Irrigation Systems for Idaho Agriculture

Howard Neibling

Idaho has approximately 4 million acres of irrigated agricultural land. Most of it is in pasture and hay crops, grain crops, potatoes, and sugar beets, in hierarchical order. Table 1 shows the number of irrigated acres in the state by crop for 1994. Nearly all of this land is irrigated by either sprinklers (59 percent) or surface irrigation systems (40 percent), with only a very small amount (less than 1 percent) in micro-irrigation systems (trickle or drip) (table 2).

The selection of an irrigation system, or the decision to continue with a gravity system rather than convert to a sprinkler system, is a matter of tradeoffs among the following factors: initial investment costs, operating costs, site factors, and management skills. A relative comparison of these factors is given on pages 4-5. In general, the higher-investment, higher-water-application-efficiency systems are found in areas where large fields of high-value, water-sensitive crops are grown, or where water supply may be limited or pumping lift is high. Lower-initial-investment surface systems are generally used in short-growing season areas or areas where soil depth or texture limits production. Lack of available three-phase electric power and seed production requirements for dry foliage (for disease control) may also dictate the continued use of surface irrigation.

In a ideal irrigation system, on a field with uniform soil properties, water is supplied uniformly over the entire area of a field at a rate not to exceed the rate at which water will enter the soil (infiltration rate), and with a frequency and amount to meet the crop need. Since crop water use varies during the year, water application should also vary to just meet this need. Water in excess of crop need should be applied only on

Table 1. 1994 Idaho acreage irrigated by crop (adapted from *1995 Idaho Agricultural Statistics*, Idaho Agricultural Statistics Service, Boise, ID).

Crop	Acres irrigated
Alfalfa	820,000
Barley	458,000
Beans, dry	138,000
Corn (grain and silage)	97,000
Flower seed	100
Grapes	1,000
Grass seed	500
Hops	4,037
Melons	500
Oats	12,000
Pasture/Hay crops	1,148,363
Potatoes	408,000
Small Fruits	600
Turfgrass/sod	100
Sugar Beets	201,000
Tree Fruits	12,400
Wheat	760,000
Mint	17,500
Onions	8,600
Sweet corn	17,100

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fields where soil or water supply quality requires overirrigation for salinity control.

Application Efficiency

Application efficiency is the percentage of water delivered to the head of a field that is actually stored in the crop-root zone. Application efficiencies for typical surface and sprinkler irrigation systems are given in table 3.

Surface Irrigation Systems

Water applied by surface irrigation systems may be stored in the root zone, lost to surface runoff, or lost to deep percolation below the root zone because of excess application. Evaporation losses are minimal compared to sprinkler irrigation. Surface irrigation methods have relatively low application efficiencies because runoff from the field may be up to 20-40 percent of water applied, and deep percolation may be up to 20-40 percent. Application efficiencies for traditional furrow-irrigated systems supplied by siphon tubes or gated pipe range between 30 and 40 percent, with efficiencies of 50-60 percent possible with excellent management. Land grading to eliminate low spots reduces local overirrigation and raises efficiency by about 5-10 percentage points. Improved systems that give better control over water application rates, or improved management to reduce runoff or deep percolation, will increase the fraction of applied water that is usefully stored and raise application efficiency. Improved surface irrigation systems with good irrigation water management can have application efficiencies comparable to handline or wheelline sprinkler systems.

Table 2. Idaho acreage irrigated by specific irrigation method (adapted from information developed for the *1995 Annual Irrigation Survey,* Irrigation Journal 46(1):27-28.

Sprinkler systems	Acres irrigated
Center-pivot/Linear-move	841,000
Side-roll (wheelline)	671,700
Hand-move	845,400
Solid-set	74,200
Big-gun	1,600
Total	2,433,900
Low flow/Micro-irrigation systems	
Surface micro-spray	6,100
Surface drip	450
Subsurface drip	200
Total	6,750
Surface/Gravity systems	
Flooding from ditches	733,350
Open ditch/Siphon tube	852,500
Gated pipe	77,100
Lay-flat pipe	1,000
Total	1,663,950

Sprinkler Systems

Water applied by sprinkler systems may be stored in the root zone, lost to evaporation or wind drift during application, or lost to deep percolation if more water is applied than the root zone can hold. If application rate exceeds the rate at which water can enter the soil, water can also be lost to surface runoff on sloping land. Equipment that applies water closer to the ground with good areal uniformity will reduce losses to evaporation and wind drift and losses to deep percolation or runoff caused by localized areas of excess application.

Micro-irrigation (Drip) Systems

Nearly all water applied by micro-irrigation (drip) systems should be stored in the crop-root zone if water is not overapplied. Since application is at or below the soil surface, evaporation is minimal, runoff should be zero, and deep percolation losses due to nonuniformity of application should be minimal. Therefore, application efficiencies are quite high.

Surface Irrigation Systems

Furrow or Corrugate Irrigation

Before advances in sprinkler design and aluminum pipe production in the 1950s, almost all irrigated land was surface irrigated. Row crops are irrigated by supplying water to the upslope end of furrows that are spaced from 22-36 inches apart, depending on the crop grown. Water is supplied to close-growing crops, such as alfalfa or small grains, by corrugates spaced 24-30 inches apart. Furrows are deeper and wider than corrugates. Water supply to the furrows or corrugates is by feed ditches and cutouts, earthen or concrete head ditches with siphon tubes, or gated pipe. Siphon tubes or gated pipe allow closer, more repeatable control of water discharged into each furrow or corrugate. This allows better water management and improved application efficiencies with little additional labor. It should be emphasized that concrete ditches with siphon tubes or gated pipe do not by themselves improve irrigation efficiency: they are a tool to help improve water management, which does improve efficiencies.

Border or Graded-Border Irrigation

Irrigation of alfalfa, pastures, or small grain may also be accomplished by graded- or level-border irrigation. In border irrigation, water is supplied at the head of 40-100 foot wide borders separated by earthen ridges. Border width is designed so that the entire border width is flooded, and the flood wave moves downslope. Fields with very little sideslope and low infiltration rates will allow wider borders than will fields with higher infiltration rates or more pronounced slope across the border. Water supply may be by large siphon tubes, riser outlets from surface or buried mainline, or gates in a supply ditch.

Wild Flooding

Wild flooding may be the irrigation method of choice when water is plentiful, crop value per acre is relatively low, and improved irrigation management will not yield a significantly higher financial return. Wild flooding involves diverting water from cross-slope ditches at intervals to assure adequate coverage of a slope. The water flows downslope and may concentrate in low areas or skip high areas. The spacing between diversion points on the supply ditch and between successive downslope ditches must be reduced as topography becomes more undulating, soils become more sandy or gravelly (higher infiltration rates), or resistance to water flow increases (plant density at the soil surface increases).

Improved Surface Systems

Surge Irrigation

Surge irrigation is a relatively new technique that reduces tailwater runoff and deep percolation. Initial testing suggests that it can reduce water losses by 30-50 percent. Water is applied to each furrow in a series of pulses rather than as a continuous stream. A valve controlled by a clock or microprocessor allows flow to be alternated between two adjacent sets of furrows. This surging action in a furrow allows water to travel faster to the lower end, resulting in less deep percolation at the head of the furrow. Changing cycle time within an irrigation can reduce tailwater runoff, saving additional water. This system works best on light, loose soils and is less effective on heavier soils or on soils where compaction occurs during the growing season. Cost is about $1,500-$2,000 per surge valve. Typically, one or at most two valves are used per run of gated pipe.

Table 3. Typical irrigation system application efficiencies for surface and sprinkler irrigation systems.

	Application efficiency, %	**Water required to put 1 inch in crop-root zone**
Surface systems		
Furrow	35-60	1.7-2.8
Corrugate	30-55	1.8-3.3
Border, level	60-75	1.3-1.7
Border, graded	55-75	1.3-1.8
Flood, wild	15-35	2.8-6.7
Surge	50-55	1.8-2.0
Cablegation	50-55	1.8-2.0
Sprinkler systems		
Stationary lateral (wheel- or hand-move)	60-75	1.3-1.7
Solid-set lateral	60-85	1.2-1.7
Traveling big gun	55-67	1.5-1.8
Stationary big gun	50-60	1.7-2.0
Center-pivot lateral	70-85	1.2-1.4
Moving lateral (linear)	80-87	1.1-1.2
Micro-irrigation systems		
Surface drip	90-95	1.05-1.1
Subsurface drip	90-95	1.05-1.1
Micro-spray or mist	85-90	1.1-1.2

Source: Sterling, R., and W. H. Neibling, 1994. *Final Report of the Water Conservation Task Force*. IDWR Report. Idaho Department of Water Resources, Boise.

Cablegation

Cablegation is an automated surface irrigation system that uses a travelling plug inside a gated pipe delivery system. The plug restricts water application to only those gates nearest the plug. Flows nearest the plug are the greatest and advance fastest down the furrows. Flow in any furrow gradually decreases as the plug moves downstream. This nearly matches the natural decrease in infiltration rate with time and thus reduces tailwater runoff. Because the system encourages rapid initial advance and later cutback of flow, water application is more uniform, and runoff and deep percolation are reduced. Cost is approximately $100 per acre.

Tailwater Recovery Systems

Tailwater recovery systems are typically used in surface systems where water supply is short or where sediment discharge in runoff must be eliminated. A pond installed at the base of the field catches all runoff and stores it until it is pumped back to the head of the field for irrigating another set of furrows. Tailwater recovery systems can improve application efficiencies to val-

Comparison of irrigation systems in relation to site and situation factors

	Improved surface systems		
Site and situation factors	**Redesigned surface systems**	**Level basins**	**Intermittent mechanical m**
Infiltration rate	Moderate to low	Moderate to low	All
Topography	Moderate slopes	Nearly level	Level to rollin
Crops	All	All	Generally sho
Water quality	All but very high salts	All	Salty water m plants
Efficiency	Average 55-70%	Average 80%	Average 60-70
Labor requirement	High, training required	Low, some training	Moderate, so
Capital requirement	Low to moderate	Low to Moderate	Moderate
Energy requirement	Low	Low	Moderate to h
Management skill	Moderate	Moderate	Moderate
Machinery operations	Medium fields	Short field	Medium to lo length, small
Duration of use	Short to long	Long	Short to medi
Weather	All	All	Poor in windy conditions
Chemical application	Fair	Fair to good	Good

ues near 70 percent (comparable to sprinkler irrigation) and are compatible with cablegation and traditional gated-pipe or head-ditch systems. Cost is about $100 to $200 per acre, depending on distance from the nearest power line to the pond.

Sprinkler Irrigation Systems

Set-Move Systems

Set-move systems are operated for a given set time, usually 5, 11, or 23 hours, and then moved to a new location for operation again. If about one hour is allowed for moving, then one, two, or four sets can be irrigated per day. Examples of systems most used in Idaho are wheellines (figure 1) and handlines. Initial system cost is about $250-$300 per acre for handlines and $300-$350 per acre for wheellines. Required operating pressure is about 45-55 psi. Labor is required for moving, but the entire field may be irrigated. Since impact sprinklers are mounted 3-4 feet above the ground, these systems are good for low-growing crops but not for corn. Spacing between nozzles on a lateral is 40 feet and spacing between moves is 50 or 60 feet.

	Sprinkler systems		Micro-irrigation systems
move	**Continuous mechanical move**	**Solid-set and permanent**	**Bi-wall tubing or drip tubing with in-line emitters**
	Medium to high	All	All
ng	Level to rolling	Level to rolling	All, but special design required on rolling topography
orter crops	All but trees and vineyards	All	High value required
nay harm	Salty water may harm plants	Salty water may harm plants	All–can potentially use high salt water
0%	Average 80%	Average 65-75%	Average 90-95%
me training	Low, some training	Low to seasonal high, little training	Low to high, some training
	Moderate to high	High	High
high	Moderate to high	Moderate	Low to moderate
	Moderate to high	Moderate	High
ong field interference	Some interference circular fields	Some interference	May have considerable interference
ium	Short to medium	Long term	Long term with good management (10-15 years)
y	Better in windy conditions than other sprinklers	Poor in windy conditions, good for cooling or frost protection	All
	Good	Good	Very good

Solid-Set Systems

Solid-set systems are typically used for center-pivot corners and for potato production. They are like handlines but with enough equipment to cover the entire area to be irrigated without moving pipe. Equipment costs are higher, but labor costs are lower since sets may be started or stopped by adjusting valves and no pipe must be moved. Spacing is usually 40 x 40 or 40 x 50 feet. Equipment cost can be up to $1,000 per acre.

Center-Pivot Systems

Continuous-move systems typically used in Idaho are center-pivot systems (figure 2) and linear-move systems. Initial center-pivot system cost is $350-$450 per acre. Since center-pivot systems irrigate a full- or part-circle pattern, not all of a square or rectangular field can be irrigated by the system. For example, a typical pivot on 160 acres will irrigate about 134 acres. About 10-12 additional acres can be irrigated with a folding attachment that swings out to irrigate more of the corners. Otherwise, the corners must be irrigated by handlines or solid-set systems.

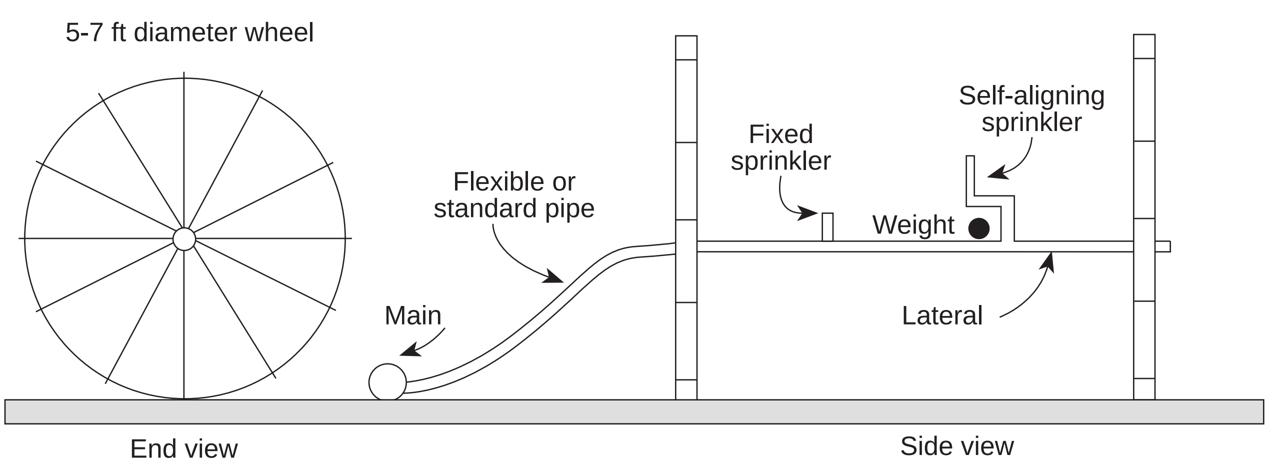
Because of the system geometry, more water must be applied per foot of pivot as one moves outward from the pivot point. This is usually accomplished by closer nozzle spacing and larger nozzles. Typical water application packages for pivots are either a high-pressure impact sprinkler (50-60 psi) mounted on the top of the pivot lateral pipe or a low-pressure system (15-25 psi) mounted about 6 feet off the ground on drop pipes mounted under the pivot lateral pipe. Average system cost is about $350-$400 per acre.

If the pump is properly sized and designed for the low-pressure system, considerable energy cost savings may be achieved. However, in the conversion from high to low pressure, many pumps remain unchanged either to reduce capital costs or to support the high-pressure end gun and sprinkler lines necessary to water the corners. In this case, no energy is saved although system uniformity is improved. In many cases, an additional, smaller high-pressure pump can be installed to serve the corners and a booster pump added for the end gun. The larger pivot pump may then be reworked to reduce energy use and energy costs.

Almost all new pivots are equipped with the low-pressure package, and about half of existing pivots have been converted to low pressure. Because nozzle spacing is closer, application uniformity is improved for low-pressure pivots. With the discharge point closer to the ground, water droplets reach the ground sooner and thus evaporate less. As a result, typical application efficiencies are about 70 percent for a high-pressure pivot and 80-85 percent for a low-pressure pivot. High-pressure impact sprinklers typically cover about a 100-foot wetted diameter, while low-pressure spray nozzles cover about a 20-foot diameter. Since the same amount of water is applied over a 20-foot circle instead of a 100-foot circle, runoff is a problem in soils with low infiltration rates.

One option to avoid surface runoff under low infiltration conditions is to mount a number of spray nozzles along a boom running parallel to

Figure 1. Mechanical-move sprinkler system: Side-roll lateral (hand or mechanical move).



the direction of pivot travel (thus spreading water over about 50-60 feet instead of 20 feet). Another widely used option is the use of "rotators," "spinners," or "wobblers" to apply water at low pressure but over a 40-55 foot wetted diameter. The wetted area may be further increased (to avoid surface runoff) by mounting these devices on offset booms about 5-10 feet in front of and behind the pivot lateral pipe on the outer one-third to one-half of the pivot lateral.

Linear-Move Systems

Linear-move systems are continuous-move systems with water supplied by (1) a dragging hose that must be periodically reattached to another riser, (2) automated mechanical attachment to special risers on a buried mainline, or (3) pumping from a concrete ditch. The first two supply methods are used in Idaho. Linear-move systems have the advantages of irrigating an entire rectangular field and of having excellent water application uniformity. They may be configured as either high- or low-pressure systems, with nearly all new installations being low-pressure systems. Initial system cost is $600-$750 per acre.

Micro-irrigation and Drip Irrigation Systems

"Micro-irrigation" describes a number of irrigation systems that supply water in a carefully controlled rate to a limited area of soil adjacent to the plant to be irrigated. This precision placement of water and water-carried fertilizers or other chemicals also provides higher fertilizer- (or chemical-) use efficiency and less impact to the groundwater than any other type of irrigation system. Because of low flow rates and small orifices, it is extremely important that the supply water be properly filtered before use. These systems can be fully automated, thus reducing labor costs for system operation. Irrigation equipment typically placed in this category includes micro-sprinklers, surface or subsurface drip irrigation with individual emitters, and drip tape.

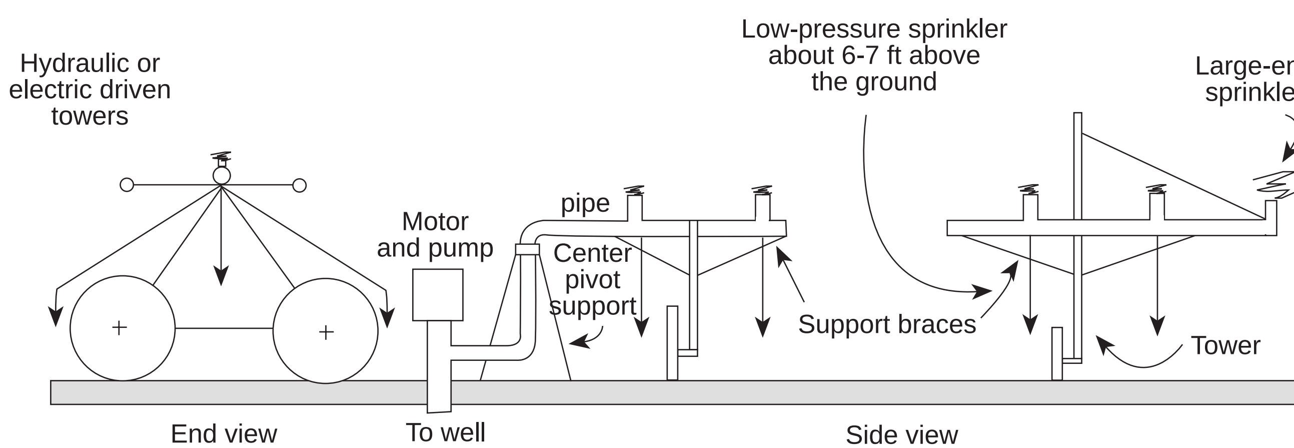
Micro-sprinklers

Micro-sprinklers are miniature impact sprinklers that operate at low pressure and may cover an area only 5-10 feet in diameter. They may be supplied by buried or surface mainlines and laterals. Sprinklers are usually mounted on 1-3 foot risers. One frequent application for this type of system is in orchards, where the trees must be irrigated but the area between the trees can remain dry. Energy and water use per tree are significantly reduced compared to sprinkler irrigation. Supply water must be filtered to remove debris of sufficient size to clog the sprinkler nozzles. Equipment cost is approximately the same as for a solid set sprinkler.

Drip Tubing with Individual Emitters

Drip tubing with individual emitters allows precise water placement with minimal evaporation. Water is supplied to the irrigated area by a properly sized mainline and distributed by submains to each set (the area to be irrigated at

Figure 2. Mechanical-move sprinkler system: Self-propelled (center-pivot) lateral.



any one time). Submains supply a number of lines of rigid plastic drip tubing, which supply individual emitters. In either an orchard or landscape setting, each plant may be watered by one or more emitters, with additional emitters added as the plant grows and water use increases. Water supply filtration requirements are more demanding. Filtration costs of $300-$400 per acre for surface water supply can equal the cost of the remaining system hardware.

Bi-wall Drip Tape

Bi-wall drip tape provides a line source of water to row crops. It may be placed either on the surface and retrieved after each crop year (typical in onions) or buried at a depth of 12-16 inches and used for 10-15 years (typical for drip tape used in center pivot corners). This flexible plastic tubing has in-line emitters formed during manufacturing. Available tubing thicknesses range from 6-25 mil, and emitter spacings range from 2-24 inches. Most manufacturers have both a "low flow" tape for heavy soils and a "high flow" tape for sandy soils. For surface placement in row crop applications, one tape is used per row. When buried, tape spacings vary from 3-5 feet, depending on soil properties. Tape cost is about $0.03-$0.10 per foot, depending on wall thickness. *Proper supply water filtration is essential,* with costs ranging from $300-$500 per acre for surface water supply.

One potential use for bi-wall drip tape is irrigation of center pivot corners. It may be buried 12-16 inches deep with all farming practices performed at a shallower depth. An alternate arrangement installs tape at a depth of 2-3 inches with yearly retrieval. Complete system cost for installing drip tape in a center-pivot corner (excluding installation labor) is about $1,000-$1,300 per acre, depending upon source of water.

For more information . . .

Patterson, Paul E., Bradley A. King, and Robert L. Smathers. 1996. *Economics of Low-pressure Sprinkler Irrigation Systems: Center Pivot and Linear Move.* University of Idaho Cooperative Extension System and College of Agriculture Bulletin 787. Moscow, Idaho $3.00.

Patterson, Paul E., Bradley A. King, and Robert L. Smathers. 1996. *Economics of Sprinkler Irrigation Systems: Handline, Solid Set, and Wheelline.* University of Idaho Cooperative Extension System and College of Agriculture Bulletin 788. Moscow, Idaho $3.50.

Smathers, Robert L., Bradley A. King, and Paul E. Patterson. 1995. *Economics of Surface Irrigation Systems.* University of Idaho Cooperative Extension System and College of Agriculture Bulletin 779. Moscow, Idaho. $1.50.

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