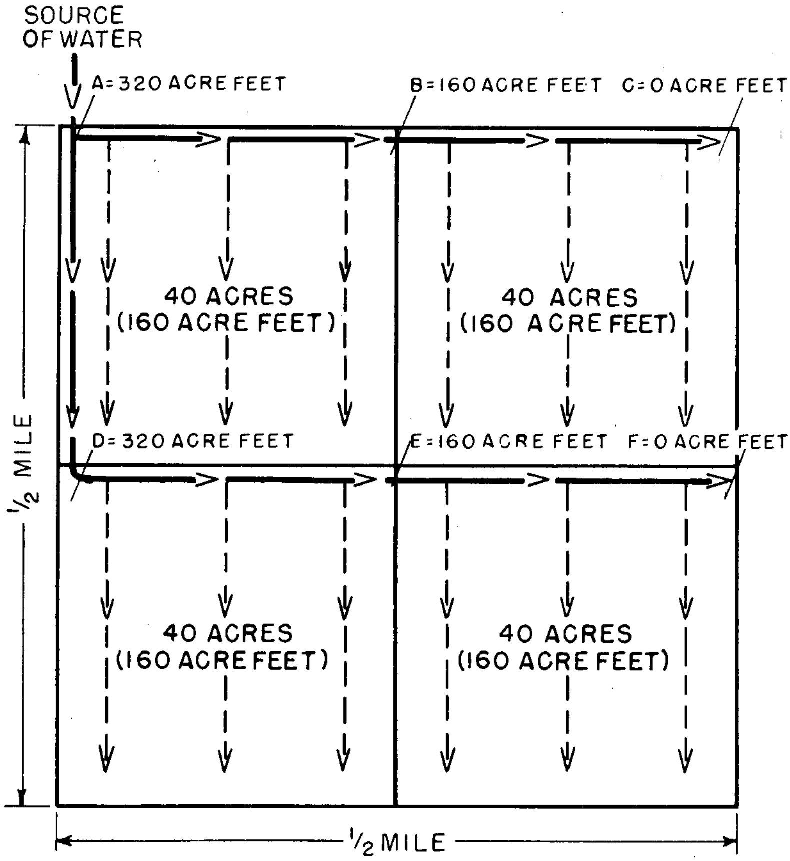

FIGURE 5.—Field layout and amount of water carried in each section of the ditch where the water is delivered to the high point of each ¼ section of land.

ditch carrying 100 acre-feet of water per year will cost $50 in water loss with a seepage loss of 8⅓ per cent with water at $6 per acre-foot, 10 per cent with water at $5 per acre-foot, and 12½ per cent at $4 per acre-foot. A ¼-mile ditch carrying 500 acre-feet of water per year will lose the same amount with a seepage loss of 1.7 per cent with water at $6 per acre-foot; 2.0 per cent at $5 per acre-foot and 2.5 per cent at $4 per acre-foot.

The three factors listed above—the rate of seepage loss, the value of irrigation water, and the amount of water carried in the ditch—are the factors which determine the economic advisability of lining a particular section of ditch, after an allowance has been made for the saving in weed control costs, irrigator's labor, and the land occupied by the ditch.

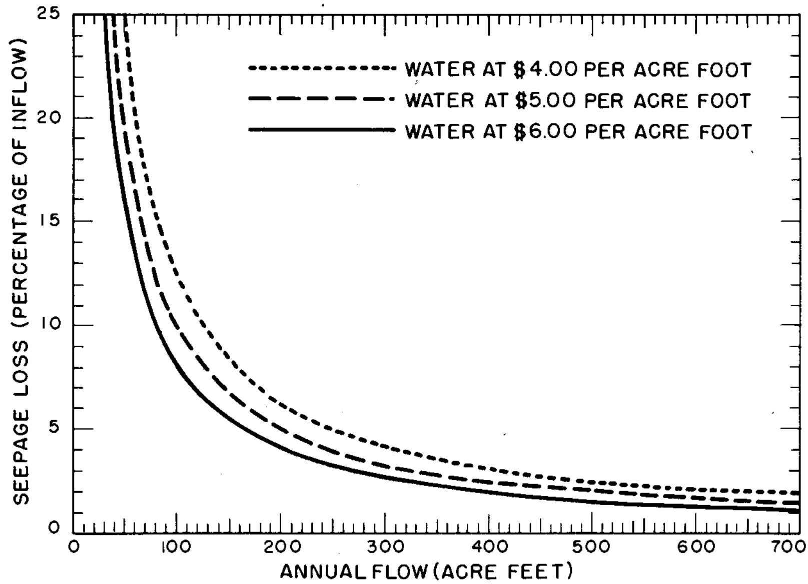

FIGURE 6.—Combination of factors resulting a $50 water loss. The variables are (a) Acre-feet of water carried in the ditch section; (b) seepage loss as percentage of inflow; (c) value of water per acre-foot.

UNLINED-UNFENCED VS. UNDERGROUND PIPE

The system that was the most expensive to install and which resulted in the greatest gross savings was the underground pipe system. Using the average costs and savings obtained in 1950, about $150 worth of water must be saved per ¼ mile in order to justify the investment of $4,500 (Table 6). If, on the other hand, half of the installation cost is refunded, through the conservation payments, only about $40 worth of water must be saved per ¼ mile per year to justify the investment. In addition, there may be a credit for a decrease in irrigation labor costs that was not included in the budget. An over-all picture of the farm as a unit is necessary before this estimate can be made.

LINED VS. UNDERGROUND PIPE

Although the budget analyses presented in Tables 5 and 6 are useful in estimating the relative profitability of a lined ditch or an underground pipe, several other factors influence the choice between the two systems. These factors are difficult to measure and express in monetary terms. They are:

a. Long range water outlook for the area. An underground pipe system is a long range investment. The annual use-cost presented in Table 3, is based on the assumption that the pipe will be used fifty years. If for any reason the pipe is abandoned before that time, the annual use-cost

TABLE 6. — BUDGETED COSTS AND SAVINGS
CONVERSION FROM UNLINED-UNFENCED TO UNDERGROUND SYSTEM

1950 records		Individual's estimate	
Additional cost		Additional cost	
¼-mile of underground pipe	$4,500	¼-mile of underground pipe....	$............
Less government payment	$	Less government payment	$............
Net cost	$4,500	Net cost	$............
Annual costs		Annual costs	
Interest ......(2.5%)	$113	Interest ....(......%)	$............
Depreciation ....(2.0%)	$ 90	Depreciation (......%)	$............
Repairs ......(0.5%)	$ 22	Repairs ....(......%)	$............
Total annual cost............	$225	Total annual cost......	$............
Annual savings		Annual savings	
Land— ½ A. @ $50 A.....	$ 25	Land	$............
Weed control	$ 47	Weed control	$............
Irrigator's labor	$......	Irrigator's labor	$............
Total annual savings (excluding water)	$ 72	Total annual savings (excluding water)	$............
Remaining cost (to be paid by savings in water)	$153	Remaining gcost (to be paid by savings in water)	$............
Value of water $5 A.F.=31 A.F.		Value of water $............ A.F.=............A.F.	
Average annual flow through canal section	240 A.F.	Average annual flow through canal section	............A.F.
Seepage loss per ¼-mile required to equal 31 A. F. = 13 per cent.		Seepage loss per ¼-mile required to equal ............A.F. = ...per cent.	

will be increased. A lined ditch is a shorter term investment.

b. Financial condition of the land owner. The high initial cost of the underground system is a serious obstacle to a land owner who is short of capital or operating on capital borrowed at a high rate of interest. On the other hand, under certain conditions an underground pipe system offers an opportunity for an owner with excess funds to invest in a long term farm improvement that promises to yield a greater return than other types of investment available to him.

c. Value placed on appearance. The installation of an underground system eliminates the need for open ditches.

For some, the elimination of open ditches, especially in the vicinity of the residence, is an important consideration. It may not add to the income from the farm but may add to the satisfaction of living there. It is difficult to express such satisfaction in monetary terms.

d. Flexibility of the system. The means of getting the water from the ditch onto the fields is more flexible with a lined ditch than with an underground system. In areas where siphon tubes are used any change in the spacing between borders or between rows does not greatly alter the effectiveness of the system. With the underground system, the spacing between valves is fixed at the time of installation.

EFFECT OF FUTURE PRICES AND COSTS

The uncertainty as to future prices and costs greatly complicates investment decisions. While the cost of an improved system can be determined at the time of installation, the savings are influenced by the price of the factors saved during the life of the installation. If the cost of water, labor, and weed control materials rise during the life of the ditch, an improved system will be a more profitable investment than it will if the prices of these factors decline.

In this report all savings were valued at the prevailing price at the time of the study because of the absence of a valid reason for using any other price assumptions. In the budgets presented for analysis each individual should feel free to use his own price estimates in cases where they differ from those presented.