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Determining the Amount of Irrigation Water Applied to a Field

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Introduction

Critical to any irrigation management approach is an accurate estimate of the amount of water applied to a field. Too often, growers apply water to make the fields and rows "look good" (blacken-up the beds) or continue irrigating until the water reaches the end of every furrow. However, quite often they never realize just how much water they have applied. When growers do not take their system's efficiency into account , they may apply too little or too much water. Too little water causes unnecessary water stress and can result in yield reductions. Too much water can cause water logging, leaching, and may also result in loss of yield.

The Irrigator's Equation

How Much Did I Apply?

Estimating the amount of water applied to a field or to a set is fairly easy for surface systems. The Irrigator's Equation, Q x t = d x A, can be used to estimate the depth of water applied. In the equation:

$$\mathbf{Q \times t = d \times A}$$

Q is the flow rate, in cubic feet per second (cfs); t is the set time or total time of irrigation (hours); d is the depth of water applied (inches) and A is the area irrigated (acres).

If you are working with a pump, remember that 450 gallons per minute equals 1 cfs. Also, there are 40 miners-inches per 1 cfs. However, miners-inches change from region to region. Make sure you check which type of miners-inches you are working with. Table 1 has some useful conversions.

To determine how much water was applied, use the Irrigator's Equation and solve for the unknown value, d, depth of water applied in inches. For example, suppose you irrigated a set 320 ft. wide (that's 96 rows at 40 inches apart); 800 ft. long with a head of 6 cfs. Your set time was about 6.5 hours. How much water have you applied? First, calculate the area irrigated:

320 ft. × 800 ft. = 256,000 ft.^{2}

There are 43,560 ft.^{2} in 1 acre, so:

256,000 ft. ^{2} / (43,560 ft.^{2}/acre) = 5.9 acres

Now, using the Irrigator's Equation we get:

6.0 (cfs) × 6.5 (hours) = d (inches) × 5.9 (acres)

Solving for d (depth of water applied) we get:

d (inches) = (6 × 6.5) / 5.9 = 6.6 inches

The total amount of water applied to the field was 6.6 inches in depth.

How Long Should My Set Time Be?

The Irrigator's Equation can also be used to estimate how long your set times should be. By choosing a target amount of water to apply, you can use the same equation but solve for time instead of depth of application.

For example, suppose you estimated that your soilwater deficit was 4.0 inches. You want to refill the soil and apply the full 4.0 inches. Your set size is 150 feet wide (that is 45 rows at 40 inches apart), 1100 feet long, and you are running 5 cfs. How long should your set time be?

Again, first calculate the total area to be irrigated. In this case, we have:

150 ft. × 1100 ft. = 165,000 ft.^{2}

To convert to acres:

165,000 ft.^{2} /(43,560 ft.^{2}/acre) = 3.8 acres

Now using the Irrigator's Equation, we get:

5.0 (cfs) × t (hours) = 4 (in) × 3.8 (acres)

Solving for t we get:

t (hours) = (4 × 3.8)/5 = 3 hours

The set time should be three hours to apply 4.0 inches of water.

The Irrigator's Equation can be used to determine any of the four variables in the equation, providing you know the other three.

Don't Forget the Efficiency

The one factor in irrigation that is most often overlooked is the efficiency of the irrigation system itself. There are many different types of efficiency and many different ways to define it. Efficiency here refers to the overall system's ability to apply an equal amount of water to all parts of the field. A system with 100% efficiency would be able to

Table 1. Conversion from cubic feet per second (cfs) to gallons per minute (gpm) to Miners inches.

Flow Rate Conversion Table		
Cubic Feet per Second (cfs)	*Gallons per Minute (gpm)*	*Miner's Inches*
1	450	40
2	900	80
4	1800	160
6	2700	240
8	3600	320
10	4500	400

apply the same amount of water to every inch of the field, head end, tail end, center, side, etc. No system is 100% efficient. Drip systems are the most efficient and they are usually near 95% efficient. Surface systems are notorious for inefficiency, but properly maintained fields can achieve efficiencies as high as some sprinkler systems.

Table 2 gives the range of efficiencies normally associated with different types of irrigation systems. In order to apply the proper amount of water to a field, first you must decide what efficiency to use in your calculations. The table gives a range of values for seasonal and peak use periods. These are provided because some systems are better equipped to handle large applications and during times of peak water use, when water demand is high, the system's efficiency is increased.

For example, all of the surface systems have an increase in their efficiency from seasonal to peak use periods because surface systems can apply large amounts of water more efficiently than smaller amounts. During the early part of the season, these systems are inefficient because they over-water. Overall, seasonal efficiency is relatively low compared to the efficiency during peak use. Sprinkler and drip systems (with the exception of the traveler sprinkler system), on the other hand, maintain their efficiencies regardless of seasonal or peak use periods. This is because these systems apply large and small quantities of water at about the same efficiency.

Taking the average of the ranges in Table 2 is probably a good start, although many surface systems operate at the very low end of the ranges given. Also, many sprinkler systems with LEPA (Low Energy Precision Application) systems and drop nozzles achieve even higher efficiencies than those given. You can contact your local Natural Resources Conservation Service office or local consultant who may be able to perform an analysis on your system to determine the irrigation efficiency. Once the efficiency has been determined, use that to adjust your irrigation amounts.

Let's take the second example where the grower was determining how long the set time should be to irrigate 4.0 inches. If he has a system that is 75% efficient, then the target amount would be increased from 4.0 inches to 5.3 inches. In order to account for the system's inefficiency, the efficiency must be divided into the targeted amount. In the example above, the efficiency of 75% (or 0.75) is divided into the target amount of 4 inches:

$$\mathbf{4.0/0.75 = 5.3}$$

This gives the actual amount of water that needs to be applied to assure that the entire field receives at least 4 inches of water. Of course, some of the field will receive more water, but that is the cost of the system's inefficiency.

To determine the set time for the example above, we use the Irrigator's Equation and calculate for 5.3 inches instead of 4.0 inches:

$$\mathbf{5 \times t = 5.3 \times 3.8}$$

$$\mathbf{Q \times t = d \times A}$$

Solving for t we get:

$$\mathbf{t = (5.3 \times 3.8) / 5 = 4 \text{ hours}}$$

The set time should be four hours to assure that all parts of the field receive at least 4.0 inches of water.

Proper calculation and keeping records of irrigation amounts and set times, as well as a realistic estimate of system efficiency, will help to assure that your crop receives all the water it needs.

The information provided in this bulletin is also available in an *Irrigation Slide Chart* (1999), which helps to determine set times and flow rates. The slide chart is written in both English and Spanish and is easy to use. The slide chart is available through your local Cooperative Extension office.

References

Hoffman, G.J., T.A. Howell and K.H. Solomon, eds. 1990. Management of Farm Irrigation Systems. Amer. Soc. Agric. Engr. ASAE Monograph No. 9. St. Joseph, MI 1040 pp.

Irrigation Slide Chart. 1999. The University of Arizona, Cooperative Extension, Pub. az1135, *Arizona Water Series*: Number 21. (English/Spanish)

For further information contact your local Cooperative Extension office.

Table 2. Estimated seasonal average and peak water-use period irrigation efficiencies.*

Type of Irrigation System		Efficiency Range (%)	
		Seasonal Average	*Peak Use Period*
Surface	Furrow (without reuse)	55-77	77-80
	Border (without reuse)	63-84	77-87
	Basin	70-80	70-87
	Precision-leveled basin	77-84	80-87
Sprinkler	Moved lateral	70-80	70-80
	Traveler or boom	67-75	55-70
	Solid set	70-87	70-87
	Center pivot	80-87	80-87
	Lateral move	84-90	84-90
Drip	Point source	74-93	74-93
	Drip tape	85-95	85-95

* Modified from Hoffman et al. (1990)

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