# WATER QUALITY PROGRAMS DIVISION

Standard Operating Procedure for the Measurement of Stream Discharge

Revised and Adopted November 2016

*Draft Copy*

OWRB
the water agency

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**STANDARD OPERATING PROCEDURE FOR MEASUREMENT OF STREAM DISCHARGE**
**DRAFT**
**REVISED AND ADOPTED NOVEMBER 2005**

## 1.0 General Information.

This SOP will provide general information for the collection of discharge information as well as the establishment of stage-discharge relationships. The obtainment of accurate flow measurements is more a matter of physical technique than it is of instrument operation. Each stream will present you with a unique physical situation; therefore, it is not possible to describe to you what to do under any situation. The following instructions are presented as guidelines but you will have to exercise considerable judgement in the field to obtain good results.

## 2.0 Site Selection

**2.1 Controls.** Following is a brief description of controls. These will be explained more fully in the field. An excellent resource is the USGS "Techniques of Water Resources Investigations Reports" which can be found on the USGS website.

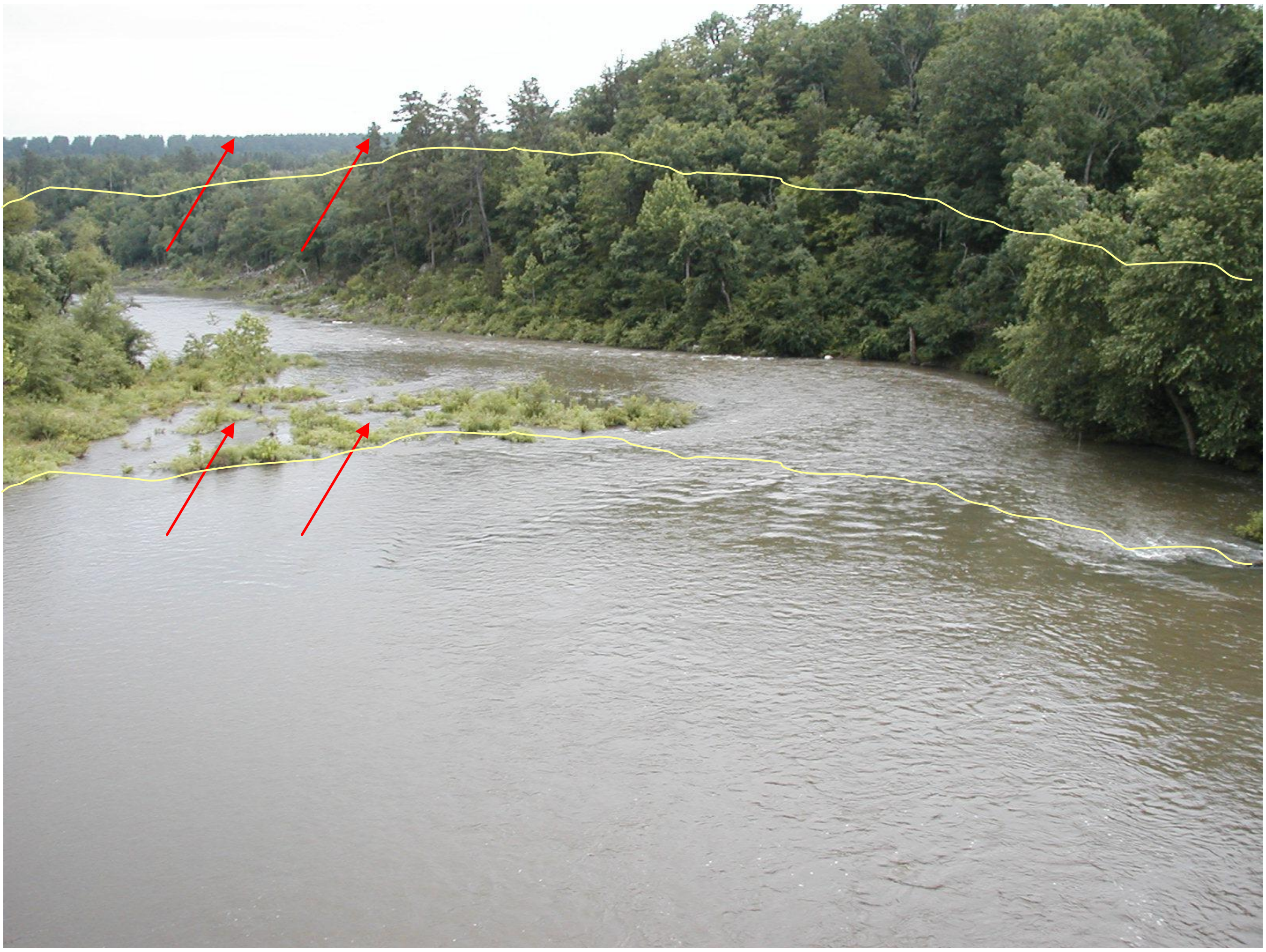
**Low Water Controls.** An LWC governs the stage discharge relationship at low water. Figure 1 is an example of a rock dam controlling the upstream pool elevation.

Figure 1. Low Water Control

**Medium Water Controls.** An MWC governs the stage discharge relationship at medium water. Figure 2 is an example of an MWC. As the photo shows, stage is being controlled by the U-shaped channel and not the LWC.

**High Water Controls.** The HWC governs the stage discharge relationship when the water extends past the MWC. The actual HWC is the floodplain of the waterbody.

Figure 2. Medium Water Control



## 2.2 Measurement Location

For wadeable measurements, the portion of the stream where flow is to be measured should be as uniform as possible. Avoid stagnant areas or those with irregular bottoms, turbulent flow, standing waves, or strongly sloping bottoms. For small streams, the narrowest portions are generally best as velocities will be higher and fewer measurements will be required. Consult the location descriptions and/or supervising FTE to assist in the determining optimal location to measure flow.

## 3.0 Collecting discharge Measurements

Accurately measuring discharge requires that real differences in both the vertical and horizontal profile of the stream be adequately characterized. By following the general rules of this section, stream discharge should reach the level of needed accuracy. Following is a description of the various activities involved in taking stream measurements. These are general rules and each stream during varying conditions may need to be approached in a different manner. This experience comes through time, observation, and direction from experienced technicians.

### 3.1 Establishment of Measurement Verticals

Before measurements begin, the stream should be divided into a number of measurement verticals (intervals). The more segments, the more accurate the results. The ideal setup divides the stream so that each segment accounts for 5% of the flow, but under some circumstances, each measurement may unavoidably account for no more than 10% of the flow. Using this method establishes more accurate readings in two ways. First of all, if one measure is inaccurate, it will not significantly affect the results. Secondly, by dividing the stream into a number of segments, the chance of missing an area of significantly higher or lower flow decreases. The following is a general rule of thumb to be used when establishing measurement verticals:

- **<u>ALWAYS ESTABLISH THE GENERAL TREND OF VERTICAL WIDTHS BEFORE BEGINNING MEASUREMENTS.</u>**
- **Minimum vertical width is 3 inches.**
- **In streams greater than 5 feet wide, at least 20 and no greater than 35 verticals should be established.**
- **Vertical width should lessen as depth increases and widen as depth decreases.** Generally, an increase of 25% in depth, should cause a 50% decrease in vertical width, and vice-versa.
- **Vertical width should lessen as velocity increases and widen as velocity decreases.** Generally, an increase of 25% in velocity, should cause a 50% decrease in vertical width, and vice-versa.

### 3.2 Edges of Water

In many streams, the first foot or so of stream from the bank is very shallow and stagnant. These areas are known as the left edge of water (LEW) and the right edge of water (REW). Edge of water is determined by looking downstream with the right bank being the REW and the left bank being the LEW. There are two approaches to dealing with this problem. The first is to ignore the shallow portion while the second involves averaging the depth and velocity between the bank and the first sample point. The best approach is to take the first measurement at the closest point where depth and flow are adequate. Any stream area closer to the shore than one-half the segment width from this point is not measured for velocity.

### 3.3 Placement of tag line

A tag line is Kevlar line that has been marked in graduated intervals to assist in accurate determination of width and interval locations. The graduations are in 1 (blue), 5 (single red), 10 (double red), 50 (single green), and 100ft (double green) increments.

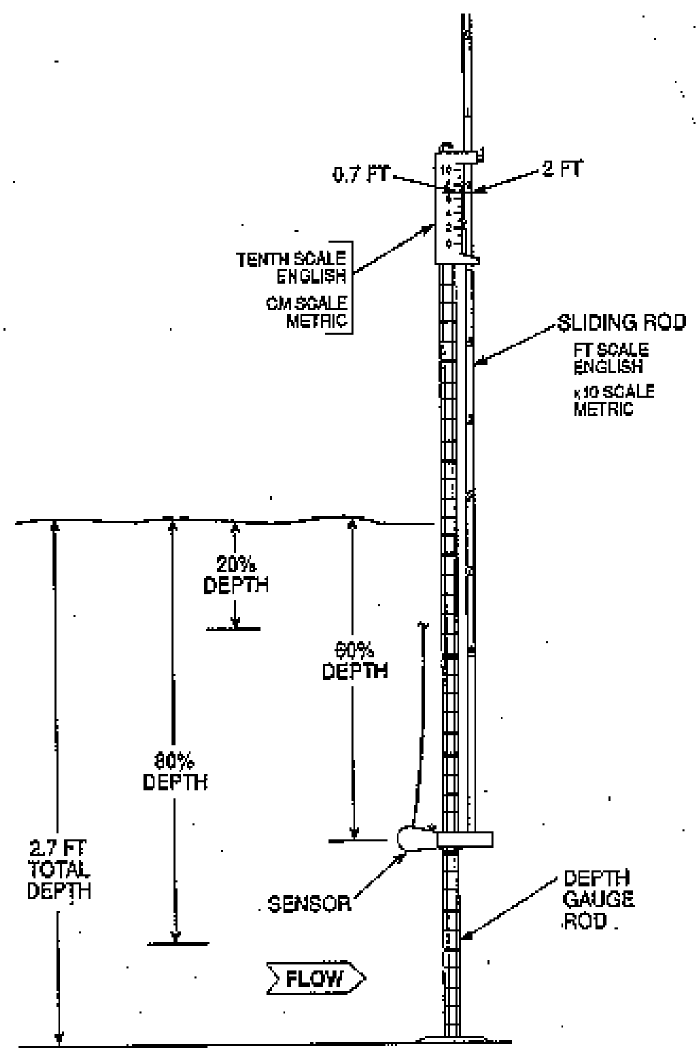
Process of tag line placement:

1) The beginning of the tag line is normally started at the Left Edge of Water (LEW).
2) Stretch a graduated line from LEW to REW at the cross section to be sampled. The tagline should be strung perpendicular to the direction of the majority of stream flow. This decreases the likelihood of needing to use horizontal angle coefficients in the measurement.
3) Anchor line and reel firmly to both banks ensuring that the line is taut.
4) Determine the measurement interval from both the width and the variable depths/velocities across the section (refer to 3.1).
5) Establish point of LEW. Preferably this point should be “0”. However, this is often not the case and should be the actual measured distance on the tagline.

6) Point the head of the instrument directly into the current and hold steady. Stand to the side and away from the wading rod.
7) Observe the depth and flow and if sufficient, this is your first point of measurement.
8) Measure your distance from LEW to this point. For example, if LEW is at 10 and the first measurement vertical is 5 feet past 10, then the distance for vertical 1 is 15 feet. Record the distance on the flow sheet in the *Distance from initial point* column.
9) Using the segment interval, move to the next measure point. Continue to measure adjusting the distance between measurement verticals as needed. (refer to 3.1)
10) Continue this procedure until you reach the area of insufficient depth or flow at the REW, and record the distance from the last point of measurement to REW.

### 3.4 Wading Rod

The wading rod is a top-adjusting model divided into feet and tenths of feet (not inches). The rod not only suspends the meter when wading but also is used to provide vertical depth and set the sensor in the correct location for measurement. The vertical depth is read on the main rod at the point where the velocity head is. Velocity should be measured at different depths, dependent upon the depth of the water column. The wading rod is designed to facilitate the placement of the meter at the correct sensor depth. See figure and explanation below.
Figure 3. Wading Rod




### 3.41 Use of wading rod

The rod should always be maintained in an even upright position. Depending on the depth of flow, the meter will be set at 0.2, 0.6, or 0.8 of water depth. To set the meter at these depths, do the following:

1) 0.6 of depth
    a. Determine depth of segment to be measured using the gradations on the wading rod (e.g. 2.7 ft)
    b. Slide smaller rod up until the "2" on the small rod lines up with the "7" on the rod handle.
2) 0.2 of depth
    a. Determine depth of segment to be measured (e.g. 2.7 feet)
    b. Multiply depth by 2 = 5.4 feet
    c. Slide small rod until "5" on the rod lines up with the 4 on the rod handle
3) 0.8 of depth
    a. Determine depth of segment to be measured (e.g. 2.7 feet)
    b. Divide depth by 2 = 1.35.
    c. Slide small rod until "1" on the rod lines up with the 3.5 on the rod handle.

### 3.5 Use of Sontek Flow tracker

The Flow Tracker uses acoustic Doppler technology to measure 2D flow in a small sampling volume located at a fixed distance (10 cm or 3.9 in.) from the probe. Sound generated by the transmitter bounces off suspended particles in the water. This reflected sound returns to the receivers, is averaged together by the processor, and results in water velocity measurements that are recorded at a rate of one per second. At the end of the measurement, the FlowTracker calculates the discharge. Follow manufactures instructions on setup, data recording, and data downloads.

### 3.6 Use of Pygmy and Price-Type AA meters.

The mechanical principle is as the flow makes revolutions of the bucket wheel, a tiny piece of carbide/tungsten known as a cat whisker is tripped. As this is tripped, an electrical current is sent to a set of headphones or a flow computer and is recorded as a tic, or revolution. These revolutions are counted for at least 40 seconds until a multiple of 5 tics is reached. The time and number of tics is then compared to a rating table to determine velocity. Use and maintenance of these meters will be demonstrated. Refer to the operations manual for a more complete understanding of operation and maintenance. The OWRB also uses magnetic head meters, which operate under the same principle as described above. The only differences are changes to the contact chamber and shaft. Magnetic head meters should be used in slower moving waters or areas of higher conductivity. Follow these general rules when choosing a meter to use:

- Depths from 0.3-1.5 feet use pygmy
- Depths greater than 2.5 feet use AA
- For depths from 1.5-2.5 feet use meter needed for the majority of the cross-section
- Do not change meter in middle of a measurement
- When suspending from a bridge cable, always use the AA

When using a pygmy or Price-Type AA meters, record discharge measurements using either a Sutron DMXpert or JBS Aquacalc flow computer. Follow manufactures instructions on setup, data recording, and data downloads.

### 3.7 Recording Data Using Headphones and Stopwatch.

The classic way of collecting the revolutions and time is use of headphones and stopwatch. Follow this procedure to collect data:

1) Before beginning, perform a spin test ensure that headphones are recording revolutions. This can be done by holding meter into the wind or starting revolutions with hand.

2) Place meter into water at appropriate depth and establish sound. The tics may be more or less audible depending on the conductivity of the water.
3) Reset stopwatch to "0", and simultaneously begin counts and stopwatch.
4) Continue counting tics until stopwatch passes 40 seconds. Because counts must be in increments of "5" to use the rating table, the stopwatch may go past 40 seconds.
5) Record the seconds and revolutions in the appropriate boxes on the Discharge Notes. Refer to rating table to establish velocity.

### 3.8 Measurement of Velocity

As was stated before, accurately measuring discharge requires that real differences in both the vertical and horizontal profile of the stream be adequately characterized. Accurately measuring the vertical profile involves adequately characterizing the mean velocity of each vertical. Several factors make this difficult including stream depth, upstream obstructions (e.g., rocks), upstream sandbars, surging flows, etc. To counteract these problems, several methods have been developed to measure velocity including several one point methods, a two point method, and a three point method.

### 3.81 Six-tenths Depth Method

When using this method, a single measurement is made at 0.6 depth and is considered to be the mean velocity for the vertical. This method should be used under the following conditions:

- Depths between 0.3 and 2.5 feet for both the pygmy and AA meters
- When any 2-point method is circumvented because of stream conditions (e.g., ice) or equipment (e.g., can not extend meter to 0.8 depth due to sounding weight size)
- When conditions require that a measurement be made quickly (e.g., rapidly increasing or decreasing discharge)

### 3.82 Two-tenths Depth Method

When using this method, a single measurement is made at 0.2 depth and, after a coefficient is applied, is considered to be the mean velocity for the vertical. This method should only be used under the following conditions:

- Velocities are too great to extend to 0.6 depth. This requires a depth profile so that the 0.2 depth can be calculated without extending into the water column.
- When sounding weight can not reach to 0.6 depth in shallowest verticals, but a measurement is still required.

### 3.83 Two Point Method

When using this method, measurements are made at 0.2 and 0.8 depths. These two measurements are averaged to obtain the mean velocity of the vertical. This method should always be used when depths exceed 2.5 feet unless stream conditions do not allow. It should never be used under 2.5 feet because of the proximity of the meter to the streambed.

### 3.84 Three Point Method

When using this method, measurements are made at 0.2, 0.6 and 0.8 depths. The mean velocity is obtained by one of two ways. All three measurements may be averaged to obtain the mean velocity when more weight is desired for the upper and lower depths. Conversely, when equal weight is desired between the upper/lower and the middle, the 0.2 and 0.8 measurements are averaged and that mean is then averaged with the 0.6 measurement to acquire the mean vertical velocity. This method should be used under the following conditions:

- When the velocities are abnormally distributed. Normally, the upper measurement should be more than the lower measurement in a two point method. However, occasionally this may flip and measuring the 0.6 depth will be useful.
- When the lower depth is seriously affected by the friction or turbulence along the streambed (e.g., sandbars).

## 4.0 Completion of Discharge Measurement Notes

### 4.1 Front Section

The front section of the Form is broken into five main sections. Many data items are self explanatory, such as date and site name, but others require some thought to further investigation to determine. It is very important that each section be completed. When using the Sutron, many of the items are contained in the different fields of the instrument. A supervising FTE will demonstrate how to gather the information. When using the Sutron, all of this information may be entered in the various menus.

The first section contains biographical information specific to the site and the measurement including station name and ID, and measurement number, date, and time. The second section contains biographical information about the meter including type and number as well as calibration information. The third section describes the measurement location.

The fourth section is the data and QA section. This section should be completed at the station if time and conditions permit. Most of the items are self-explanatory, but several do need further review. The percent difference from rating is used only when the station has an updated rating curve. This difference may demonstrate that an inadequate measurement has been made or that the station needs an updated survey. Rating a measurement is somewhat subjective. Based on the information gathered in the field, the technician should attempt to rate the measurement, but the data manager may change this measurement when reviewing the data. It is important that the technician be explicit in this section and includes all required information. If another sheet is necessary, please attach.

The fifth section contains information about the gages at the station. It is important that all necessary gages be read during each visit both before and after the discharge measurement. It is equally as important that the point of zero flow (PZF) be measured when accessible. The PZF is described in the station plan.

### 4.2 Recording and Completion of Data on Discharge Measurement Notes

When manually recording data, the following steps should be followed to fill in the discharge notes. A supervising FTE will demonstrate all steps.

1) In the first row, mark LEW (Left edge of water) in the width square. When circumstances require starting from the right edge of water, REW should be written. Also, write the starting point on the tagline in the “distance from initial point”. This may be a number other than zero.
2) On the following line, your distance from initial point is the first reading of measurable flow. Exclude areas that are too shallow for a measurement.
3) Write down the corresponding total depth and velocity on the line.
4) Mark your observation depth (0.2, 06, or 8.0) according to your percentage of depth.
5) Proceed by measuring depth and flow as you have been until you have recorded your last measurement that falls on a whole distance interval.
6) Record the depth and velocity of the REW.
7) Average any multiple depth measurements and record in the average velocity on the 0.2 line.
8) For width, the first section width is equal to ½ the distance between the first observation point and the second observation point. The width of the second section

is equal to ½ the distance between the preceding observation point and the succeeding observation point. For example, if the preceding observation point is 7, and the succeeding observation point is 4, then the width for observation point is (7-4) / 2 = 1.5. Final section width is the ½ of the difference between the last observation point distance and the preceding observation point distance. In the figure below. This will be demonstrated by a supervising FTE.

9) Sum all widths along the bottom row of the discharge notes and record on the front. This measurement should equal the distance between LEW and REW.
10) Area for each vertical is determined by multiplying the width by the total depth. Sum all areas on the last row of the notes for the total area of the measurement. Record sum on the front page of the notes.
11) Discharge for each vertical is determined by multiplying the area by the mean velocity of that segment. Sum all discharges on the last row of the notes for the total discharge of the measurement. This is the total discharge. Record sum on the front page of the notes.

**NOTE: The sum of the widths should equal your measured width of stream and the sum of the area and discharge should be computed individually for their respective columns.**

## 5.0 Data Storage

All paper and digital copies of Discharge Measurement Notes should be maintained with the station data set. The data from the notes should be quality assured and entered into the Water Quality Database.

## 6.0 References

Discharge measurements at gaging stations, by T.J. Buchanan and W.P. Somers: USGS—TWRI Book 3, Chapter A8. 1969.

Calibration and maintenance of vertical-axis type current meters, by G.F. Smoot and C.E. Novak: USGS—TWRI Book 8, Chapter B2. 1968.

Measurement and computation of streamflow Volume 1. Measurement of stage and discharge Volume 2. Computation of discharge, By S. E. Rantz, et al.: USGS—Water Supply Paper 2175.