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Economics of Surface Irrigation Systems

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Background

Irrigated agriculture in Idaho faces a decline in the availability of water and increasing costs for that available water. The demand for recreational and environmental urban water use continues to grow. Adopting improved irrigation technology is one of the few remaining alternatives that agriculture can use to address this problem. Development of large-scale water projects to enhance water supplies are unlikely and development of additional groundwater will not occur until the coordinated management of surface and groundwater is achieved. More efficient allocation and conservation of existing water supplies may represent the only new water available to agriculture. Agriculture in the United States consumes 80 percent of the country's water resources.

Introduction

A grower needs to consider many technical, economic, and financial factors when choosing or upgrading an irrigation system, or evaluating conversion from one system to another. Technical factors include the physical characteristics of the resources available to the grower, including climate, topography, soil texture, soil productivity, top soil depth, and the quality, quantity, and source of water. Availability and quality of labor, crop mix alternatives, and field shape are other important considerations. The need to improve energy and water use efficiency are becoming increasingly important parts of the decision-making process.

Although the use of sprinkler irrigation has increased over the past 20 years, the traditional method of surface flooding is still the most common. Worldwide, about 95 percent of all irrigation is surface flooding. In Idaho, the percentage is about 50 percent. The primary method of surface or gravity irrigation in Idaho is furrow irrigation. Other types of surface irrigation—border and basin irrigation—are less common in Idaho but practiced in other parts of the world.

Lower energy and capital requirements relative to sprinkler irrigation systems make surface irrigation an attractive alternative. However, surface irrigation systems generally have higher labor requirements, lower water use efficiencies, and sometimes cause significant soil erosion. Because of greater environmental awareness today and in the future, and greater competition for available water, pressures will exist to increase the efficiency of irrigation water use and reduce the level of soil erosion. Technologies are available to address these problems in surface irrigation but do involve additional capital investment. This publication summarizes the costs of four types of surface irrigation systems and costs of incorporating tailwater reuse (pumpback) systems to reduce return flow.

Alternatives and selection

Irrigation systems should be designed to meet the site-specific conditions. An economic analysis should be performed to determine which system will accomplish the job at the lowest cost. Once the most cost-efficient system is chosen, it should be evaluated for financial feasibility, long-term profitability, and sustainability. These steps should lead to an informed decision.

Surface irrigation is best suited to soils with low to moderate infiltration rates and lands with uniform slopes less than 3 percent (2 percent on erodible soils). Furrow irrigation is accomplished by running water in small channels (furrows or corrugates) down the slope of a field. Water infiltrates from the bottom and sides of the furrow moving laterally and downward to wet the soil. Soluble salts, fertilizers, and herbicides are moved with the water. Water is conveyed to the field and along the head of the field in open ditches or in pipes. Various outlet devices are used to divert water into each furrow. Outlets of equal size with uniform pressure head are desirable to deliver nearly equal flows to all furrows irrigated in one set. The type of conveyance system and outlet employed and degree of automation influence the capital cost of the system and the labor requirements.

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Five furrow irrigation systems have been modeled using the assumptions outlined in Appendix A. These systems include a siphon tube system with concrete and earthen head ditches, a gated pipe system, a surge flow gated pipe system, and a cablegation gated pipe system. Capital investment costs for the five systems are summarized by component in Appendix C, Tables C1 - C5. Tailwater reuse (pumpback) systems were also modeled to evaluate the costs of reducing off-site soil loss and increasing irrigation efficiencies. These systems were modeled for the standard siphon tube and gated pipe system. Pumpback systems designed for surge flow and cablegation irrigation would be smaller and therefore less capital intensive. See Tables C6 - C8 in Appendix C for capital investment costs associated with the tailwater reuse systems.

The size and shape of gravity irrigated fields in southern Idaho vary greatly from just several acres to 40 acres or more. Consequently, three different field sizes for each of the four systems was used to evaluate costs. Head lengths are assumed to be the same (1,320 feet) for all three field sizes, with run lengths of 660, 990, and 1,320 feet. This translates into 20-, 30-, and 40-acre gravity systems. Row spacing on all systems was assumed to be 30 inches. Labor requirements to operate systems for each of the three field sizes are reported in Table 8.

Water requirements for the four irrigation systems modeled in this paper are different, however, the water cost does not reflect this difference. For institutional reasons Idaho irrigators are charged a flat fee per acre for the right to use the water regardless of the quantity used. The water assessment may differ from one irrigation district to another.

The earthen ditch siphon tube system is the least efficient and uses the greatest amount of water and the surge flow and cablegation system are the most efficient, using the least amount of water. Although it's difficult to estimate exact water savings associated with the different surface systems, some relative estimates have been made by experts in the field. A starting point for these comparisons could be made by assuming losses of (1) earthen ditch: 40 percent runoff, 20 percent deep percolation, 10 percent ditch loss/spill; (2) concrete ditch and gated pipe: 40 percent runoff, 20 percent deep percolation; (3) surge flow and cablegation: 20 percent runoff, 15 percent deep percolation; (4) tailwater reuse saves 80 percent of the runoff.

The siphon tube irrigation system

Siphon tube systems utilize curved aluminum or plastic pipes that are laid over the bank of an open ditch to divert water into the furrows. Water flows into the submerged end of the tube, is siphoned over the bank of the open ditch, and delivered into the furrow when there is sufficient operating head and the tube is positioned correctly and primed. The flow rate of the siphon tube is controlled by its diameter and the elevation difference (head) between the water level in the open ditch and the center of the outlet end. The advantage of siphon tubes is the ease with which nearly equal inflows to all furrows can be achieved. When the desired depth of water has been infiltrated at the lower end of the field, the siphon tubes are collected, redistributed along the head of the field where the next irrigation set is to occur and each is primed again. Trash screening is often required to remove floating debris from the water to prevent clogging the siphon tubes. A nearly constant water supply is required to ensure that siphon tubes do not stop flowing (loose prime) during the irrigation. Farmers often spill 3 to 6 percent of this water at the end of the ditch to reduce flow fluctuations to their siphon tubes.

Earthen head ditch with siphon tubes.

The modeled siphon tube system consists of a 1,320-foot long concrete ditch with 12-inch bottom width located along the head end of the field. The elevation of the water surface in the concrete ditch is controlled using portable galvanized steel checks. Two hundred 1-inch diameter, 5-foot long aluminum siphon tubes are used to divert and control the flow water into the furrows. A concrete control box and bubble trash screen is located at the inlet to the concrete ditch for flow control and trash removal.

The gated pipe system

Gated pipe systems utilize portable rigid pipes or flexible tubing with uniformly-spaced rectangular adjustable outlets for diverting water into the furrows. Water flow from each outlet is regulated by adjusting the size of the outlet opening. Short flexible sleeves may be attached to the outlets to dissipate energy and minimize erosion at furrow inlets. When the desired depth of water has been infiltrated at the lower end of the field, outlets along the head end

Concrete head ditch with siphon tubes.

of the field where the next irrigation set is to occur are opened and the previous ones are closed. The newly flowing outlet openings are then adjusted to provide nearly equal flow to all furrows in the irrigation set. This can be an iterative process depending upon the care used to equalize furrow flows, type of outlet employed and slope of the gated pipeline. Trash screening is required when utilizing a surface water source to remove floating debris which may clog the outlets. The advantage of gated pipe is that it may be temporarily removed to eliminate restrictions on equipment travel. Gated pipe can also be located at intermediate locations within a field to reduce furrow lengths and increase application uniformity and efficiency.

The modeled gated pipe system consists of 1,320 feet of 8-inch diameter plastic gated pipe with 30-inch outlet spacing located along the head end of the field. A concrete box and bubble trash screen are included for flow control and trash removal. A pipe trailer is included for retrieval and distribution of the gated pipe to facilitate winter storage.

The surge flow system

Surge flow irrigation is defined as the intermittent water flow to furrows in a series of “on” and “off” periods of constant or variable duration. The duration of time between successive inflow periods is chosen so that several cycles are required to advance the water to the end of the furrow. After the water has advanced to the furrow end, irrigation is completed with a continuing series of short “on” - “off” cycles or with reduced continuous flow. Surge irrigation results in more rapid advance and reduced runoff making higher frequency, light irrigation possible while improving application uniformity and efficiency. However, greater management skill is required to select the proper cycle times that reduce deep percolation and runoff, and realize increased application uniformity and efficiency.

Surge flow irrigation inherently requires automation to be economically feasible. Commercially available automated valves and a battery/solar powered controller are added to the conventional gated pipe system to switch water from one set to another. An operational advantage of surge flow irrigation is that cutback application to reduce runoff is possible with a constant water supply. A buried or surface pipeline is normally used to convey the water to the automated surge valves spaced along the head of the field. Gated pipe is attached to both sides of the surge valve and each side serves one or more irrigation sets. To minimize cost of the automated surge valves, one portable controller can be used to operate several surge valves. Controllers are removed from the surge valve body and installed in the next one to start irrigation using a different surge valve. Water flow to the automated surge valve is controlled by an alfalfa or butterfly valve between the supply pipeline and the surge valve. The gated pipe outlets are normally set during the first, second, and third irrigation and may not be adjusted again unless the furrow inflow rate is changed or multiple irrigation sets are controlled from one surge valve. Labor is required to initially layout the gated pipe system and set the outlet flows during the first few irrigations of the season.

The model surge flow system utilizes 1,155 feet of 10-inch diameter buried plastic pipe located along the head of the field to supply water to equally spaced risers. Each riser consists of an alfalfa valve, valve opener, and automated surge valve body. Water is distributed from each side of the automated surge valve using 8-inch diameter plastic gated pipe with outlets spaced 30 inches apart. A single battery/solar powered

Surge flow system.
The surge controller is shown.

controller is used to operate the automated surge valve bodies. A concrete box and bubble trash screen located at the inlet to the buried supply line are included for flow control and trash removal. A pipe trailer is included for retrieval and distribution of the gated pipe and to facilitate winter storage.

The cablegation pipe system

Cablegation is a semiautomated system for achieving furrow inflow cutback that capitalizes on the natural reduction in infiltration rate as irrigation progresses to greatly reduce runoff. The system consists of gated pipe oriented such that the outlets are located near the top of the pipe laid on a uniform graded slope along the head of the field. A moveable plug retained by a cable through the pipe inlet diverts water through the open outlets into the furrows. The other end of the cable is attached to a reel located at the gated pipe inlet structure. As irrigation progresses, the cable is unrolled from the reel and the plug travels slowly downstream. As the plug passes an outlet, the new discharge begins to flow as flow from the last upstream outlet ends. The rate of outlet discharge steadily decreases as the distance from the plug increases due to decreasing pressure (increasing elevation relative to the plug). The size of the outlet openings and rate of plug movement are adjusted to adequately irrigate the lower end of the furrow while minimizing runoff. The operational advantage of cablegation is the ability to cut back furrow inflow while maintaining a constant delivery of water to the field along with inherent automation.

The modeled cablegation system consists of 1,320 feet of 10-inch diameter plastic gated pipe with spigot outlets spaced every 30 inches located along the head end of the field. The cable release mechanism is a commercially available battery/solar powered electronically controlled unit. The 10-inch diameter plug is also available commercially. Labor required to operate the system consists of initially installing the gated pipe on grade, installing the plug and attaching the retaining cable, and setting the speed of cable release. The outlet spigot openings are set during the first irrigation. Spigot type outlets facilitate this task by providing an index upon which to set the openings evenly. A concrete box and bubble trash screen are included at the inlet to the gated pipe for flow control and trash removal.

Tailwater reuse systems

Tailwater reuse systems allow for collecting and returning surface irrigation runoff for use in subsequent irrigations. Tailwater reuse systems include collection ditches at the lower end of the field, an open ditch or pipe drain that directs the collected water to a storage pond and a means of distributing the collected water. Runoff generated by an irrigation set can be used for subsequent irrigation sets on the same field or other fields. Runoff should be collected and used to reduce the amount of primary water source used or to supplement the primary source flow rate used in subsequent irrigation sets. It can also be used to provide all the water for smaller sets. Runoff water can be used to increase initial supply rates to a set for better distribution.

The modeled tailwater reuse systems in Tables C6-C8 are designed for the modeled siphon tube and gated pipe systems based on a 40 percent runoff. The storage pond is sized to store 65 percent of the runoff from a 12-hour irrigation set. The captured runoff is assumed to be utilized at a constant rate during the next 12-hour irrigation set. The storage pond is assumed to be located at the opposite corner of the field from the primary water source. The static lift used to compute the pumping head is based on a field having a 2 percent furrow slope and 1 percent side slope. The return piping system is assumed to be buried plastic pipe which traverses the field diagonally ending at the

Cablegation gated pipe system.
The cable release mechanism is shown mounted on the control box.

Close up of concrete head ditch siphon tubes.

field inlet of the primary water source. The specific components of each tailwater reuse system are detailed in Appendix C Tables C6 through C8. Single-phase electrical service to the pump is assumed to be installed by the owner.

Capital investment

Capital requirements for the five surface irrigation and accompanying pumpback systems are shown in Appendix C, Tables C1 through C8. The capital investment costs per acre for the irrigation systems are inversely proportional to the length of the field runs. With longer runs, total investment is spread over a greater number of acres. This may be economic incentive to increase run lengths, but physical factors such as field shape, soil type, slope, and performance factors such as application uniformity, leaching, runoff, and erosion should also be addressed.

Total capital requirements for the siphon system (concrete head ditch) are $7,760. The investment per acre ranges from $388.00 per acre for a 660-foot run to $194.00 for a 1,320-foot run. Capital requirements for the gated pipe system range from $202.60 per acre for the 660-foot run to $101.30 for the 1,320-foot run.

Total capital requirement for this system is $4,052.00. The other two gravity systems, surge flow gated pipe and cablegation gated pipe, have total capital requirements of $11,510.00 and $6,470.00 respectively. Capital requirements per acre for the 1,320- and 660-foot runs range from $287.75 to $575.50 for the surge flow gated pipe and $161.75 to $323.50 for the cablegation gated pipe. Land leveling was not included in the above capital requirements as it is not considered to be a depreciable asset. For purposes of this study, it was assumed that land leveling was accounted for in land value.

Annual costs

A summary of annual costs for all five gravity systems is shown in Table 7. Total annual costs include both operating and ownership costs. Operating costs include maintenance, labor, water assessments, and interest on operating capital. Ownership costs include depreciation, interest on investment, and insurance. Ownership costs were calculated using the annual equivalent cost method instead of the average method (See appendix B). The annual equivalent method of estimating ownership costs allows the user to estimate ownership costs for equipment consisting of components with differing useful lives. This method is more exact than the average method mentioned above. Ownership costs are summarized in Appendix D, Tables D1 through D8.

Costs were based on a crop rotation common to the Minidoka and Cassia counties in southern Idaho. This rotation consists of one year of sugarbeets, one year of spring wheat, and one year of spring barley. The average annual consumptive water requirement for this rotation is 21 inches. The average number of irrigations per year for the three crop rotation is about seven irrigations. This was used to determine labor costs for the four systems.

Total annual costs for the gated pipe system were the lowest at $82.56 per acre for the 660-foot run and $56.73 per acre for the 1,320 foot run. Total annual costs for the surge flow gated pipe system were the highest at $121.25 per acre for the 660-foot run and $75.64 for the 1,320 foot run (Table 7). Annual costs for the siphon tube system with concrete head ditch are $103.66 per acre for the 20-acre system and $67.29 per acre for the 40-acre system. This compares with $104.71 and $69.37 for the earthen ditch siphon system. Annual costs per acre for the cablegation gated pipe system are $90.00 for 20 acres and $59.77 for 40 acres. Labor requirements for the five gravity systems are reported in Table 8. It was assumed that labor requirements per irrigation for the siphon tube (concrete head ditch) and gated pipe systems were about the same but used one half as much labor as the siphon tube (earthen head ditch) system. The surge flow gated pipe system was assumed to use one quarter less labor per irrigation and the cablegation one third less than the gated pipe and siphon tube system with concrete. This is due to a higher level of automation associated with these systems.

Summary

There are many technical, economic, and financial questions that need to be answered when selecting an irrigation system. Technical questions should address physical characteristics of the resources available to the grower including climate, topography, soil texture, soil productivity, topsoil depth, and the quality, quantity, and source of water. Labor supply, crop mix alternatives, and field shape are other important considerations. Once the grower determines the systems that will technically satisfy his situation, he then needs to look at economics. An economic analysis of the systems being considered will help him determine the most cost efficient system. Once the most cost efficient system is determined, the question should be "can I afford it?" A financial analysis that considers net income generated from the new system and cash flow will help answer this question.

Annual operating and ownership costs were presented for five different gravity irrigation systems and pumpback systems. Investment costs for these systems were collected from irrigation supply companies in February, 1993.

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Table 1. Annual Costs for Earthen Head Ditch with Siphon Tubes.

Item	Total	660 ft run 20 acres	990 ft run 30 acres	1,320 ft run 40 acres
		Cost per irrigated acre		
Operating Costs				
Maintenance (25 hrs./year)		$7.81	$5.21	$3.91
Labor [1]		50.75	35.88	28.00
Water [2]		27.00	27.00	27.00
Interest on operating capital (6 months at 8.75%)		4.71	3.75	3.24
Total operating				
20 acres	$1,805.40	90.27		
30 acres	$2,155.20		71.84	
40 acres	$2,486.00			62.15
Ownership Costs [3]				
Depreciation & interest		14.06	9.37	7.03
Insurance		.39	.26	.19
Total ownership		14.44	9.63	7.22
Total Annual Costs				
20 acres	$2,094.20	104.71		
30 acres	$2,444.10		81.47	
40 acres	$2,774.80			69.37

1 See Table 8 on labor requirements for surface irrigation systems. Labor cost per hour : $6.25.
2 Water rates are an average of the rates quoted by the 1993 Minidoka and Burley Irrigation Districts in 1993. Water costs are calculated on a per acre basis, therefore, water usage is not reflected in the comparisons.
3 See Appendix D, Table D1.

Table 2. Annual Costs for Concrete Head Ditch with Siphon Tubes.

Item	Total	660 ft run 20 acres	990 ft run 30 acres	1,320 ft run 40 acres
		Cost per irrigated acre		
Operating Costs				
Maintenance (1% of investment)		$3.88	$2.59	$1.94
Labor [1]		25.38	17.94	14.00
Water [2]		27.00	27.00	27.00
Interest on operating capital (6 months at 8.75%)		2.46	2.08	1.88
Total operating				
20 acres	$1,174.43	58.72		
30 acres	$1,488.28		49.61	
40 acres	$1,792.80			44.82
Ownership Costs [3]				
Depreciation & interest		44.72	28.81	22.36
Insurance		.22	.15	.11
Total ownership		44.94	29.96	22.47
Total Annual Costs				
20 acres	$2,073.20	103.66		
30 acres	$2,387.10		79.57	
40 acres	$2,691.60			67.29

1 See Table 8 on labor requirements for surface irrigation systems. Labor cost per hour : $6.25.
2 Water rates are 1993 charges for Minidoka Irrigation District. Water costs are calculated on a per acre basis, therefore, water usage is not reflected in the comparisons.
3 See Appendix D, Table D2.

Table 3. Annual Costs for a 1/4 Mile Gated Pipe System.

Item	Total	660 ft run 20 acres	990 ft run 30 acres	1320 ft run 40 acres
		Cost per irrigated acre		
Operating Costs				
Maintenance (1% of investment)		$2.03	$1.35	$1.01
Labor [1]		25.38	17.94	14.00
Water [2]		27.00	27.00	27.00
Interest on op. cap (6 months at 8.75%)		2.38	2.03	1.84
Total operating				
20 acres	$1,135.80	56.79		
30 acres	$1,449.60		48.32	
40 acres	$1,754.00			43.85
Ownership Costs [3]				
Depreciation & interest		24.90	16.60	12.45
Insurance		.87	.58	.43
Total Ownership		25.77	17.17	12.88
Total Annual Costs				
20 acres	$1,651.20	82.56		
30 acres	$1,964.70		65.49	
40 acres	$2,269.20			56.73

1 See Table 8 for surface irrigation labor requirements. Labor cost per hour : $6.25.
2 Water rates are 1993 charges from Minidoka Irrigation Company. Water costs are calculated on a per acre basis, therefore, water usage is not reflected in the comparisons.
3 See Appendix D, Table D3.

Table 4. Annual Costs for a 1/4 Mile Surge Flow Gated Pipe System.

Item	Total	660 ft run 20 acres	990 ft run 30 acres	1320 ft run 40 acres
		Cost per irrigated acre		
Operating Costs				
Maintenance (1% of investment)		$5.75	$3.84	$2.88
Labor [1]		19.25	13.56	10.50
Water [2]		27.00	27.00	27.00
Interest on op. cap (6 months at 8.75%)		2.28	1.94	1.77
Total operating				
20 acres	$1,085.50	54.28		
30 acres	$1,390.28		46.34	
40 acres	$1,686.00			42.15
Ownership Costs [3]				
Depreciation & interest		64.70	43.13	32.35
Insurance		2.28	1.52	1.14
Total ownership		66.97	44.65	33.49
Total Annual Costs				
20 acres	$2,425.00	121.25		
30 acres	$2,729.70		90.99	
40 acres	$3,025.60			75.64

1 See Table 8 for surface irrigation labor requirements. Labor cost per hour : $6.25.
2 Water rates are 1993 charges from Minidoka Irrigation Company. Water costs are calculated on a per acre basis, therefore, water usage is not reflected in the comparisons.
3 See Appendix D, Table D4.

Table 5. Annual Costs for a 1/4 Mile Cablegation Gated Pipe System.

Item	Total	660 ft run	990 ft run	1,320 ft run
		20 acres	30 acres	40 acres
		Cost per irrigated acre		
Operating Costs				
Maintenance (1% of investment)		$3.24	$2.16	$1.62
Labor [1]		17.06	12.25	9.19
Water [2]		27.00	27.00	27.00
Interest on operating capital (6 months at 8.75%)		2.07	1.81	1.65
Total operating				
20 acres	$987.39	49.37		
30 acres	$1,296.65		43.22	
40 acres	$1,578.57			39.46
Ownership Costs [3]				
Depreciation & interest		39.23	26.16	19.62
Insurance		2.28	1.52	1.14
Total ownership		40.63	27.08	20.31
Total Annual Costs				
20 acres	$1,800.00	90.00		
30 acres	$2,109.00		70.30	
40 acres	$2,390.97			59.77

[1] See Table 8 for surface irrigation labor requirements. Labor cost per hour : $6.25.
[2] Water rates are 1993 charges from Minidoka Irrigation Company. Water costs are calculated on a per acre basis, therefore, water usage is not reflected in the comparisons.
[3] See Appendix D, Table D5.

Table 6. Annual Costs for Tail-water Reuse Systems (Pumpback).

Item	Total	20 acres	30 acres	40 acres
		Cost per Irrigated Acre		
Operating Costs				
Maintenance (3% of investment)		$10.01	$6.68	$5.01
Power		2.33	2.74	3.04
Interest on operating capital (6 months at 8.75%)		.54	.41	.35
Total operating costs				
20 acres	$257.00	12.88		
30 acres	$294.90		9.83	
40 acres	$336.00			8.40
Ownership Costs [1]				
Depreciation & interest		39.90	29.86	24.51
Insurance		.94	.62	.48
Total ownership		40.84	30.47	24.99
Total Annual Costs		53.72	40.30	33.39

[1] See Appendix D, Tables D6-D8.

Table 7. Total Annual Costs per Acre by Irrigation System.

	20 acres	30 acres	40 acres
Siphon tubes - earthen ditch [1]	$104.71	$81.47	$69.37
Siphon tubes - concrete ditch [2]	103.66	79.57	67.29
Gated pipes [3]	82.56	65.49	56.73
Surge flow [4]	121.25	90.99	75.64
Cablegation [5]	90.00	70.30	59.77
Siphon tubes with tailwater reuse [6,7]	157.38	119.87	100.68
Gated pipes with tailwater reuse [6,7]	136.28	105.79	90.12

[1] See Table 1.
[2] See Table 2.
[3] See Table 3.
[4] See Table 4.
[5] See Table 5.
[6] See Table 6.
[7] The pumpback systems modeled in this paper were designed specifically for conventional gated pipe or siphon tubes and concreteditch. Capital requirements for tailwater reuse would differ in the case of surge flow and cablegation.

Table 8. Labor Requirements for Surface Irrigation Systems.

System	Hrs./acre/irrig[1]	Hrs./acre/season[2]
Siphon Tube - Concrete Head Ditch		
660 ft run (20 acres)	.58	4.06
990 ft run (30 acres)	.41	2.87
1,320 ft run (40 acres)	.32	2.24
Siphon Tube - Earthen Head Ditch		
660 ft run (20 acres)	1.16	8.12
990 ft run (30 acres)	.82	5.74
1,320 ft run (40 acres)	.64	4.48
Gated Pipe		
660 ft run (20 acres)	.58	4.06
990 ft run (30 acres)	.41	2.87
1,320 ft run (40 acres)	.32	2.24
Surge Flow		
660 ft run (20 acres)	.44	3.08
990 ft run (30 acres)	.31	2.17
1,320 ft run (40 acres)	.24	1.68
Cablegation		
660 ft run (20 acres)	.39	2.73
990 ft run (30 acres)	.28	1.96
1,320 ft run (40 acres)	.21	1.47

[1] Source: Washington State Irrigation Guide, USDA SCS, 1985.
[2] The number of irrigations required for the season was estimated from information in Appendix A.

Appendix A

Basic Assumptions

Location: The Mini-Cassia area of southern Idaho was used as a reference.

Soil type: A silt loam soil with a water holding capacity of 2.6 inches per foot and soil depth not a limit to crop root zone.

Crop rotation: Sugarbeets, spring barley, and winter wheat

Allowable soil moisture depletion and crop rooting depth:

Crop	Allowable Depletion	Rooting Depth
Sugarbeets	50%	2.5 ft
Winter wheat	50%	3.0 ft
Spring barley	50%	3.0 ft

Seasonal water requirements:

Crop	Total
Sugarbeets	25 inches
Winter wheat	17 inches
Spring barley	21 inches

Peak water use month and amount:

Crop	Peak Month	Water Requirement
Sugarbeets	July	9.5 inches
Winter wheat	June	9.0 inches
Spring barley	June	8.5 inches

Peak Daily Water Requirement (PDWR):

PDWR = Peak Month ET # of days/month

Crop	PDWR
Sugarbeets	.30 in/day = 5.7 gpm/acre
Spring barley	.28 in/day = 5.3 gpm/acre
Winter wheat	.30 in/day = 5.7 gpm/acre

Application efficiency for surface irrigation is assumed to be 40%.
Runoff is 40% and deep percolation is 20%.

Irrigations per crop with surface irrigation:

Crop	Irrigations
Sugarbeets	9
Winter wheat	5
Spring barley	6

Appendix B

Ownership Cost Calculations

Depreciation and interest is calculated using an exact technique that finds the annual equivalent of first cost less annual equivalent of salvage. This method was chosen over the estimated technique using straight-line depreciation (repayment) plus return on the average investment. When using the estimated technique the magnitude of error increases as: (1) years of useful life increase and (2) interest rate increases.

Depreciation and Interest $= B(a/p)^{i}_{n} - v(a/f)^{i}_{n}$

where B = initial investment

v = salvage value

i = interest rate in decimal

n = years of useful life

$$(a/p)^{i}_{n} = \frac{i(1+i)n}{(1+i)n-1} =$$ uniform series end-of-period amount (a) equivalent to present sum, (p); or capital recovery factor.

$$(a/f)^{i}_{n} = \frac{i}{(1+i)n-1} =$$ uniform series end of period amount (a) equivalent to future sum, (f); or sinking fund factor.

Source: Smith, Gerald W. Engineering Economy: Analysis of Capital Expenditures, Iowa State University Press, 1973, pp. 93-98.

Insurance

$$\text{Insurance} = (a/p)^{i}_{n}\left[\left((p/a)^{i}_{n\,\text{BEGIN}}\, B\left(\tfrac{I}{\text{Rate}}\right) - \left((p/g)^{i}_{n}\right)\frac{(B-V)\left(\tfrac{I}{\text{Rate}}\right)}{n} + (p/a)^{i}_{n\,\text{END}}\frac{(B-V)\left(\tfrac{I}{\text{Rate}}\right)}{n}\right)\right]$$

where B = initial investment
v = salvage value
i = interest rate in decimal notation
n = years of useful life
I = insurance rate

$$(a/p)^{i}_{n} = \frac{i(1+i)^{n}}{(1+i)^{n}-1}$$ = uniform series end-of-period amount (a) equivalent to present sum, (p); or capital recovery factor.

$$(p/a)^{i}_{n\,\text{BEGIN}} = \frac{((1+i)^{n}-1)(1+i)}{i(1+i)^{n}}$$ = present sum (p) equivalent to uniform beginning-of-period series (a).

$$(p/g)^{i}_{n} = \frac{1}{i}\left[\frac{(1+i)^{n}-1}{i(1+i)^{n}} - \frac{n}{(1+i)^{n}}\right]$$ = present sum (p) equivalent to gradient series (g).

$$(p/a)^{i}_{n\,\text{END}} = \frac{(1+i)^{n}-1}{i(1+i)^{n}}$$ = present sum (p) equivalent to uniform end-of-period series, (a).

BEGIN = payments in advance
END = payments in arrears.

Source: Formula developed by David J. Walker, Assistant Professor and Brian L. Calkins, Graduate Student, Agricultural Economics and Applied Statistics, University of Idaho.

Appendix C

Investment Cost Summaries

Table C1. Capital Investment for Earthen Head Ditch with Siphon Tubes.[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Head Ditch/Pad			
1,320' earthen ditch	$660.00	$0.00	25
Tubes			
200 60" x 1" double bend aluminum[2]	400.00	40.00	15
Checks			
20 Pre-cast concrete[3]	800.00	0.00	25
Miscellaneous			
Control box with bubble screen	600.00	0.00	15
Total capital cost	2,294.00		
20 Acres (660 ft. run) total/irr. acre	114.70		
30 Acres (990 ft. run) total/irr. acre	76.47		
40 Acres (1320 ft. run) total/irr. acre	57.35		

1 Prices were quoted February, 1993.
2 Number of tubes is based on system design flow rates and 4 gpm, 5 gpm and 6 gpm furrow flow for 20, 30 and 40 acre field sizes respectively.
3 Includes installation of checks.

Table C2. Capital Investment for Concrete Head Ditch with Siphon Tubes.[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Head Ditch/Pad			
1,320' concrete ditch			
16" x 12" installed	$6,700.00	$0.00	20
Tubes [2]			
200 60" x 1" double bend aluminum	400.00	40.00	15
Checks			
10 12î x 16î galvanized steel	60.00	0.00	15
Miscellaneous			
Control box with bubble screen	600.00	0.00	15
Total capital cost	7,760.00		
20 Acres (660 ft. run) total/irr. acre	388.00		
30 Acres (990 ft. run) total/irr. acre	259.00		
40 Acres (1320 ft. run) total/irr. acre	194.00		

1 Prices were quoted February, 1993.
2 Number of tubes is based on system design flow rates and 4 gpm, 5 gpm and 6 gpm furrow flow for 20, 30 and 40 acre field sizes respectively.

Table C3. Capital Investment for a 1/4 mile Gated Pipe System.[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Gated Pipe			
1,320' 8" PVC (30"spacing)	$2,402.00	$240.00	15
Miscellaneous			
End plug, elbows, etc.	400.00	40.00	15
Pipe trailer[2]	650.00	65.00	20
Control box w/bubble screen	600.00	0.00	15
Total capital cost	4,052.00		
20 Acres (660 ft. run) total/irr. acre	202.60		
30 Acres (990 ft. run) total/irr. acre	135.10		
40 Acres (1320 ft. run) total/irr. acre	101.30		

1 Prices were quoted February, 1993.
2 Typically the cost of a pipe trailer would be spread over entire farm acreage.

Table C4. Capital Investment for a 1/4 mile Surge Flow Gated Pipe System.[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Mainline			
1,132' 10" PVC pipe 80#	$2,717.00	$0.00	30
Installation	1,132.00	0.00	30
Gated Pipe			
1,320' 8" PVC pipe (30" spacing)	2,363.00	240.00	15
Valves, Risers, Hydrants, Timers			
4 Risers 10" x 10" x 8"	328.00	0.00	20
4 Alfalfa valves	404.00	0.00	20
4 - 8" Valve openers	1,132.00	0.00	20
2-Surge flow valve bodies	1,320.00	0.00	20
Battery/solar powered controller	864.00	0.00	20
Miscellaneous			
Pipe trailer[2]	650.00	65.00	20
Control box w/trash screen	600.00	0.00	15
Total capital cost	11,510.00		
20 Acres (660 ft. run) total/irr. acre	575.50		
30 Acres (990 ft. run) total/irr. acre	383.67		
40 Acres (1,320 ft. run) total/irr. acre	287.75		

1 Prices were quoted February, 1993.
2 Typically, the cost of a pipe trailer would be spread over the entire farm acreage.

Table C5. Capital Investment for a 1/4 mile Cablegation Gated Pipe System.[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Gated Pipe w/Spigot Gates			
1,320 10" PVC (30" spacing)	$3,736.00	$374.00	20
Graded pad and installation	1,320.00	0.00	20
Miscellaneous			
1,350'-3/16" Polypropyline cable	54.00	0.00	5
1-10" Cablegation plug	60.00	0.00	5
Cable release mechanism - electronic	700.00	0.00	10
Control box w/bubble screen	600.00	0.00	15
Total capital cost	6,470.00		
20 Acres (660 ft. run) total/irr. acre	323.50		
30 Acres (990 ft. run) total/irr. acre	215.67		
40 Acres (1320 ft. run) total/irr. acre	161.75		

1 Prices were quoted February, 1993.

Table C6. Capital Investment for Pump Back System for Surface Irrigation (20 Acre Field).[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Mainline			
1,475' 6" PVC pipe 80#	$1,239.00	$0.00	30
Installation charge	1,475.00	0.00	30
Pumping Equipment			
Pump & motor			
(1HP)/base & housing	1,172.00	117.00	20
Suction and discharge[2]	360.00	0.00	20
Electrical panel and wiring	1,100.00	110.00	20
Installation/setup charge	270.00	0.00	20
Power installation (1/8 mile)[3]	660.00	0.00	30
Reservoir			
274 yd.^{3} pond w/overflow structure	500.00	0.00	5
Total capital cost	6,676.00		
Total per acre	333.80		

1 This pump back system is designed for conventional surface irrigation using gated pipe or siphon tubes and ditch.
2 Includes screen, vacuum, air relief valves, control valve, foot valve, priming system, and piping.
3 Power installation cost depends on distance from power source and installer. This example assumes that electrical panel is only 1/8 mile from power source and owner installs ditch, wire, and conduit.

Table C7. Capital Costs for Pump Back System for Surface Irrigation (30 Acre Field).[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Mainline			
1,650' 6" PVC pipe 80#	$1,386.00	$0.00	30
Installation charge	1,650.00	0.00	30
Pumping Equipment			
Pump & motor			
(1.5HP)/base & housing	1,200.00	120.00	20
Suction and discharge[2]	368.00	0.00	20
Electrical panel and wiring	1,100.00	110.00	20
Installation/setup charge	276.00	0.00	20
Power installation (1.8 mile)[3]	660.00	0.00	30
Reservoir			
411 yd^3 pond			
w/overflow structure	700.00	0.00	5
Total capital cost	7,240.00		
Total per acre	241.33		

1 This above pump back system is designed for conventional surface irrigation using gated pipe or siphon tubes and ditch.
2 Includes screen, vacuum, air relief valves, control valve, foot valve, priming system, and piping.
3 Power installation cost depends on distance from power source and installer. This example assumes that electrical panel is only 1/8 mile from power source and owner installs ditch wire and conduit.

Table C8. Capital Investment for Pump Back System for Surface Irrigation (40 Acre Field).[1]

Item	Purchase Price	Salvage Value	Useful Life Years
Mainline			
1,870' 6" PVC pipe 80#	$1,571.00	$0.00	30
Installation charge	1,870.00	0.00	30
Pumping Equipment			
Pump & motor			
(2.0HP)/base & housing	1,195.00	120.00	20
Suction and discharge[2]	365.00	0.00	20
Electrical panel and wiring	1,100.00	110.00	20
Installation/setup charge	275.00	0.00	20
Power installation (1/8 mile)[3]	660.00	0.00	30
Reservoir			
544 yd.^{3} pond w/overflow structure	900.00	0.00	5
Total capital cost	7,836.00		
Total per acre	195.90		

1 This pump back system is designed for conventional surface irrigation using gated pipe or siphon tubes and ditch.
2 Includes screen, vacuum, air relief valves, control valve, foot valve, priming system, and piping.
3 Power installation cost depends on distance from power source and installer. This example assumes that electrical panel is only 1/8 mile from power source and owner installs ditch, wire, and conduit.

Appendix D

Ownership Cost Summaries

Table D1. Annual Ownership Costs for Earthen Head Ditch with Siphon Tubes.

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Head Ditch/Pad			
1,320' earthen ditch	$69.93	$0.00	$69.93
Tubes			
200 60" x 1" double bend aluminum	47.79	1.71	50.50
Checks			
20 pre-cut concrete	84.77	3.60	88.36
Miscellaneous			
Control box w/ bubble screen	76.65	2.42	79.06
Total annual system cost	281.14	7.73	288.85
20 Acres (550 ft. run) total/irr. acre	14.06	.39	14.44
30 Acres (990 ft. run) total/irr. acre	9.37	.26	9.63
40 Acres (1,320 ft. run) total/irr. acre	7.03	.19	7.22

1 Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively.

Table D2. Annual Ownership Costs for Concrete Head Ditch with Siphon Tubes.

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Head Ditch/Pad			
1,320' concrete 16" x 12" installed	$760.29	$0.00	$760.29
Tubes			
200 60" x 1" double bend aluminum 49.79	1.71	51.50	
Checks			
10 12" x 16" galvanized steel	7.66	0.24	7.91
Miscellaneous			
Control box w/ bubble screen	76.65	2.42	79.06
Total annual system cost	894.39	4.37	898.76
20 Acres (550 ft. run) total/irr. acre	44.72	.22	44.94
30 Acres (990 ft. run) total/irr. acre	28.81	.15	29.96
40 Acres (1,320 ft. run) total/irr. acre	22.36	.11	22.47

1 Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively for interest and insurance.

Table D3. Annual Ownership Costs for a 1/4 mile Gated Pipe System.

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Gated Pipe			
1,320' 8" PVC (30" spacing)	$298.98	$10.28	$309.27
Miscellaneous			
End plug, elbows, etc.	49.79	1.71	51.50
Pipe trailer	72.56	2.93	75.49
Control box w/ bubble screen	76.65	2.42	79.06
Total annual system cost	497.98	17.34	515.32
20 Acres (660 ft. run) total/irr. acre	24.90	.87	25.77
30 Acres (990 ft. run) total/irr. acre	16.60	.58	17.17
40 Acres (1,320 ft. run) total/irr. acre	12.45	.43	12.88

1 Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively for interest and insurance.

Table D4. Annual Ownership Costs for a 1/4 mile Surge Flow Gated Pipe System.

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Mainline			
1,132' 10" PVC pipe 80#	$276.27	$12.73	$289.00
Installation	115.10	0.00	115.10
Gated Pipe			
1,320' 8" PVC pipe (30" spacing)	294.00	10.13	304.13
Valves, Risers, Hydrants, Timers			
4 Risers 10" x 10" x 8"	37.22	1.40	38.62
4 Alfalfa valves	45.84	1.73	47.57
4 - 8" Valve openers	128.46	4.84	133.30
2 - Surge flow valve bodies	149.79	5.65	155.44
Battery/solar powered controller	98.04	3.70	101.74
Miscellaneous			
Pipe trailer	72.56	2.93	75.49
Control box w/trash screen	76.65	2.42	79.06
Total annual system cost	1,293.93	45.53	1,339.45
20 Acres (660 ft. run) total/irr. acre	64.70	2.28	66.97
30 Acres (990 ft. run) total/irr. acre	43.13	1.52	44.65
40 Acres (1,320 ft. run) total/irr. acre	32.35	1.14	33.49

1 Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively for interest and insurance.

Table D5. Annual Ownership Costs for a 1/4 mile Cablegation Gated Pipe System.

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Gated Pipe w/Spigot Gates			
1,320 10" PVC (30" spacing)	$417.04	$16.84	$433.88
Graded pad and installation149.79	5.65	155.44	
Miscellaneous			
1,350'-3/16" polypropyline cable	14.06	0.17	14.24
1-10" cablegation plug	15.63	0.19	15.82
Cable release mechanism - electronic	111.49	2.60	114.09
Controll box w/bubble screen	76.65	2.42	79.06
Total annual system cost	784.66	27.87	812.53
20 Acres (660 ft. run) total/irr. acre	39.23	2.28	40.63
30 Acres (990 ft. run) total/irr. acre	26.16	1.52	27.08
40 Acres (1,320 ft. run) total/irr. acre	19.62	1.14	20.31

[1] Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively for interest and insurance.

Table D6. Annual Ownership Costs for a Pump Back System for Surface Irrigation (20 Acre Field).

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Mainline			
1,475' 6" PVC pipe 80#	$125.98	$5.81	$131.79
Installation charge	149.98	-	149.98
Pumping Equipment			
Pump & motor			
(1HP)/base & housing	130.83	5.28	136.12
Suction and discharge	40.85	1.54	42.39
Electrical panel and wiring	122.79	4.96	127.75
Installation/setup charge	30.27	1.20	31.47
Power installation (1/8 mile)	67.11	-	67.11
Reservoir			
274 cu. yd. pond			
w/overflow structure	130.22	-	130.22
Total annual system cost	798.03	18.79	816.83
Total per acre	39.90	.94	40.84

[1] Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively for interest and insurance.

Table D7. Annual Ownership Costs for Pump Back System for Surface Irrigation (30 Acre Field).

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Mainline			
1,650' 6" PVC pipe 80#	$140.93	$6.50	$147.43
Installation charge	167.77	0.00	167.77
Pumping Equipment			
Pump & motor			
(1.5HP)/base and housing	133.95	5.41	139.36
Suction and discharge	41.76	1.57	43.33
Electrical panel and wiring	122.79	4.96	127.75
Installation/setup charge	31.32	0.00	31.32
Power installation (1.8 mile)	74.89	0.00	74.89
Reservoir			
411 cu. yd. pond			
w/overflow structure	182.31	0.00	182.31
Total annual system cost	895.72	18.44	914.16
Total per acre	29.86	.62	30.47

[1] Both interest and insurance costs are calculated as a percent of average capital investment.The rates are 9.5 and .6 percent respectively for interest and insurance.

Table D8. Annual Ownership Costs for Pump Back System for Surface Irrigation (40 Acre Field).

Item	Depreciation and Interest[1]	Insurance	Total Ownership Costs
Mainline			
1,870' 6" PVC pipe 80#	$159.74	$7.36	$167.10
Installation charge	190.14	0.00	190.14
Pumping Equipment			
Pump & motor			
(2.0HP)/base & housing	133.39	5.39	138.78
Suction and discharge	41.42	1.56	42.98
Electrical panel and wIring	122.79	4.96	127.75
Installation/setup charge	31.21	0.00	31.21
Power installation (1/8 mile)	67.11	0.00	67.11
Reservoir			
544 cu. yd. pond			
w/overflow structure	234.39	0.00	234.39
Total annual system cost	980.19	19.27	999.46
Total per acre	24.51	.48	24.99

[1] Both interest and insurance costs are calculated as a percent of average capital investment. The rates are 9.5 and .6 percent respectively for interest and insurance.

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