IRRIGATION COSTS

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Contents

NOTE

Costs presented in this publication are averages for California and were obtained through a survey conducted during 1977 and 1978. Present costs may be higher due to inflation and increased energy costs. The approach presented here can be used to calculate the present annual costs of various irrigation systems.

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IRRIGATION COSTS

Several methods are used to apply irrigation water to crops. Some methods require much labor, others require less labor but call for large investments in equipment. Some methods require large amounts of water, others may use less. Some methods are suitable for one situation only, others are suited to several.

This publication compares the costs of irrigation using the major methods of application and discusses the pros and cons of the various methods. The costs listed here will not apply to all situations but are representative of the assumed conditions. The same procedures could be used to compare costs under other conditions such as higher water or energy costs, and different crop, soils and weather conditions.

METHODS OF IRRIGATION

Various methods of irrigation have been developed to meet the needs of different areas and crops being produced in California. Some of the variable conditions which influence the selection of one particular method of irrigation include:

- Slope of ground
- Soil depth
- Soil intake rate
- Soil texture
- Type of crop
- Availability, cost, quantity and quality of water
- Existence of special problems such as salinity and poor drainage
- Need for frost protection

The methods analyzed in this publication are:

Surface	Sprinklers	Drip
a) Border check-flood	a) Hand move	—
b) Furrow	b) Wheel line	
	c) Center pivot	
	d) Hose drag	
	e) Permanent set	

A recent survey indicates that about 80 percent of the 9 million irrigated acres in California are surface irrigated. Sprinklers are used on 18 percent of the land and the acreage irrigated by drip is approaching 2 percent of total.

Border check-flood irrigation

Surface irrigation has developed in areas of flat topography, low cost water, and large water deliveries.

The border check-flood method of irrigation utilizes two parallel levees which guide a stream of water moving down the slope. The land between two levees is called a border strip or a strip check, and varies from 10 to 100 feet in width and from 300 to 2,600 feet in length.

Border check-flood irrigation is used for a wide variety of crops ranging from hay and pasture to orchards and vineyards. Rice is flood-irrigated in contour checks.

Typical conditions which promote border irrigation are:

Soil slope of less than 3 percent—note that crops such as alfalfa and pasture require 0.2 to 0.3 foot slope per 100 feet of run

Water deliveries of 2 to 20 cubic feet per second (900 to 9,000 gallons per minute)

Uniform soils

Furrow irrigation

Furrow irrigation is a variation of flood irrigation where the water flows down narrow channels (furrows) rather than the much wider border check. Furrows may be either straight, zig-zag (made by furrow blocking), or formed along the contour. Furrow irrigation is used for row crops, tree crops, and in vineyards.

General conditions under which furrow irrigation is used include:

- Slopes of less than 2 percent
- Water costs and supply similar to border irrigation
- One irrigator can handle about 5 cubic feet per second (2,250 gpm) of water

Sprinklers

Sprinklers are generally used where surface irrigation cannot be used effectively or efficiently. Conditions favoring sprinklers include:

- Intake rate of soil is either excessively high or low
- Variable textured soils
- Slopes in excess of 3 percent
- Water expensive and in limited supply
- Special problems such as frost control, germination, non-tillage, leaching, or crops planted before land grading.

In general, energy requirements of sprinkler systems are higher than those of surface irrigation because of the additional pressure required to operate sprinklers (40 to 70 pounds per square inch [psi]—equivalent to 90 to 160 feet of pumping lift).

Some sprinkler systems may require less labor than does surface irrigation, but initial capital investment is higher, particularly in mechanically-moved and permanent sprinkler systems.

Hand move. These were the first sprinkler systems and they are still used in many situations. Portable aluminum pipes with sprinklers are hand moved to subsequent positions until an irrigation cycle is completed.

Wheel line. These systems are mechanically moved, and were developed primarily to reduce labor required for hand-move systems (moving sprinklers is often an unpleasant task which workers do not like to perform). Most wheel lines are propelled by a power unit mounted on the sprinkler line.

Center pivot. These systems are a variation of the mechanical move where, rather than moving the entire line move across the field, one end is fixed and the system pivots around that point. Water is also supplied at the fixed end. One disadvantage has been that the irrigation pattern is a circle and the corners of a square field are either not irrigated or must be irrigated by a hand-move or other type of system. Because only 126 acres of a square 160-acre field is covered, center-pivot systems have been limited for use on lower-priced land. Recently, however, center pivots with a corner irrigation device were introduced. Although they are more expensive, they make it possible to irrigate 96 percent of a field, thus expanding use of pivots to costlier land. A technical limitation of center pivots is that water must be applied at very high rates (1 to 4 inches/hour) in the outer parts of the circle. Many California soils cannot absorb water at such rates, and this results in runoff and poor irrigation efficiency.

Hose drag. This is another variation of the hand-move system but employs flexible hose rather than rigid pipe. The hoses, with several sprinklers attached, are pulled from one position to another by hand. These systems have been confined largely to tree crops. Ex-

perience has indicated a savings in labor as compared to other hand-move systems, but there is still a relatively high labor requirement.

Permanent set. These systems have sprinklers that are permanently installed, but high investment cost has limited their use largely to orchards and vineyards (relatively high-income crops). They are also used for frost protection when water quantity and delivery capacity are adequate.

Drip irrigation

This is the frequent, slow application of water (usually, 0.5 to 2.0 gallons per hour) from small-diameter tubes or mechanical devices called emitters. Each emitter wets a relatively small area; the number of emitters required depends on the size of the plant and on soil conditions.

The volume of soil wetted around each plant is less than that wetted by other methods of irrigation. Wetted volume may vary from 5 to 10 percent of the soil area around young trees to 40 to 70 percent of the soil area around mature trees or annual crops.

IRRIGATION EFFICIENCY

Irrigation efficiency refers to the percent of applied irrigation water used by the crop after various losses occur. Water losses can occur throughout the irrigation complex. Total losses will vary from area to area depending on rate of leakage and distance from source to site, conveyance used, method of irrigation, soil and crop characteristics, weather conditions, salt load of the water applied, and need to maintain adequate salt control by leaching.

Water-conveyance efficiency

Losses of water during conveyance from water source to destination may be an important factor in irrigation costs, particularly where water must be transported for some distance. Good efficiencies of various conveyance structures are:

Conveyance	Efficiency
Pipelines	90–100 percent
Concrete-lined ditches	80–90 percent
Earth ditches	60–80 percent

Water-application efficiency

Water-application efficiency, which is the efficiency we are primarily concerned with in this comparison of systems, is the ratio of water stored in the root-zone of the soil and available to the plants compared to water delivered to the field. Water losses are largely due to deep percolation below the root-zone, but also include surface runoff and evaporation from water and soil surfaces. In a well-designed sprinkler or drip system, rate of application should be less than intake rate of the soil so that no runoff will occur. Runoff from surface irrigation can be recovered and recycled by means of a tailwater system to increase application efficiency.

Many waters contain soluble salts which must be controlled within tolerance of the crop being grown. To accomplish this and maintain a favorable salt balance, some deep percolation is required.

Common water-application efficiencies vary from 40 to 90 percent depending upon type of irrigation system, type of soil, length of irrigation run, slope, temperature, wind, irrigation scheduling, management practices, and other factors.

COSTS OF IRRIGATION

To compare costs of different methods of irrigation, we have assumed a 160-acre field with water supplied by a well having a 100-

foot pumping lift. With flood irrigation, we have also assumed a situation where water is obtained from an irrigation district. Annual costs have then been calculated for each irrigation system on the 160-acre field. With conventional center-pivot sprinklers, we deviated to provide a sprinkler system which covered approximately 130 acres in a quarter section (160 acres).

Seasonal net irrigation requirements were assumed to be 30 inches. After correcting for losses in the irrigation systems, a figure of 3.5 acre-feet per acre was used as seasonal applied water in surface irrigation and 3.0 acre-feet per acre were used in sprinkler and drip. Six to eight irrigations were assumed for a medium-textured soil.

Investment costs

Investment costs are determined from initial costs adjusted for the rate of depreciation of the equipment plus the interest on money spent in development of the system. Taxes and insurance are usually included in this item.

Years of use for depreciation purposes are:

Wells	25 years
Pumps	20 "
Pipeline	20 "
Movable sprinklers	10 "
Permanent sprinklers	20 "
Hose drag	8 "
Drip systems	10 "

Other estimated durations which may be useful include:

Aluminum tubing	10 years
Steel pipe, 14 gauge, dipped, buried	8 "
Steel pipe, 12 gauge, dipped, buried	15 "
Steel pipe, dipped, surface use	10 "
Steel pipe, galvanized, surface use	15 "
Asbestos-cement pipe	25 "
Plastic pipe	25+ "
Concrete pipe	20 "
Electric motors	15–20 "
Pumps (50,000 hours)	10–20 "
Sprinkler heads	7–8 "
Emitters	7–8 "
Hose	10 "
Sprinkler pipe— permanent	10 "
— movable	5 "

Interest was calculated at 8 percent on the average value of the equipment.

Taxes and other overhead were calculated at 2 percent of the original costs.

Operating costs

Operating costs are a function of the cost of water, energy, labor and equipment maintenance. Water costs from districts presently vary from $4 to $50 per acre-foot. We have used $15 in the calculation of border irrigation costs using district water.

Labor was charged at $4.50 per hour and includes fringe benefits.

Power costs were based on P.G. & E. rates (as of July 19, 1977) and were calculated for the operating pressures of each system by using the formula: kilowatt-hour per acre-foot = $1.024 \frac{H}{E_o}$ where H is the total lift in feet and E_o is the over-all efficiency of the pumping plant expressed as a decimal.

Repairs were estimated either at so much per acre-foot of water or on a percent of the original costs, depending on our best sources of information.

Flood Irrigation Using District Water

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Grading[1]	$240	—	$19.20	$4.80	$24.00
Pipeline and valves	150	$7.50	6.00	3.00	16.50
Tailwater system[2]	35	1.75	1.40	.70	3.85
Total	$425	$9.25	$26.60	$8.50	$44.35

Operating cost	Per Acre
Irrigation preparation	$ 10.00
Labor 5 hours per acre @ $4.50 (including fringes)	22.50
Water 3.5′ @ $15.00	52.50
Repairs 3.5′ @ $.60	2.10
Total operating cost	$ 87.10
Overhead	44.35
Total irrigation cost	$131.45

[1] Based on earth movement of 800 cubic yards per acre.

[2] Tailwater systems are recommended for all border systems.

Flood Irrigation Using Well Water

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Grading[1]	$240		$19.20	$ 4.80	$24.00
Well	150	$ 6.00	6.00	3.00	15.00
Pump 60 HP, 1,600 gpm[2]	75	3.75	3.00	1.50	8.25
Pipeline and valves	150	7.50	6.00	3.00	16.50
Tailwater system[3]	35	1.75	1.40	.70	3.85
Total	$650	$19.00	$35.60	$13.00	$67.60

Operating cost	Per Acre
Irrigation preparation	$ 10.00
Labor 5 hours per acre @ $4.50 (including fringes)	22.50
Power for 3.5′ @ $7.65	26.80
Repairs 3.5′ @ $1.00	3.50
Total operating cost	$ 62.80
Overhead	67.60
Total irrigation cost	$130.40

[1] Based on earth movement of 800 cubic yards per acre.

[2] The size of motor required for a pump is obtained by using the following formula:

$$HP = \frac{\text{gallons per minute (gpm) x head or lift in feet}}{3{,}960 \text{ x efficiency of the pump}}$$

For the flood irrigation situation, the HP is as follows:

$$HP = \frac{1{,}600 \text{ gpm} \times 100'}{3{,}960 \times .65} = 62.2 \simeq 60$$

[3] Tailwater systems are recommended for all border systems.

Center Pivot Sprinklers[1/]

Investment		Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total: Low pressure	Total: High pressure
Well		$ 150	$ 6.00	$ 6.00	$ 3.00	$ 15.00	$ 15.00
Pump– 1,000 gpm							
Low pressure	75 HP[2/]	100	5.00	4.00	2.00	11.00	––
High pressure	125 HP[3/]	145	7.25	5.80	2.90	––	15.95
Sprinkler		275	27.50	11.00	5.50	44.00	44.00
Unused Land 0.23 acres		460	––	36.80	9.20	46.00	46.00
Total	Low pressure	$ 985	$38.50	$57.80	$19.70	$116.00	$ ––
	High pressure	$1,030	$40.75	$59.60	$20.60	––	$120.95

Operating cost		Per Acre: Low pressure	Per Acre: High pressure
Labor	– 1 hour per acre @ $4.50 (including fringes)	$ 4.50	$ 4.50
Power	– Low pressure 3' @ $14.50	43.50	––
	High pressure 3' @ $23.40	––	70.20
Repairs	– Well and pump 3.0' @ $0.45	1.35	1.35
	– Sprinkler 4%	11.00	11.00
Total operating cost:	Low pressure	$ 60.35	$ ––
	High pressure	$ ––	$ 87.05
Overhead		$116.00	$120.95
Total irrigation cost		$176.35	$208.00

[1/] Based on 130 acres irrigated in a 160-acre field.

[2/] Low pressure HP = $\frac{1{,}000 \times 205}{3{,}960 \times 0.65}$ = 79.6 ≃ 75 HP (Spray Nozzle, 45 psi).

[3/] High pressure HP = $\frac{1{,}000 \times 330}{3{,}960 \times 0.65}$ = 128.2 ≃ 125 (Impact Sprinklers, 100 psi).

Due to the high application rates at the outer part of the sprinkler line, this system is restricted to soils of high infiltration rates.

Center Pivot Sprinklers With Corner Device

Investment		Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total: Low pressure	Total: High pressure
Well		$150	$ 6.00	$ 6.00	$ 3.00	$15.00	$15.00
Pump– 1,000 gpm							
Low pressure	75 HP[1/]	100	5.00	4.00	2.00	11.00	––
High pressure	125 HP[2/]	145	7.25	5.80	2.90	––	15.95
Sprinkler		360	36.00	14.40	7.20	57.60	57.60
Total	Low pressure	$610	$47.00	$24.40	$12.20	$83.60	––
	High pressure	$655	$49.25	$26.20	$13.10	––	$88.55

Operating cost		Per Acre: Low pressure	Per Acre: High pressure
Labor	– 1 hour per acre @ $4.50 (including fringes)	$ 4.50	$ 4.50
Power	– Low pressure 3′ @ $14.50	43.50	––
	High pressure 3′ @ $23.40	––	70.20
Repairs	– Well and pump 3′ @ $0.45	1.35	1.35
	– Sprinkler 4%	14.40	14.40
Total operating cost:	Low pressure	$ 63.75	$ ––
	High pressure	$ ––	$ 90.45
Overhead		$ 83.60	$ 88.55
Total irrigation cost		$147.35	$179.00

[1/] Low pressure HP = $\frac{1{,}000 \times 205}{3{,}960 \times 0.65} = 79.6 \simeq 75$ (Spray Nozzle, 45 psi).

[2/] High pressure HP = $\frac{1{,}000 \times 330}{3{,}960 \times 0.65} = 128.2 \simeq 125$ (Impact Sprinklers, 100 psi).

Due to the high application rates at the outer part of the sprinkler line, this system is restricted to soils of high infiltration rates.

Wheel-Line Sprinklers

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Well	$150	$ 6.00	$ 6.00	$ 3.00	$15.00
Pump 100 HP, 1,000 gpm[1/]	135	6.75	5.40	2.70	14.85
Sprinklers[2/]	285	28.50	11.40	5.70	45.60
Total	$570	$41.25	$22.80	$11.40	$75.45

Operating cost	Per Acre
Labor 6 hours per acre @ $4.50 (including fringes)	$ 27.00
Power for 3' @ $17.70	53.10
Repairs — well and pump 3.0' @ $.40	1.20
— sprinkler 4%	11.40
Total operating cost	$ 92.70
Overhead	75.45
Total irrigation cost	$168.15

[1/] $HP = \frac{1{,}000 \times 250}{3{,}960 \times .65} = \frac{250{,}000}{2{,}574} = 97.1 \simeq 100.$

The equivalent of about 150 feet of lift is required to put the water under pressure to operate the sprinklers.

[2/] This system is usually designed to apply water at a rate of 0.4 to 0.5 in./hr. In low-permeability soils, more wheel lin may be needed and thus additional investment is required.

Hand-Move Sprinklers

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Well	$150	$ 6.00	$ 6.00	$ 3.00	$15.00
Pump 100 HP, 1,000 gpm[1/]	135	6.75	5.40	2.70	14.85
Sprinklers	225	22.50	9.00	4.50	36.00
Total	$510	$35.25	$20.40	$10.20	$65.85

Operating cost	Per Acre
Labor 12 hours per acre @ $4.50 (including fringes)	$ 54.00
Power for 3.0' @ $17.70	53.10
Repairs — well and pump 3.0' @ $.40	1.20
— sprinkler 6%	13.50
Total operating cost	$121.80
Overhead	65.85
Total irrigation cost	$187.65

[1/] $HP = \frac{1{,}000 \times 250}{3{,}960 \times .65} = \frac{250{,}000}{2{,}574} = 97.1 = 100.$

Hose Drag

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Well	$150	$ 6.00	$ 6.00	$ 3.00	$15.00
Pump 100 HP, 1,000 gpm[1/]	135	6.75	5.40	2.70	14.85
Sprinklers	360	45.00	14.40	7.20	66.60
Total	$645	$57.75	$25.80	$12.90	$96.45

Operating cost	Per Acre
Labor 8 hours per acre @ $4.50	$ 36.00
Power 3' @ $17.70	53.10
Repairs — well and pump 3.0' @ $.40	1.20
— sprinklers 6%	21.60
Total operating cost	$111.90
Overhead	96.45
Total irrigation cost	$208.35

[1/] HP = $\frac{1,000 \times 250}{3,960 \times .65} = \frac{250,000}{2,574} = 97.1 = 100$

Permanent Set Sprinklers

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Well	$ 150	$ 6.00	$ 6.00	$ 3.00	$ 15.00
Pump 1,000 HP, 1,000 gpm[1/]	135	6.75	5.40	2.70	14.85
Sprinklers	800	40.00	32.00	16.00	88.00
Total	$1,085	$52.75	$43.40	$21.70	$117.85

Operating cost	Per Acre
Labor 2 hours per acre @ $4.50 (including fringes)	$ 9.00
Power for 3' @ $17.70	53.10
Repairs — well and pump 3.0' @ $.40	1.20
— sprinklers 3%	24.00
Total operating cost	$ 87.30
Overhead	117.85
Total irrigation cost	$205.15

[1/] HP = $\frac{1,000 \times 250}{3,460 \times .65} = \frac{250,000}{2,574} = 97.1 = 100$

Furrow Irrigation

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Grading[1]	$240		$19.20	$ 4.80	$24.00
Well	150	$ 6.00	6.00	3.00	15.00
Pump 60 HP @ 1,600 gpm[2]	75	3.75	3.00	1.50	8.25
Tailwater system[3]	35	1.75	1.40	0.70	3.85
Total	$500	$11.50	$29.60	$10.00	$51.10

Operating cost	Orchards	Field Crops
Irrigation Preparation:[4]		
Ditch @ $1.00	6x = $ 6.00	2x = $ 2.00
Furrow @ $6.00	4x = 24.00	2x = 12.00
Disk[5] @ $6.00	4x = 24.00	— —
Landplane @ $6.00	1x = 6.00	1x = 6.00
Subtotal	$ 60.00	$ 20.00
Labor 14 hours per acre @ $4.50[6]	63.00	10 hours per acre @ $4.50 45.00
Power for 3.5' @ $7.65	26.80	26.80
Repairs 3.5' @ $0.50	1.75	1.75
Total operating cost	$151.55	$ 93.55
Overhead	$ 51.10	$ 51.10
Total irrigation cost	$202.65	$144.65

[1] Based on earth movement of 800 cubic yards per acre.

[2] $HP = \frac{1,600 \times 100}{3,960 \times 0.65} = \frac{160,000}{2,574} = 62.2 \simeq 60.$

[3] Tailwater systems are recommended for all furrow systems.

[4] Cost of irrigation preparation depends on the number of times (indicated by x) each operation needs to be performed over the season.

[5] Some comparisons do not include disking as an irrigation cost.

[6] In some areas the use of gated pipe has substantially reduced labor costs.

Drip Irrigation

Investment	Per Acre	Annual Cost: Depreciation	Interest	Taxes, etc.	Total
Well	$150	$ 6.00	$ 6.00	$ 3.00	$ 15.00
Pump 75 HP, 1,000 gpm[1/]	100	5.00	4.00	2.00	11.00
Drip system[2/]	550	55.00	22.00	11.00	88.00
Total	$800	$66.00	$32.00	$16.00	$114.00

Operating cost	Per Acre
Labor 4 hours per acre @ $4.50 (including fringes)	$ 18.00
Power for 3.0' @ $12.70	38.10
Repairs — pump and well 3.0' @ $.40	1.20
— drip system @ 6%	33.00
Total operating cost	$ 90.30
Overhead	114.00
Total irrigation cost	$204.30

[1/] $HP = \frac{1{,}000 \times 180}{3{,}960 \times .65} = \frac{180{,}000}{2{,}574} = 69.9 \simeq 75.$

[2/] The cost of equipment varies depending on the lateral spacing and number of emitters which depends on type of crop. This assumed cost applies to mature orchards.

Summary of Costs for Various Methods of Irrigation

	Flood		Center Pivot Sprinkler		Center Pivot With Corner Device				Furrow			Permanent	
	District water	Well water	Low pressure	High pressure	Low pressure	High pressure	Wheel Line Sprinkler	Hand-Move Sprinkler	Orchard	Field crop	Hose Drag	Set Sprinkler	Drip
Number of irrigations	6	6	–	–	–	–	8	8	6		8	8	–
Water applied (feet)	3.5	3.5	3.0	3.0	3.0	3.0	3.0	3.0	3.5		3.0	3.0	3.0
Investment per acre	$425.00	$650.00	$985.00	$1,030.00	$610.00	$655.00	$570.00	$510.00	$500.00		$645.00	$1,085.00	$800.00
Overhead per acre													
Depreciation	9.25	19.00	38.50	40.75	47.00	49.25	41.25	35.25	11.50		57.75	52.75	66.00
Interest	26.60	35.60	57.80	59.60	24.40	26.20	22.80	20.40	29.60		25.80	43.40	32.00
Taxes, etc.	8.50	13.00	19.70	20.60	12.20	13.10	11.40	10.20	10.00		12.90	21.70	16.00
Total	44.35	67.60	116.00	120.95	83.60	88.55	75.45	65.85	51.10		96.45	117.85	114.00
Operating cost per acre													
Irrigation preparation	10.00	10.00	–	–	–	–	–	–	60.00	20.00	–	–	–
Labor	22.50	22.50	4.50	4.50	4.50	4.50	27.00	54.00	63.00	45.00	36.00	9.00	18.00
Power	–	26.80	43.50	70.20	43.50	70.20	53.10	53.10	26.80	26.80	53.10	53.10	38.10
Water	52.50	–	–	–	–	–	–	–	–	–	–	–	–
Repairs	2.10	3.50	12.35	12.35	15.75	15.75	12.60	14.70	1.75	1.75	22.80	25.20	34.20
Total operating	$ 87.10	$ 62.80	$ 60.35	$ 87.05	$ 63.75	$ 90.45	$ 92.70	$121.80	$151.55	$ 93.55	$111.90	$ 87.30	$ 90.30
Total cost	$131.45	$130.40	$176.35	$ 208.00	$147.35	$179.00	$168.15	$187.65	$202.65	$144.65	$208.35	$ 205.15	$204.30

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