University of California
Agriculture and Natural Resources

ANR Publication 8490 | February 2013
http://anrcatalog.ucanr.edu

UC PEER REVIEWED

Low-Cost Methods of Measuring Diverted Water

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The California State Water Resources Control Board requires that the amount of water diverted from the surface waters of the state be reported. For many years diverters were able to estimate the amount of water they diverted and report this estimate. Legislation passed in 2010 requires that the amount of water diverted be measured. Many water right owners are seeking to comply with this regulatory requirement.

Other reasons to measure water could include the following:

- to assure that the appropriate amount is diverted
- to divide shared interest in water
- to identify opportunities to save water for other uses

This publication focuses on simple and inexpensive methods of measuring surface water to irrigate pastures and other lower-value crops where more advanced methods of measurement may not be as feasible. A simple method of estimating flow in open channels, along with installation and use of contracted rectangular and V-notch weirs, are discussed. Examples of how to apply the flow measurements are also provided.

Basic Water Measurement in Open Channels (Float Method)

The volume of water passing through a point on a stream per unit of time is used to measure stream flow. Two factors are required to determine volume (quantity) of water: cross-sectional area, generally in square feet (ft^2), and flow velocity, generally in feet per second (ft/sec). Flow is usually expressed in cubic feet per second (cfs). (For converting

U.S. customary units to metric units, see the table at the end of this publication.) The formula for calculating flow is

$$\text{stream flow (cfs)} = \text{cross-sectional area (ft}^2\text{)} \times \text{average velocity (ft/sec)} \quad \text{[Eq. 1]}$$

Determining Cross-Sectional Area

The first step is to determine the cross-sectional area of the channel. This can be done by measuring the width and depth of the water. First, select a stretch of the channel that is located in a convenient place to take measurements: accessible, ideally straight, and with similar geometric conditions before and after the cross-section. Because variation in depth often occurs, several measurements may need to be taken across the channel. The depth of the water should be measured from the surface to the channel bottom. Measure the depth at a minimum of three points for narrow channels, and preferably five or more points across wider channels, to arrive at a representative average. Then multiply the average depth by the width to determine the cross-sectional area.

The formula is

$$\text{cross-sectional area} = \text{depth} \times \text{width}$$

For example, if the average depth is 1 foot and the width is 2.5 feet, the cross-sectional area is

$$\begin{aligned}\text{cross-sectional area (ft}^2\text{)} &= 1 \text{ ft} \times 2.5 \text{ ft} \\ &= 2.5 \text{ ft}^2\end{aligned}$$

Determining Velocity

Velocity is estimated by determining the time it takes for a floating object to travel a given distance. The choice of object used as a float will affect the measurement of velocity. A round wooden rod, 1 or 2 inches in diameter, that is weighted on one end and stands vertical in the stream, will improve accuracy. The rod should be immersed in at least one-fourth of the stream depth, but it should not be immersed so deep that it touches the bottom of the channel. Objects that float on the surface of the stream channel are prone to drifting and are not as likely to represent an average velocity of the stream channel. Measure time of travel at least seven times, discard the largest and smallest measurements, and obtain the average with the five remaining records. Measuring flow in more than one segment of the stream or ditch will also improve estimates of velocity.

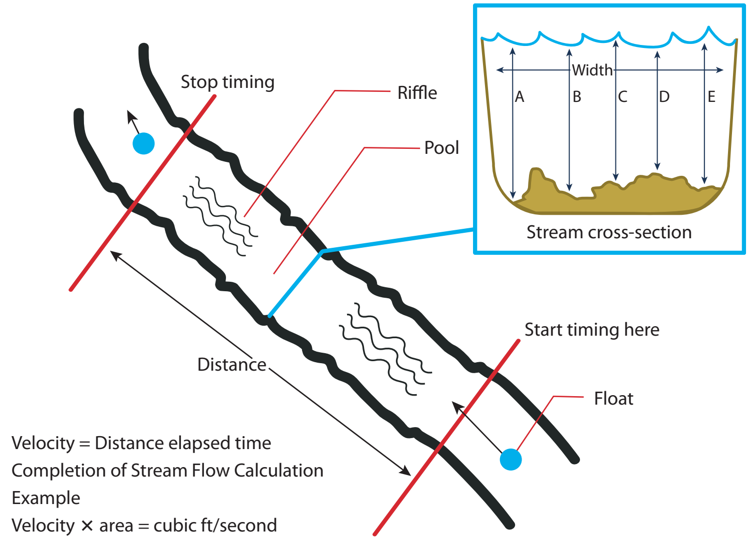

Figure 1. Simple method for determining water velocity.
Source: Adapted by Elizabeth Wilson from Nader et al. 1997.

The formula is

$$\text{velocity} = \text{distance} \div \text{time}.$$

For example, if it takes 10 seconds for a floating object to travel 20 feet, the velocity of the water would be

$$\begin{aligned}\text{velocity} &= 20 \text{ ft} \div 10 \text{ sec} \\ &= 2 \text{ ft/sec}.\end{aligned}$$

Figure 1 illustrates the float technique for determining velocity.

Determining Flow (Q)

To determine flow, the formula is

$$\text{flow} = \text{cross-section} \times \text{velocity}$$

The examples above note a cross-sectional area of 2.5 square feet and a water velocity of 2 feet per second. Multiplying these two attributes together gives a total stream flow of 5 cubic feet per second (cfs), as shown below:

$$\begin{aligned}\text{total stream flow} &= 2.5 \text{ ft}^2 \times 2 \text{ ft/sec} \\ &= 5 \text{ cfs}\end{aligned}$$

Using Flow Data to Determine Acre-Feet

Sometimes it is necessary to determine the amount of water diverted during a production season in acre-feet (ac-ft). To determine this, multiply the flow by the length of time water is diverted and divide by the number of square feet in an acre (43,560). For example, if the water is diverted for 150 days (d) and flow is 5 cubic feet per second during the entire season, the volume of acre-feet diverted can be calculated as follows:

$$(150 \text{ d} \times 24 \text{ hr/d} \times 60 \text{ min/hr} \times 60 \text{ sec/min} \times 5 \text{ cfs}) \div 43{,}560 \text{ ft}^2/\text{ac}$$
$$= 1{,}488 \text{ ac-ft of water diverted}$$

The formula shown below can be used as a shortcut to determine the quantity of water diverted. To apply the shortcut, the flow rate must be expressed as cfs and the irrigation time must be expressed in hours. Multiplying the flow rate (cfs) by the irrigation time (hours) will give the volume of diverted water in acre-inches. The volume of diverted water in acre-inches can then be converted to acre-feet by dividing by a constant of 12 (there are 12 acre-inches in 1 acre-foot of water).

$$A = Q \times T \div 12 \qquad \text{[Eq. 2]}$$

where:
A = the volume of water diverted, expressed in acre-feet
Q = the stream flow, in cfs
T = the total hours (days × 24 hours/day)
12 = constant

Using the example above and equation 2 [5 cfs × (150 days × 24 hours/day) ÷ 12], the volume of water diverted would be

$$A = 5 \text{ cfs} \times (150 \text{ d} \times 24 \text{ hr/d}) \div 12$$
$$= 1{,}500 \text{ ac-ft}$$

Expressing Flow Conversions

Water flow can be expressed in several ways; cubic feet per second (cfs) is probably the unit most commonly used. Table 1 shows different units and conversion factors.

Measurement Weirs

Weirs are good tools that work well to measure water flow in ditches and streams that convey water to irrigate pastures and other lower-value crops. They are relatively inexpensive, while improving accuracy over the most basic float technique of measuring flow in open channels. Properly installed, they provide an accurate measure of cross-sectional area and water velocity. To measure water flow accurately, weirs must be designed specifically for each water-conveyance system and installed correctly. Head (or H, the height of water passing over the weir crest) is key to measuring water flow with weirs. It is measured at a point upstream from the crest of the weir, where the surface drawdown from water spilling over the weir does not affect the measurement. Once installed, the flow should be

Table 1. **Conversion table for units of flow**

Units	Cubic feet per second	Gallons per minute	Millions gallons per day	Southern California miner's inches	California statutory miner's inches	Acre-inches per 24 hours	Acre-feet per 24 hours
cubic feet per second	1.0	448.8	0.646	50.0	40.0	23.80	1.984
gallons per minute	0.00223	1.0	0.00144	0.1114	0.0891	0.053	0.00442
million gallons per day	1.547	694.4	1.0	77.36	61.89	36.84	3.07
Southern California miner's inches	0.020	8.98	0.0129	1.0	0.80	0.476	0.0397
California statutory miner's inches	0.025	11.22	0.0162	1.25	1.0	0.595	0.0496
acre-inches per 24 hours	0.042	18.86	0.0271	2.10	1.68	1.0	0.0833
acre-feet per 24 hours	0.504	226.3	0.3259	25.21	20.17	12.0	1.0

measured or calibrated using a second method to validate the measurements.

The length of a weir crest—that is, the width of the weir notch across the channel—should be such that the maximum head is no greater than one-third of the length of the weir crest and the minimum head exceeds 2 inches. The distance from the side of the weir notch to the sides of the ditch should be at least twice that of the head. The crest and sides of the weir notch should not be more than 1/8-inch thick.

Determining Weir Dimensions

For a weir to function properly, it must have proper dimensions (see fig. 4). Having a reasonable estimate of the head (H) is important to determine the weir dimensions. The average depth of water flowing in an unchecked, relatively uniform, straight stretch of the ditch, where it is free of turbulence, provides a good initial estimate of H. The height of the crest of a correctly sized weir must be at least 2 times H to prevent submergence on the downstream side of the weir and assure accurate flow measurements. Submergence is the backing up of the water on the downstream side of the weir, such that the water does not spill freely over the weir crest and instead interferes with the ability to measure H as water crosses the weir crest. Submergence is more likely to occur in ditches with very little fall or irregular slope. For the above example, if H is equal to 0.5 foot, the crest of the weir must be at least 1 foot above the bottom of the channel.

Locating the Appropriate Site for a Weir

Having a reasonable estimate of H is also critical to correctly site the weir. As a general guide, the weir should be set in a channel that is straight, with a distance upstream of the weir of at least 10 times the length of the weir crest. For the above example, if the weir crest (width of the notch across the channel) is 1 foot long, there should be a minimum of 10 feet of straight ditch upstream of the weir. However, other practical aspects apply to siting a weir appropriately. Water will pond upstream from where the weir is placed, because flow is directed through the weir and confined by the length of the weir crest. The ditch must have sufficient freeboard (unfilled ditch) to retain the backed-up water and prevent water from breaching the ditch banks. Keep in mind that many ditches are designed with a constant slope to maintain a steady water elevation in the ditch, especially if siphons or gates are used to discharge water into the pasture checks.

In the aforementioned example (where the crest of the weir was 1 foot above the bottom of the ditch), a 1% ditch fall will back up water 100 feet and require sufficient storage for the water in that stretch of the ditch. (Ditch fall is the "downhill" grade of a ditch. Ditches are generally constructed with minimal fall so elevation is conserved.) A ditch with less slope (0.5%) will back up water 200 feet and require sufficient freeboard in that stretch of the ditch. Stretches of a ditch where the banks have settled or have deteriorated should be avoided or repaired when choosing where to site the weir. If consideration is being given to locating a weir in the stream at the point of diversion, keep in mind that this may require streambed alteration permits; check with local authorities before proceeding.

Installing Weirs

Weirs can be built in place. To do this requires skill in building forms and pouring concrete. A simpler approach might be to purchase a precast concrete structure (fig. 2) with slots for boards (e.g., a rice box). Depending upon the size, these are generally modestly priced. However, equipment is required to unload and set the structure in the ditch. You can check with a local precast firm or look online for a dealer.

Figure 2. Setting a precast weir with a backhoe.

Follow these guidelines for setting a weir:

- Set the weir structure in a channel that is straight for a distance upstream from the weir equal to 10 times the length of the weir crest (e.g., if the weir crest is 2 feet, the channel should be straight for 20 feet).
- Place the weir at right angles to the direction of water flow.
- Install the face of the weir perpendicular to the flow, with the weir crest straight and level.
- Obstructions on the upstream side of the weir should be avoided.
- Set the weir structure at the lower end of a long pool sufficiently wide and deep so that the water will approach the weir free from eddies at a velocity not exceeding 0.5 feet per second.

Regardless of the approach taken, the structure must be backfilled in a manner to assure there are no water leaks around or under the structure. Diligent compaction of backfill material as it is added and use of riprap material on the waterside of the weir reduce the incidence of leakage around the structure (fig. 3). The use of bentonite may help reduce the chance of leakage around the structure.

Figure 3. Precast weir with riprap.

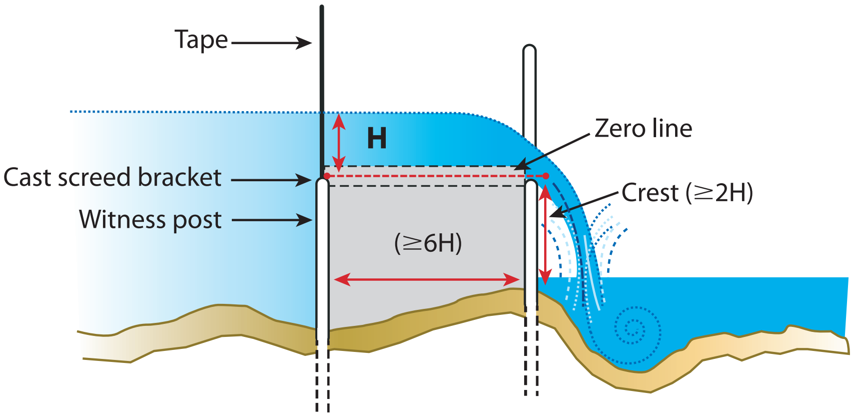

Figure 4. Relationship between measurement location and weir crest.
Source: Adapted by Elizabeth Wilson from Scott and Houston 1977.

Determining Where to Measure Water Height

If the weir is properly installed, the only direct measurement that will need to be made is the head (H), the height of the water spilling over the crest of the weir. Once H is known, determine the flow rate from a table of predetermined values. Deciding where to measure the water height is important. As water approaches the weir crest, velocity increases and water height decreases. Figure 4 shows the location of the measurement in relation to the weir crest. The place where this measurement is made must be a minimum of 6 times H from the weir crest. This measurement location should be easily identifiable with a permanent monument, often referred to as a witness post (i.e., a sturdy, permanent stake in clear view and free of potential obstruction such as tree limbs, bushes, or other vegetation). The witness post will serve as a consistent measurement point where a ruler or staff gauge will be installed to properly measure H in relation to where the weir is placed. It will also provide a zero (0) reference point for measuring H, which is the height on the witness post that is level with the crest of the weir.

An accurate witness post can be developed and installed using the following steps:

1. Bore a hole into a precast concrete block using a ¾-inch masonry bit. Try to bore the hole as straight as possible.

Figure 5. Leveling the witness post to the weir crest.

Figure 6. The pressure transducer is submerged below the water in the channel at a depth equal to the weir crest and is tied to the witness post. The transducer cable extends from the witness post back to the shoreline, where the datalogger storage device is tied to a T-post.

2. Fit a ¾-inch concrete form stake into the concrete block.
3. In the field, set the block in the ditch at an appropriate distance from the weir crest (minimum of 6 times H). Set the concrete block in the ditch, excavating enough material so the top of the block is about level with the floor of the ditch. This should be done with the stake in place. As this block (with the stake) is set, the level of the stake should be checked regularly.
4. Once the witness post is in place, take a form stake 2-by-4-inch hanger and thread the set screw so it is just snug against the concrete form stake (fig. 5).
5. Take a level and set it on the weir crest and the 2-by-4-inch hanger, and adjust the hanger until it is level with the weir crest. Tighten the set screw. This is where the measurement will be made.

Measuring Water Height and Flow

The most common device used to measure water height is some sort of ruler (frequently referred to as a staff gauge) mounted to or hung on the witness post. It is easiest to do this with a ruler that is divided into ⅒-foot intervals (as opposed to inches). This is sometimes referred to as an engineer's ruler. For accurate measurement, the ruler should be level (vertically and horizontally) in the water. The measurement reading must be recorded; later, you will determine the flow by using the appropriate table. The more measurements that are taken during the season, the more information will be gained related to volume of water diverted.

Using Automatic Water Measurement

Data logging devices can measure the height of the water automatically. They operate based on the gravitational pressure of the water exerted upon a sensor and are frequently referred to as pressure transducers. These instruments record water height at a predetermined time interval (e.g., hourly) and store the data on the device. The pressure transducer is commonly placed inside a stilling well, which is constructed out of a piece of perforated PVC pipe that allows water to flow into the well. The bottom of the pressure sensor is set inside the stilling well and must be level with the weir crest. Figure 6 shows the installation of one of these instruments. The data is downloaded from the device onto a computer, and it is read and evaluated there. These devices only measure the height of water. The amount of water diverted must still be determined from this water height data.

Types of Weirs

Rectangular Contracted Weir

This type of structure can be used to measure higher water flows, usually greater than 1 cubic foot per second. As its name implies, this weir is based on water flowing over a rectangle of known height and width (fig. 7). If this weir is installed properly, water falls over it at a constant velocity. The flow is a function of the head, the water above the weir crest. Key to this weir is the width and depth of the rectangle. The depth must be sufficient to accommodate the maximum amount of water expected to flow over the weir.

Take a moment to review table 2. Note that flow can be determined from the table, based on the height of the water and the length of the weir crest. It is much easier to determine flow if the weir's crest is of a length that is included in standard, published tables. Water needs to fall across a sharp edge of the weir crest. The edge or crest of the rectangular notch should be cut at no less than a 45° angle, such that water falls freely from the weir.

90° V-Notch Weir

The 90° V-notch weir is useful for measuring lower flows of water, typically less than 1.0 cubic feet per second. The depth must be sufficient to accommodate the maximum amount of water expected to flow over the weir.

Take a moment to review table 3. Similar to the rectangular contracted weir, flow can be determined from the table based simply on the height of the water passing over the crest of the weir. If the height of the water is known, use table 3 to determine flow.

A framing square can be used to lay out the 90° angle. Water needs to fall across a sharp edge of the weir crest. The angle of the V-notch should be cut at no less than a 45° angle, such that water falls freely from the weir. Figure 8 depicts an installed V-notch weir.

Figure 7. Rectangular weir.

Figure 8. 90° V-notch weir.

Table 2. Flow over rectangular contracted weirs in cubic feet per second*

Head (H) (ft)	Head (H) (in)	Crest length (L) (ft) 1.0 ft	1.5 ft	2.0 ft	3.0 ft	4.0 ft	For each additional foot of crest in excess of 4 ft (approx.)
		Flow (cfs)					
0.10	1 3/16	0.105	0.125	0.212	0.319	0.427	0.108
0.11	1 5/16	0.121	0.182	0.244	0.367	0.491	0.124
0.12	1 7/16	0.137	0.207	0.277	0.418	0.559	0.141
0.13	1 7/16	0.155	0.233	0.312	0.470	0.629	0.159
0.14	1 11/16	0.172	0.260	0.348	0.524	0.701	0.177
0.15	1 13/16	0.191	0.288	0.385	0.581	0.776	0.196
0.16	1 15/16	0.210	0.316	0.423	0.638	0.854	0.216
0.17	2 1/16	0.229	0.346	0.463	0.698	0.934	0.236
0.18	2 3/16	0.249	0.376	0.504	0.760	1.02	0.257
0.19	2 1/4	0.270	0.407	0.546	0.823	1.10	0.278
0.20	2 3/8	0.291	0.439	0.588	0.887	1.19	0.303
0.21	2 1/2	0.312	0.472	0.632	0.954	1.28	0.326
0.22	2 5/8	0.335	0.505	0.677	1.02	1.37	0.35
0.23	2 3/4	0.358	0.539	0.723	1.09	1.46	0.37
0.24	2 7/8	0.380	0.574	0.769	1.16	1.55	0.39
0.25	3	0.404	0.609	0.817	1.23	1.65	0.42
0.26	3 1/8	0.428	0.646	0.865	1.31	1.75	0.44
0.27	3 1/4	0.452	0.682	0.914	1.38	1.85	0.47
0.28	3 3/8	0.477	0.720	0.965	1.46	1.95	0.49
0.29	3 1/2	0.502	0.758	1.02	1.53	2.05	0.52
0.30	3 5/8	0.527	0.796	1.07	1.61	2.16	0.55
0.31	3 3/4	0.553	0.836	1.12	1.69	2.26	0.57
0.32	3 13/16	0.580	0.876	1.18	1.77	2.37	0.60
0.33	3 15/16	0.606	0.916	1.23	1.86	2.48	0.62
0.34	4 1/16	0.634	0.957	1.28	1.94	2.60	0.66
0.35	4 3/16	0.661	0.999	1.34	2.02	2.71	0.69
0.36	4 5/16	0.688	1.04	1.40	2.11	2.82	0.71
0.37	4 7/16	0.717	1.08	1.45	2.20	2.94	0.74
0.38	4 9/16	0.745	1.13	1.51	2.28	3.06	0.78
0.39	4 11/16	0.774	1.17	1.57	2.37	3.18	0.81
0.40	4 13/16	0.804	1.21	1.63	2.46	3.30	0.84
0.41	4 15/16	0.833	1.26	1.69	2.55	3.42	0.87
0.42	5 1/16	0.863	1.30	1.75	2.65	3.54	0.89
0.43	5 3/16	0.893	1.35	1.81	2.74	3.67	0.93
0.44	5 1/4	0.924	1.40	1.88	2.83	3.80	0.97
0.45	5 3/8	0.955	1.44	1.94	2.93	3.93	1.00
0.46	5 1/2	0.986	1.49	2.00	3.03	4.05	1.02
0.47	5 5/8	1.02	1.54	2.07	3.12	4.18	1.06
0.48	5 3/4	1.05	1.59	2.13	3.22	4.32	1.10
0.49	5 7/8	1.08	1.64	2.20	3.32	4.45	1.13
0.50	6	1.11	1.68	2.26	3.42	4.58	1.16
0.51	6 1/8	1.15	1.73	2.33	3.52	4.72	1.20
0.52	6 1/4	1.18	1.78	2.40	3.62	4.86	1.24
0.53	6 3/8	1.21	1.84	2.46	3.73	4.99	1.26
0.54	6 1/2	1.25	1.89	2.53	3.83	5.13	1.30
0.55	6 5/8	1.28	1.94	2.60	3.94	5.27	1.33
0.56	6 3/4	1.31	1.99	2.67	4.04	5.42	1.38
0.57	6 13/16	1.35	2.04	2.74	4.15	5.56	1.41
0.58	6 15/16	1.38	2.09	2.81	4.26	5.70	1.44
0.59	7 1/16	1.42	2.15	2.88	4.36	5.85	1.49
0.60	7 3/16	1.45	2.20	2.96	4.74	6.00	1.53
0.61	7 5/16	1.49	2.25	3.03	4.59	6.14	1.55
0.62	7 7/16	1.52	2.31	3.10	4.69	6.29	1.60
0.63	7 9/16	1.56	2.36	3.17	4.81	6.44	1.63
0.64	7 11/16	1.60	2.42	3.25	4.92	6.59	1.67
0.65	7 13/16	1.63	2.47	3.32	5.03	6.75	1.72
0.66	7 15/16	1.67	2.53	3.40	5.15	6.90	1.75
0.67	8 1/16	1.71	2.59	3.47	5.26	7.05	1.79
0.68	8 3/16	1.74	2.64	3.56	5.38	7.21	1.83
0.69	8 1/4	1.78	2.70	3.63	5.49	7.36	1.87
0.70	8 3/8	1.82	2.76	3.71	5.61	7.52	1.91
0.71	8 1/2	1.86	2.81	3.78	5.73	7.68	1.95
0.72	8 5/8	1.90	2.87	3.86	5.85	7.84	1.99
0.73	8 3/4	1.93	2.93	3.94	5.97	8.00	2.03
0.74	8 7/8	1.97	2.99	4.02	6.09	8.17	2.08
0.75	9	2.01	3.05	4.10	6.21	8.33	2.12
0.76	9 1/8	2.05	3.11	4.18	6.33	8.49	2.16
0.77	9 1/4	2.09	3.17	4.26	6.45	8.66	2.21
0.78	9 3/8	2.13	3.23	4.34	6.58	8.82	2.24
0.79	9 1/2	2.17	3.29	4.42	6.70	8.99	2.29

Note: *Computed from Cone's formula: $Q = 3.247\ LH^{1.48} - [0.566\ L^{1.8} \div (1 + 2\ L1.8)]\ H^{1.9}$

Table 3. Flow over 90° V-notch weir in cubic feet per second and gallons per minute*

Head (H) (ft)	Head (H) (in, approx.)	Flow (cfs)	Flow (gal/min)
0.10	1 3/16	0.008	3.6
0.11	1 5/16	0.010	4.5
0.12	1 7/16	0.012	5.4
0.13	1 9/16	0.016	7.2
0.14	1 11/16	0.019	8.5
0.15	1 13/16	0.022	9.9
0.16	1 15/16	0.026	11.7
0.17	2 1/16	0.031	13.9
0.18	2 3/16	0.035	15.7
0.19	2 1/4	0.040	18.0
0.20	2 3/8	0.046	20.6
0.21	2 1/2	0.052	23.3
0.22	2 5/8	0.058	26.0
0.23	2 3/4	0.065	29.2
0.24	2 7/8	0.072	32.3
0.25	3	0.080	35.9
0.26	3 1/8	0.088	39.5
0.27	3 1/4	0.096	43.1
0.28	3 3/8	0.106	47.6
0.29	3 1/2	0.115	51.6
0.30	3 5/8	0.125	56.1
0.31	3 3/4	0.136	61.0
0.32	3 13/16	0.147	66.0
0.33	3 15/16	0.159	71.4
0.34	4 1/16	0.171	76.7
0.35	4 3/16	0.184	82.6
0.36	4 5/16	0.197	88.4
0.37	4 7/16	0.211	94.7
0.38	4 9/16	0.226	*101.0
0.39	4 11/16	0.240	108.0
0.40	4 13/16	0.256	115
0.41	4 15/16	0.272	122
0.42	5 1/16	0.289	130
0.43	5 3/16	0.306	137
0.44	5 1/4	0.324	145
0.45	5 3/8	0.343	154
0.46	5 1/2	0.362	162
0.47	5 5/8	0.382	171
0.48	5 3/4	0.403	181
0.49	5 7/8	0.424	190
0.50	6	0.445	200
0.51	6 1/8	0.468	210
0.52	6 1/4	0.491	220
0.53	6 3/8	0.515	231
0.54	6 1/2	0.539	242
0.55	6 5/8	0.564	253
0.56	6 3/4	0.590	265
0.57	6 3/16	0.617	277
0.58	6 15/16	0.644	289
0.59	7 1/16	0.672	302
0.60	7 3/16	0.700	314
0.61	7 5/16	0.730	328
0.62	7 7/16	0.760	341
0.63	7 9/16	0.790	355
0.64	7 11/16	0.822	369
0.65	7 13/16	0.854	383
0.66	7 15/16	0.887	398
0.67	8 1/16	0.921	413
0.68	8 3/16	0.955	429
0.69	8 1/4	0.991	445
0.70	8 3/8	1.03	462
0.71	8 1/2	1.06	476
0.72	8 5/8	1.10	512
0.73	8 3/4	1.14	512
0.74	8 7/8	1.18	530
0.80	9 5/8	1.43	642
0.81	9 5/8	1.48	664
0.82	9 13/16	1.52	682
0.83	9 15/16	1.57	705
0.84	10 1/16	1.61	723
0.85	10 3/16	1.66	745
0.86	10 5/16	1.17	767
0.87	10 7/16	1.76	790
0.88	10 9/16	1.81	812
0.89	10 11/16	1.86	835

Note: *Computed from Cone's formulas: $Q = 2.49 H^{2.48}$; and $GPM = 448.8 (2.49 H^{2.18})$.

Trapezoidal (or Cippoletti) Weir

A trapezoidal (or Cippoletti) weir is a third type of weir that can be used to measure water flows. It is very similar to a rectangular contracted weir, with no distinct advantages or disadvantages. As a result, it is not a focus in this guide. Like the rectangular contracted weir, it is most appropriately used to measure higher flows, usually above 1 cubic foot per second. The primary difference in weir design is that the weir notch is shaped as a trapezoid with sloped sides, rather than as a rectangle with vertical sides. It may be simpler to construct a rectangular notch than a trapezoidal notch. For additional information on other types of measurement weirs, UC ANR Publication 2956 *(Measuring Irrigation Water)* is a good reference.

Calibration

After installation is complete, calibration to validate the flow measurements with a weir is recommended. Calibration is the process used to compare measured flows from the weir with a second temporary method. The calibration process can be challenging, as arranging a second temporary method can be inconvenient and costly, especially if the measurement weirs are placed in remote locations. Two of the more feasible techniques to check the calibration of a weir include the float technique, as described earlier in this publication, and the catch-and-time method.

Measure the calibration flows for rectangular weirs, which are completely independent of the weir structure, using the float method outlined in the section "Basic Water Measurement in Open Channels (Float Method)." When completed, this value can be compared with the table value for the weir. Once the weir is in place, use the head gate at the diversion to turn a controlled, relatively low rate of water into the ditch. There should be at least 2 inches of head flowing over the weir crest, according to H measured at the staff gauge. Measure H at the staff gauge and calculate the cross-sectional area of the water flowing though the rectangle (depth of the water times length of the weir crest). Using the float technique described in the "Float Method" section, measure the velocity of the water and calculate the flow. Check this against the staff gauge elevation and the corresponding flow rate indicated in standard, published tables for a weir with the dimensions as installed. Small discrepancies could be a result of the zero reference point of the staff gauge not being level with the crest of the weir. Make adjustments as necessary to the position of the staff gauge to correct the difference. When the flow rate measured using the float technique closely agrees with the flow rate based on the H flowing over the crest of the weir and the appropriate standard published table (see table 2), increase the flow rate to about two-thirds of the expected maximum H into the ditch and repeat these calibration steps. When the flow measurements obtained with the float technique and with the rectangular contracted weir agree reasonably well at both relatively low and high H, it indicates that the weir is measuring water flow with reasonable accuracy.

Another method is to use a stopwatch and a container of a known volume to determine the amount of water per unit of time. This is a feasible technique to validate flow measurements from a V-notch weir. As in the calibration process for the rectangular contracted weir, use the head gate at the diversion to turn in a low rate of water. Catch and time a small volume of water spilling over the V-notch weir (e.g., 1 quart per second = 15 gallons per minute). Repeat this measurement at this low flow until a good average is developed. Check this against the staff gauge elevation and the corresponding measurement of flow rates in the standard published tables (see table 3) for the specific size of V-notch weir that has been installed. Small discrepancies could be a result of the zero reference point on the staff gauge not being level with the crest of the weir. Make adjustments as necessary to the position of the staff gauge. Once there is good agreement between the two methods of flow measurement, turn a slightly higher rate of water into the ditch and repeat these calibration steps. When the flow measurements obtained with the catch-and-time technique agree reasonably well with the measurements obtained with the V-notch weir for the two levels of H, the weir is measuring water flow with reasonable accuracy.

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Acknowledgments

The authors appreciate the contributions of Bob and Steve Moller, Vaca Creek Ranch; Joe Crowe, Morelli Ranch; Tom Martinez, McArthur Livestock; Glenn Aldridge and Shannon Wooten, Aldridge Ranch; Ed Stanton, Western Conservation Associates; the National Fish and Wildlife Foundation; and the American Land Conservancy.

Measurement Conversion Table

U.S. customary	Conversion factor for U.S. customary to metric	Conversion factor for metric to U.S. customary	Metric
foot (ft)	0.3048	3.28	meter (m)
square foot (ft^2)	0.0929	10.764	square meter (^{2})
cubic foot (ft^3)	28.317	0.353	liter (l)
acre (ac)	0.4047	2.471	hectare (ha)
acre-inch (ac-in)	102.8	0.00973	cubic meter (m^3)
acre-foot (ac-ft)	1,233.0	0.000811	cubic meter (m^3)
gallon (gal)	3.785	0.264	liter (l)

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Publication 8490
ISBN-13: 978-1-60107-839-1

An electronic copy of this publication can be found at the ANR Communication Services catalog website, http://anrcatalog.ucanr.edu.

UC PEER REVIEWED

This publication has been anonymously peer reviewed for technical accuracy by University of California scientists and other qualified professionals. This review process was managed by the ANR Associate Editor for Land, Air, and Water Sciences, Toby O'Geen.

web-7/13-LR/CR