University of Missouri Extension

G1681, Reviewed October 1993

Measuring Irrigation Water in a Ditch, Stream or Reservoir

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Measuring water is necessary to efficiently use water resources in irrigation farming. Over-irrigation can be as detrimental as under-irrigation and is economically unjustified.

Management decisions must be based on the amount of water used and how this relates to plants and soil.

Units of measuring water

Acre-inch (ac-in)
One acre-inch is the volume of water necessary to cover an acre 1 inch deep or the amount of water falling on an acre in a 1-inch rain. One acre-inch equals 3,630 cubic feet or 27,154 gallons.

Acre-foot (ac-ft)
One acre-foot is the volume of water necessary to cover an acre 1 foot deep. One acre-foot equals 43,560 cubic feet, 325,851 gallons or 12 acre-inches.

Gallons per minute (gpm)
One gallon is exactly 231 cubic inches. The gallons per minute measurement is the amount produced by a pump, stream, or pipeline in one minute.

Cubic feet per second (cfs)
One cubic foot per second is a flow of water equivalent to a stream 1 foot wide and 1 foot deep flowing at a velocity of 1 foot per second.

1 cfs = 450 gpm = 1 acre-inch per hour = 2 acre-feet per day

Head (H)
Head is a depth of water, usually in feet. It can also mean pressure; a volume of water exerts a pressure on the bottom of a container, lake or stream that is proportional to the depth of water above the bottom. One foot of water (head) exerts a pressure of 0.43 pounds per square inch on the bottom surface. Or, 1 pound per square inch is equivalent to 2.31 feet of head.

Hints for the irrigator

A good water manager needs to know:

1. Volume of water pumped.
2. Depth of water applied.
3. Number of acres covered.
4. Length of time to apply the water.

Any one of the four can be computed if the other three are known.

Example: The flow rate in a given stream is 900 gallons per minute. If you divert all of the stream flow into a 60-acre corn field, how long will it take to apply 2 inches?

450 gpm = 1 acre-inch per hour

900 ÷ 450 = 2 acre-inch per hour

60 acres x 2 inches = 120 acre-inch

120 acre-inch ÷ 2 acre-inch per hour = 60 hours

Measuring water

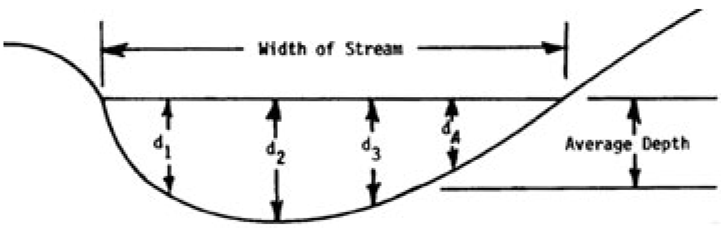

Figure 1
Stream cross section.

Float method
Flow rate of a stream is easily estimated by the float method. Use it when high accuracy is not needed and a more expensive device is not justified.

Select a section of stream 100 feet or more in length that has uniform depth and width. Measure the surface width of water and estimate the average depth of water by making depth measurements at intervals across the stream.

Place a small float in the stream a few feet upstream from the upper end of the trial section. Record the time the float takes to pass through the trial section. Make several trials and use the average time of travel.

Computation: Divide the length of the trial section in feet by the time in seconds required for the float to travel that distance to obtain the velocity in feet per second. Multiply the velocity in feet per second by the estimated stream cross-sectional area in square feet to determine the flow rate in cubic feet per second. Multiply this figure by 450 to obtain the flow rate in gallons per minute. Measure the stream in summer, during the greatest irrigation demand and the lowest natural flow rate.

Tracer method
The tracer method of flow measurement requires the injection of dyes or salts into the stream at a given point. They are then detected at some point downstream, and the velocity is determined from the time

required by the tracer to flow the measured distance. Because the dye or salt is often diffused throughout the stream, determine the velocity of the first and last portions of the dye and take the average. Multiply the average velocity of the dye by the cross-sectional area of the stream to obtain the flow rate. Computation is the same as for the float method.

Velocity head rod

The velocity head rod shown below is a fast and inexpensive method of measuring velocity in a stream. The rod, 5 feet long, can be made from wood. A 26-gauge copper sheet is sometimes fastened to the cutting edge to protect it from abuse. Mark a scale in 1/2-inch increments on the rod, starting with zero at the bottom of the rod and stopping at 18 inches.

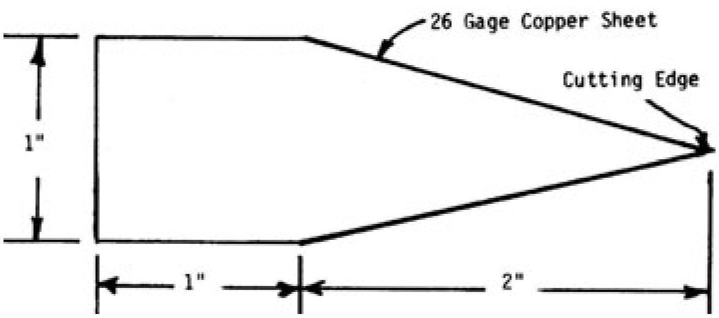

Figure 2
Velocity head rod cross section.

Steps to find the flow rate with a velocity head rod are:

- Place rod in the water with sharp edge upstream. Measure stream depth on scale.
- Place rod sideways in the water. This will create turbulence and the water will "jump" or rise above its normal depth. Stream velocity is proportional to this jump. Measure depth of turbulent water next to rod.
- Subtract stream depth from the turbulent depth reading to obtain the "jump height," or velocity head in inches.
- Find the stream velocity in feet per second from Table 1.
- Determine the stream velocity at intervals across the stream and average them to obtain the average stream velocity in feet per second.
- Multiply the average velocity by stream cross-sectional area to find flow rate in cubic feet per second. Multiply this figure by 450 to obtain the flow rate in gallons per minute.

Table 1
Stream velocities from head rod

Head	Velocity
0 inches	0 feet per second
0.5 inches	1.6 feet per second
1 inches	2.3 feet per second
2 inches	3.3 feet per second
3 inches	4.0 feet per second
4 inches	4.6 feet per second
5 inches	5.2 feet per second

6 inches	5.7 feet per second
7 inches	6.1 feet per second
8 inches	6.5 feet per second
9 inches	6.9 feet per second
10 inches	7.3 feet per second
11 inches	7.7 feet per second
12 inches	8.0 feet per second
15 inches	9.0 feet per second
18 inches	9.8 feet per second

The velocities in Table 1 were computed by this formula:

V = 8 x the square root of h

where
V = velocity in feet per second
h = velocity head in feet

The velocity head rod is inaccurate for velocities less than 1.0 foot per second and for fast streams. It is practical for estimating purposes.

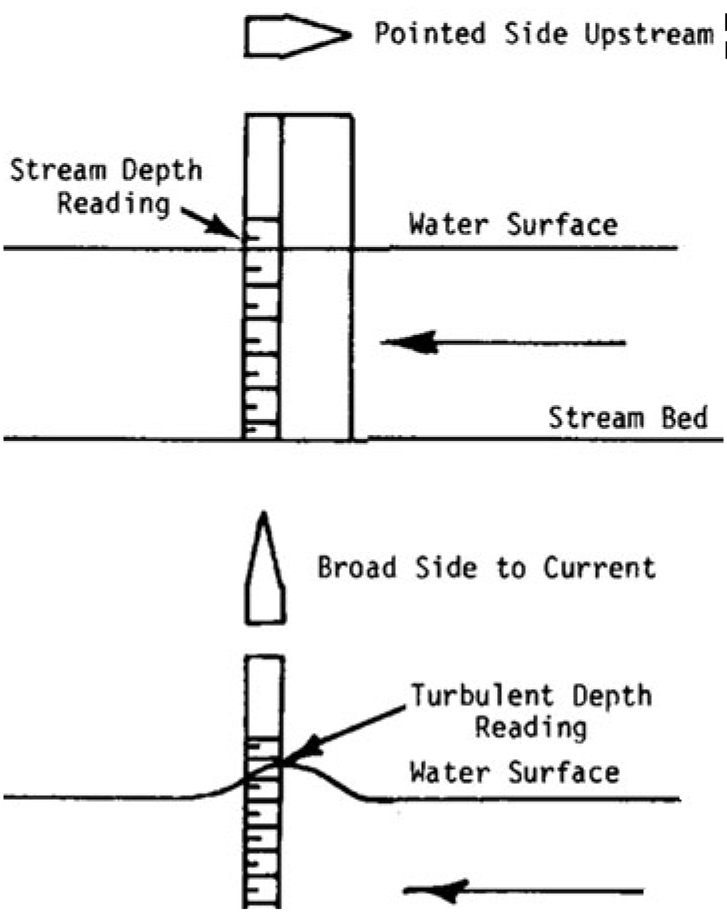

Figure 3
Placing velocity head rod in water.

Current meter method

A current meter can be used to determine velocity of a stream. This method is the standard used by the U.S. Geological Survey in gauging natural streams. This commercially made instrument contains a revolving wheel or vane that is turned by water movement. Mount the meter on a rod or lower it into the water with cable. Rod mountings can be used in shallow streams, but cable suspension may be needed in deep water.

Take meter readings at several measured locations in the stream cross-section and determine the corresponding velocities from the meter's calibration curve. Multiply the measured velocity by the cross-sectional area in square feet represented by that velocity to obtain the flow rate of each section. Sum the flow from each section to obtain the total flow rate of the stream.

Weirs

A weir is a notch of a specific shape through which water may flow. Weirs are probably the most common device for measuring irrigation water in open ditches. Weirs are simple to construct and fairly accurate if properly maintained. They require enough slope in the ditch to allow the water to be partially held back and spill over the weir. Air space is necessary under the falling sheet of water for accurate flow measurement.

The bottom of the notch over which water flows is the crest of the weir. Of the three common shapes of weirs, the rectangular and trapezoidal weirs are useful for measuring large streams. The v-notch weir is most accurate for flows of less than 1 cubic-foot per second (450 gpm).

Follow these steps in using a weir:

- Estimate the maximum flow rate in the stream to be measured using the float method or some other method.
- Select a weir and crest length with sufficient capacity to handle the estimated flow (Tables 2, 3, and 4). Note the probable head.
- Construct the weir with plywood, sheet metal or 1-inch and 2- by 4-inch boards. Make the crest and sides of the weir notch not more than 1/8-inch thick. Sometimes metal strips are fastened to plywood to provide a sturdy crest. The crest should be fairly sharp on the upstream side.
- Install the weir structure in a uniform channel that will provide a long pool, deep and wide enough to permit a uniform current with a very slow velocity. The height of the weir crest above the channel bottom should be at least twice the head. Sometimes the banks of the ditch above the weir must be raised to hold more water. Set the weir at right angles to the direction of stream flow, with the weir crest straight and level. Avoid obstructions upstream from the weir.
- Measure the depth of water flowing over the weir far enough away from the notch to be unaffected by the downward curve of the water as it approaches the crest. Drive a stake about 3 feet upstream from the weir, with its top level with the weir crest. Measure the head of water over the weir by placing a ruler on the stake.

A second method is to measure the depth of water next to the weir, but far enough to the side of the crest to be in still water. Drive a nail on the upstream side of the weir, so that the top of the nail is at the same level as the weir crest. Measure the head over the weir with a ruler. Refer to Tables 2, 3, and 4 to find the stream flow rate.

Table 2
Approximate flow over 90-degree triangular weirs

Head (H)	Gallons per minute (GPM)	Acre-inches per hour
3 inches	36	0.08
4 inches	74	0.16
5 inches	126	0.28
6 inches	200	0.44
7 inches	294	0.65
8 inches	405	0.89
9 inches	548	1.21
10 inches	714	1.58
11 inches	895	1.98
12 inches	1118	2.48
13 inches	1365	3.05
13.5 inches	1495	3.34
14 inches	1630	3.63

Table 3
Approximate flow over rectangular weirs

Head (H)	Rest length (L)							
	(L): 1 foot		(L): 2 feet		(L): 3 feet		(L): 4 feet	
	GPM	Acre-inches per hour	GPM	Acre-inches per hour	GPM	Acre-inches per hour	GPM	Acre-inches per hour
2 inches	98	0.22	198	0.44	298	0.66	398	0.88
3 inches	181	0.40	366	0.81	552	1.22	738	1.63
4 inches	278	0.62	560	1.24	852	1.88	1140	2.52
5 inches			772	1.70	1164	2.58	1560	3.45
6 inches			1010	2.22	1535	3.40	2055	4.54
7 inches			1270	2.80	1980	4.27	2590	5.75
8 inches			1540	3.40	2330	5.18	3120	6.90

Table 4

Approximate flow over trapezoidal weirs

Head (H)	Crest length (L)							
	(L): 1 foot		(L): 2 feet		(L): 3 feet		(L): 4 feet	
	GPM	Acre-inches per hour	GPM	Acre-inches per hour	GPM	Acre-inches per hour	GPM	Acre-inches per hour
2 inches	101	0.22	202	0.45	302	0.67	404	0.89
3 inches	190	0.42	376	0.83	560	1.24	750	1.66
4 inches	296	0.65	580	1.28	864	1.91	1160	2.56
5 inches			802	1.77	1196	2.66	1500	3.52
6 inches			1062	2.34	1580	3.50	2100	4.64
7 inches			1350	2.98	2000	4.42	2660	5.88
8 inches			1638	3.62	2430	5.38	3220	7.14

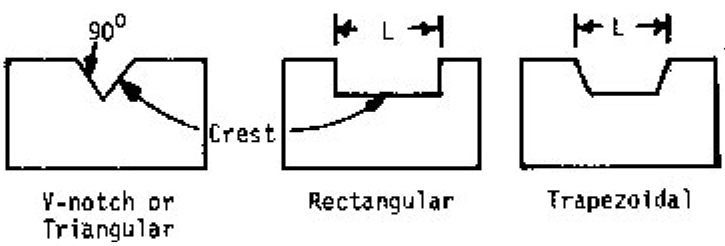

Figure 4
Types of weirs.

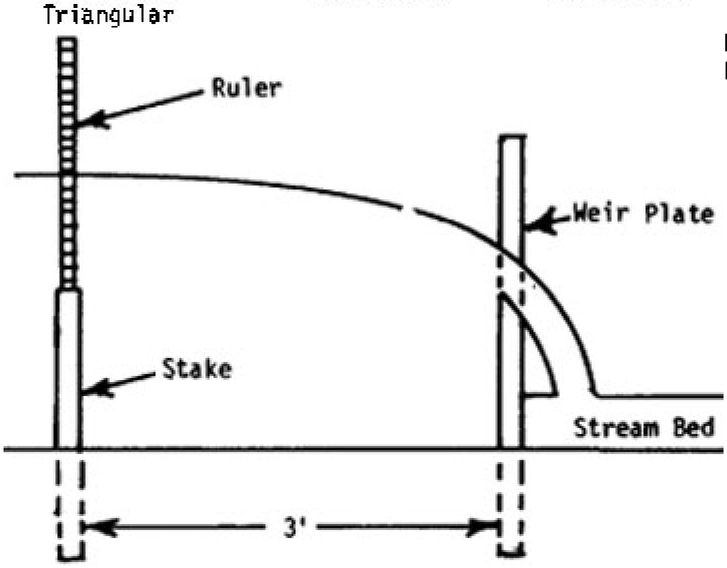

Figure 5
Measuring head on the weir.

Measuring flumes

The Parshall, HS, and WSC flumes are weir-type structures that require a drop only one-fourth as steep as the v-notch weir requires. They are also self-cleaning and are not greatly affected by stream approach velocity. These flumes can operate over a wide range of flow rates. They must be carefully constructed and carefully installed.

Measuring change in the water level of a reservoir

Determine the flow rate into or out of a reservoir by measuring the change in the water level for a given period of time. The reservoir dimensions must be known for this method. Install a post or gauge stick in the reservoir that can be easily read from the shoreline. Using a survey of the reservoir storage volume, mark the gauge stick for every 10 acre-feet, or some other convenient volume. For volume deliveries over a considerable length of time, estimate the evaporation and seepage.

References

- Scott, Verne, and Clyde Houston. *Measuring Irrigation Water,* California Agricultural Extension Service Circular 473, Davis.
- Selders, A. W. *Measuring Surface Water Flow Using Weirs,* West Virginia MU Extension, SW-5.
- Selders, A. W. *Measuring Surface Water Using Velocity-Area Methods,* West Virginia MU Extension, SW-6.
- Natural Resources Conservation Service, USDA. "Measurement of Irrigation Water," Section 15, Chapter 9 of the *NRCS National Engineering Handbook.*

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Related MU Extension publications

- WQ278, Calculating Crop Nutrient Value From Irrigation Water Inputs: A Survey of Southeast Missouri Irrigation
  http://extension.missouri.edu/publications/DisplayPub.aspx?P=WQ278

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