Reservoir Storage Measurement & Recordkeeping Guide

for

Above-Ground Reservoirs

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Table of Contents

If water will be stored in a California reservoir from one season to the next (i.e. diverted to storage), an owner is required to apply for a water right or demonstrate an appropriation has been acquired. All reservoirs diverting more than 10 AF per year must comply with measurement requirements. Quantities measured annually must be submitted to the State Water Resources Control Board.

Installing a Measuring Device

This guide focuses on using gages as a means of quantifying and reporting annual reservoir diversions. It is intended for smaller reservoirs but can be beneficial to any reservoir capacity. Collection to storage of more than 10 acre-feet per year requires installation of a measuring device, such as a pressure transducer or staff gage to record water levels and report diversion amounts to the Division of Water Rights online (Report Management System) database. Other devices used to measure streamflow into reservoirs such as weirs or flumes, etc. are options not addressed in this document. Additional information about measuring devices is available on our water measurement webpage, which includes telemetry requirements for larger reservoirs and additional measurement requirements in vulnerable watersheds.

What are my reservoir gaging options?

Reservoir volume measurement described in this document requires the use of two basic tools; (1) a method to measure water depth, (2) a reservoir storage capacity-curve or table to convert measured water depths to volume. A pressure transducer (an electronic form of a staff-gage) is recommended to record water levels at pre-programmed intervals (e.g. monthly or weekly). Staff gages come in the form of vertical plates or inclined gages anchored or fixed to a permanent structure. Many reservoir owners choose to install a staff gage in addition to a pressure transducer in order to have a visual reference to check the accuracy of their electronic loggers. Owners may install gages and take measurements themselves *if experienced in water measurement and reporting*. The UC Cooperative Extension offers a training course on measurement devices that a water right owner, operator or site superintendent can attend if needed.

Figure 1 - Gages for visual monitoring

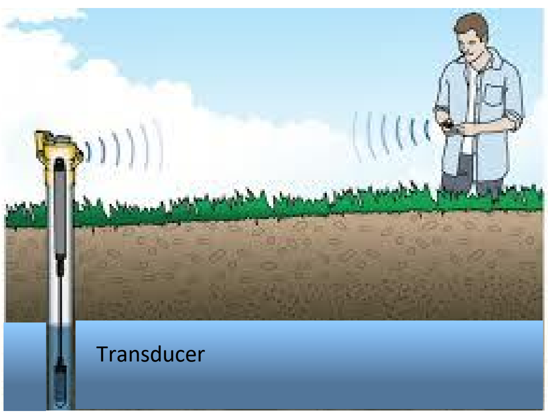
Staff Plate

Inclined Staff Gage

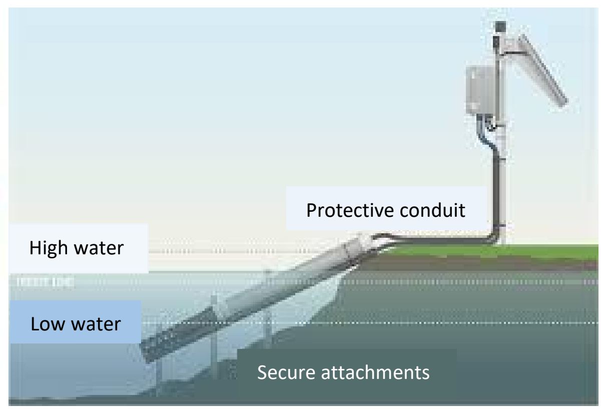
Staggered Staff Gage Markers

Figure 2 - Pressure Transducers for electronic gaging

Pressure transducer/data-logger unit
(hard-wire download)



Bluetooth unit
(wireless download)



Telemetry unit
(internet download)

Advantages of electronic data-loggers

The most convenient way of recording water levels is by using a pressure transducer/data-logger. They come in a variety of models and levels of sophistication that typically record pressure measurements in pounds per square inch (psi) units, which is then converted into depth (feet) using a conversion factor.

Pressure transducer/data-loggers are typically used:

- For reservoirs in remote locations,
- To avoid frequent travel to the site, or
- To capture water use data for irrigation planning and management purposes.

Hand-written logs can be used:

- For owners who live near the reservoir, and
- When there is a desire to visit the site frequently.

How often do I measure water levels?

Measurement requirements vary depending on diversion size and water use. Refer to our water measurement webpage to determine measurement frequencies for your water right or claim of right.

Gage Calibration and Certification

The pressure transducer or gage must be attached to a **permanent structure** in order to work correctly and produce accurate measurements. A **fixed** reference point is chosen such as the spillway invert, the top of the dam or another permanent feature upon which to reference the storage capacity-curve. Information about how to certify accuracy of a device can be found on our webpage.

Record Keeping

Hand-written data logs

If you chose to keep hand-written records in a logbook you must record the date, water level (stage) and elapsed number of days between measurements, at a minimum. An example of a Monthly Reservoir Ledger table from hand-written data is illustrated in Table 1. The storage capacity-curve in Figure 4 is used to convert measured water levels (stage) into monthly volume changes.

Table 1 - Sample Monthly Reservoir Ledger (28.2 AF capacity)

Hand-written Measurements			Conversions		Reporting Value
Date	Sampling interval (days)	Stage (ft)	Calculated volume (AF)	Volume change (AF)	Monthly diversion (AF)
09/30/19		4.62	6.6		
10/31/19	31	4.90	5.8	**(0.9)**	0.0
11/30/19	30	2.80	13.2	**7.5**	7.5
12/31/19	31	1.80	18.0	**4.8**	4.8
01/31/20	31	0.35	26.2	**8.2**	8.2
02/28/20	28	0.00	28.2	**2.0**	2.0
03/31/20	31	0.19	27.1	**(1.1)**	0.0
					22.5 Total

--Diversion season October 1 - March 31

--More frequent sampling intervals may be required if reservoir is used for Regulatory storage under (Sections 657-658, CCR, Title 23)

Electronic data logs

Most pressure transducers are designed to convert pressure measurements to feet (depth) using a conversion factor[1]. The pressure transducer data-log can be downloaded to a laptop or other portable electronic device. Depending on the type of data-logger used, data can be downloaded using a hard-wire connection (typically a laptop), or wirelessly using a blue-tooth device[2].

A *spreadsheet ledger* is useful to convert water-level data into storage quantities and diversion volumes. An example of a Weekly Reservoir Ledger table is illustrated in Table 2. In the following example, a 71.9 acre-foot reservoir has a licensed diversion season from October 1 thru March 31.

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[1] Depth in feet = gage pressure (psi)/2.3

[2] If a telemetry unit is installed, operators can access the data online with minimal travel to the site.

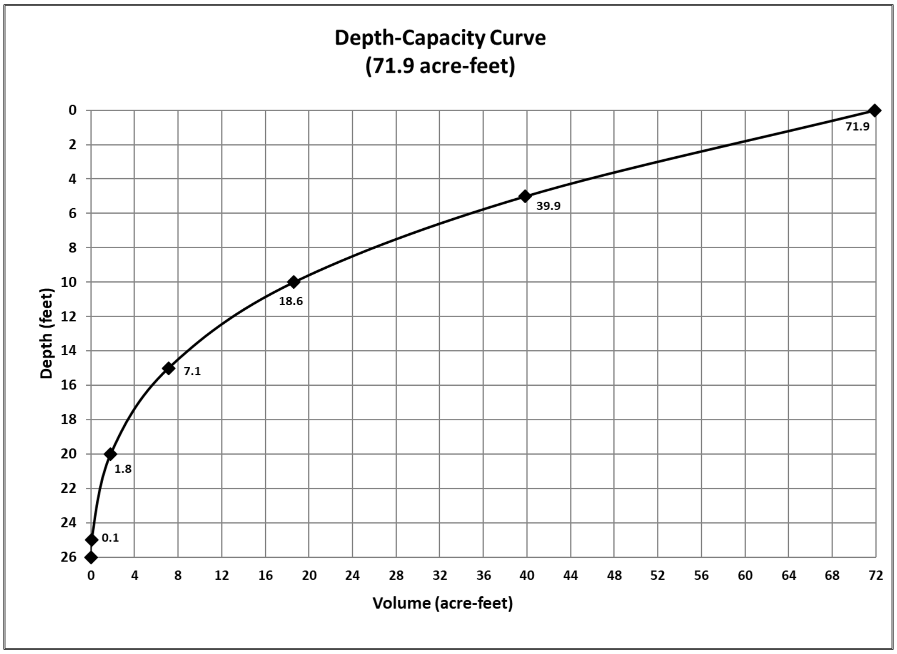
The storage capacity-curve in Figure 3 is used to convert measured water levels into weekly changes in volume.

Table 2 - Sample Weekly Reservoir Ledger (71.9 AF Capacity)

Electronic Measurements (data-logger)				Conversions				Reporting Value
Date	Time	Sampling interval (days)	Pressure (psi)	Depth conversion factor	Depth (ft)	Calculated volume (AF)	Change in volume (AF)	Monthly collection to storage (AF)
9/30/19	8:00		19.1	2.3	8.30	24.50		
10/7/19	12:0	7	19.2	2.3	8.34	24.40	**(0.10)**	
10/14/19	14:00	7	19.3	2.3	8.38	24.30	**(0.10)**	
10/21/19	10:00	7	19.4	2.3	8.42	24.20	**(0.10)**	
10/28/19	14:00	7	20.2	2.3	8.80	24.10	**(0.10)**	
10/31/19	8:00	3	19.6	2.3	8.50	24.00	**(0.10)**	0.00
11/7/19	11:30	7	19.5	2.3	8.47	23.98	**(0.02)**	
11/14/19	13:00	7	19.5	2.3	8.46	23.97	**(0.01)**	
11/21/19	9:00	7	19.4	2.3	8.43	23.95	**(0.02)**	
11/28/19	14;00	7	19.3	2.3	8.40	24.30	**0.35**	
11/30/19	16;00	2	19.1	2.3	8.30	24.60	**0.30**	0.65
12/7/19	13:00	7	18.9	2.3	8.20	25.00	**0.40**	
12/14/19	9:00	7	18.6	2.3	8.10	25.80	**0.80**	
12/21/19	16:00	7	17.9	2.3	7.80	27.30	**1.50**	
12/28/19	16:00	7	16.6	2.3	7.20	29.00	**1.70**	
12/31/19	16:00	3	15.9	2.3	6.90	30.70	**1.70**	6.10
1/7/20	16:00	7	13.8	2.3	6.00	34.80	**4.10**	
1/14/20	16:00	7	12.4	2.3	5.40	37.80	**3.00**	
1/21/20	16:00	7	11.0	2.3	4.80	41.90	**4.10**	
1/28/20	16:00	7	9.2	2.3	4.00	45.50	**3.60**	
1/31/20	16:00	3	7.8	2.3	3.40	49.40	**3.90**	18.70
2/7/20	16:00	7	5.1	2.3	2.20	56.90	**7.50**	
2/14/20	16:00	7	4.1	2.3	1.80	60.20	**3.30**	
2/21/20	16:00	7	2.3	2.3	1.00	65.80	**5.60**	
2/28/20	16:00	7	0.0	2.3	0.00	71.90	**6.10**	22.50
3/7/20	10:00	7	0.0	2.3	0.00	71.90	**0.00**	
3/14/20	15:00	7	0.0	2.3	0.00	71.90	**0.00**	
3/21/20	10:00	7	0.2	2.3	0.10	71.80	**(0.10)**	
3/28/20	9:00	7	0.7	2.3	0.3	71.70	**(0.10)**	
4/1/20	9:00	4	0.9	2.3	0.4	71.60	**(0.10)**	0.0
								48.0 Total

--Diversion season October 1 - March 31
--Assumes monitoring at gage pressure (psig)
--More frequent sampling intervals may be required if reservoir is used for regulatory storage under (Sections 657-658, CCR, Title 23)

Figure 3 – Storage capacity-curve used to calculate weekly changes in volume



Obtaining a reservoir storage capacity-curve

A storage capacity-curve (depth-capacity curve) is a tool needed to convert water level measurements into volume. The first step is to locate an existing reservoir survey and curve/data if it exists and is available from one of the following sources:

- **State Water Resources Control Board – Division of Water Rights**
  Water Right License
  If the reservoir was *licensed* by the Division of Water Rights, reservoir data from a plane-table survey might be available in Division files. Please contact the Division at (916) 341-5300 and ask for a copy of the reservoir curve/data.
- **Natural Resources Conservation Service (NRDC)**
  The NRDC (formerly Soil Conservation Service) has constructed many dams in California. You might consider contacting your local Resource Conservation District for more information.
- **Department of Water Resources - Jurisdictional Dams**
  If the reservoir is large enough to be within Department of Water Resources, Division of Safety of Dams jurisdiction, and the dam was certified, you may contact the Department by writing or by email and request a copy of the dam certification record. Although reservoir-capacity curves are not mandated by the Department, the reservoir survey often contains depth-capacity data. To determine if a reservoir is jurisdictional, link to the jurisdictional size chart.

If a storage capacity-curve is not available from any agency, a curve/table must be created by a "*qualified individual*" in order to measure reservoir diversions (in absence of measuring stream inflow directly). The definition of a qualified individual[3] can be found on our measurement webpage. There are several procedures used to create a storage capacity-curve. Some common procedures are illustrated in Appendix B.

[3] As defined in Section 931, California Code of Regulations, Title 23

Appendix A - Definitions

Acre-feet (AF) – The volume of water that would cover 1 acre to a depth of 1 foot, or equivalent to 43,560 cubic feet or 325,851 gallons.

Area-drawdown procedure – A process of developing a reservoir capacity curve by measuring reservoir surface areas at various depths. The maximum reservoir volume can be calculated using the Average End-Area Method or other applicable method.

Average End-Area Method - Calculates the volume between two cross sections; the two cross-sectional areas are averaged and multiplied by the distance between cross sections to define volume segments. Multiple volume segments are summed to determine the total volume.

Capacity – The maximum amount of water that can be stored in a reservoir.

Diversion - Volume of water captured and stored in a reservoir from a stream, tributary or spring.

Division – State Water Resources Control Board, Division of Water Rights

PSIG – Pounds per square inch-gage or gage pressure.

Qualified individual – Is defined in Section 931, California Code of Regulations, Title 23.

Reservoir storage capacity-curve – A chart that illustrates reservoir volume as a function of depth, also known as a depth capacity curve.

Stage-drawdown procedure- A process of creating depth-capacity curve data by measuring incremental volumes of water removed and recording the depth at each drawdown point.

Steady-state – The reservoir condition when the inflow rate equals the outflow rate or when the reservoir is in a state of equilibrium.

Withdrawal – The quantity of water removed or used from the reservoir for consumptive use.

Appendix B – Creating a reservoir capacity curve

Two basic procedures used to create a storage capacity-curve are illustrated below. They can be performed by any qualified individual, however, a formal reservoir survey by a professional is recommended.

The simplest procedure is the stage-drawdown procedure. It involves removing measured increments of water and recording the depth at each incremental drawdown point as drawdown progresses. For example, the operator would remove volume increments measured with a flowmeter. Each volume increment and its corresponding change in depth are recorded in a table used to create a storage capacity-curve. Figure 4 illustrates a curve developed from data in Table 3, collected from a 28.2 acre-foot reservoir with a maximum surface area at the high-water line of 6.1 acres and a maximum depth of 9.6 feet. The storage capacity-curve was generated by entering the raw field data from Table 3 into Excel and using the X-Y scatter plot function.

Table 3 - Stage-drawdown Data (28.2 AF reservoir)

Volume removed (AF)	Drawdown (ft)	Change in depth (ft)	Volume in storage (AF)
0	0	0	28.18
9.69	1.70	0.0 to 1.7	18.49
8.90	3.70	1.7 to 3.7	9.59
5.80	5.70	3.7 to 5.7	3.79
3.00	7.70	5.7 to 7.7	0.79
0.75	9.20	7.7 to 9.2	0.04
0.04	9.60	9.2 to 9.6	0

28.2 Total

Alternatively, Figure 4 can be derived from area-drawdown data. The area-drawdown procedure measures reservoir surface areas at various depths, and calculates the volume segments using the Average End-Area Method, for example. The volume segments are summed to determine the total volume.

The area-drawdown procedure requires that individuals understand the accuracy limitations of their measuring equipment (e.g. GPS units) in order to operate the equipment in such a manner to generate area contours that yield the required volume accuracy standard of 15 percent. At minimum, depth intervals should not exceed 5 feet, and in some cases should be smaller.

Given the raw data, a spreadsheet or other applicable tool can be used to generate the reservoir curve. The reservoir should be under steady-state conditions to use these procedures. Historically, the Division has used the “Average End-Area method” to create depth-capacity curves.

Table 4 – Area-drawdown data used to generate a reservoir capacity curve (28.2 AF Reservoir)

Measured Values			Equations	
Drawdown (ft)	**Area (ac)**			
0.00	6.10		$A_{avg} = (A_i + A_{i+1})/2$	
1.70	5.30		$Interval = (D_{i+1} - D_i)$	
3.70	3.60		$Volume = (A_{avg})$ x $(Interval)$	
5.70	2.20			
7.70	0.80			
9.20	0.20			
9.60	0			

Capacity Calculations (Average End-Area Method)				
Drawdown (ft)	**Area (ac)**	**A_{avg} (ac)**	**Interval (ft)**	**Volume (af)**
0.00 = D_1	6.10 = A_1			
		5.70	1.70	9.69 = V_6
1.70 = D_2	5.30 = A_2			
		4.45	2.00	8.90 = V_5
3.70 = D_3	3.60 = A_3			
		2.90	2.00	5.80 = V_4
5.70 = D_4	2.20 = A_4			
		1.50	2.00	3.00 = V_3
7.70 = D_5	0.80 = A_5			
		0.50	1.50	0.75 = V_2
9.20 = D_6	0.20 = A_6			
		0.10	0.40	0.04 = V_1
9.60 = D_7	0.00 = A_7			
				28.2 Total

Curve Data		
Depth (ft)	**Volume (af)**	
0.00	28.18 = $V_1+V_2+V_3+V_4+V_5+V_6$	
1.70	18.49 = $V_1+V_2+V_3+V_4+V_5$	
3.70	9.59 = $V_1+V_2+V_3+V_4$	
5.70	3.79 = $V_1+V_2+V_3$	
7.70	0.79 = V_1+V_2	
9.20	0.04 = V_1	
9.60		

Figure 4 - Reservoir capacity curve