Measuring Instantaneous Stream Flow

Training Module 1
Monitoring & Assessment Section
Water Quality Planning Division
February 2013
Instantaneous Flow Measurement Guidance

TCEQ Standard Operating Procedure:

This and other surface water quality monitoring guidance documents are available on the TCEQ web site at

www.tceq.texas.gov/waterquality/monitoring/index.html
General Flow Monitoring Guidelines

- Flow measurement is required at all routine freshwater stream sites if conditions allow.
- Flow measurement is not required in tidally influenced streams.
- Report flow measurements as cubic feet per second (ft³/sec or cfs).
- Parameter Code = 00061 (used to store data in the Surface Water Quality Monitoring Information System database.)
Exceptions to Reporting Flow

- Stations with no flow report as zero flow (WQ samples collected)
- Dry - streambed containing no water
- Unsafe conditions—high or flood flows
Flow Severity
Parameter Code 01351

- Record a flow severity value for each monitoring event on a freshwater stream or river.

- The six flow severity values are,
  1 = No Flow
  2 = Low Flow
  3 = Normal Flow
  4 = Flood Flow
  5 = High Flow
  6 = Dry

Note: There are no numerical flow guidelines associated with flow severity. This is an observational measurement highly dependent on the water body and the knowledge of monitoring personnel.
Flow Severity

1-No Flow

- Water bodies with water in isolated pools or long reaches with no detectable flow.
- In streams with no flow, report a flow value of 0.0 cfs and a flow severity of 1.
Flow Severity
2-Low Flow

- May be too shallow for flow measurement but flow can be detected.
- In streams with detectable flow but too shallow to measure, report a flow value of < 0.10 cfs.
- Flows might not fill the normal stream channel.
- Water would not reach the base of both banks.
- Portions of the stream channel might be dry.
- Flow might be confined to one side of the channel.
Flow Severity
3-Normal Flow

- Dependent on particular water body.
- Flow can usually be measured by wading.
- Characterized by flow that stays within the confines of the normal stream channel.
- Water generally reaches the base of both banks.
Flow Severity

4-Flood Flow

- Flow moves out of stream channel and on to the floodplain.
- Difficult to measure flow without special equipment and experience.
Flow Severity
5-High Flow

- Characterized by flow that leaves the normal stream channel but stays within stream banks.
- Usually difficult to measure flow without special equipment.
Flow Severity
6-Dry

- Dry with no visible pools.
Flow Severity
1-No Flow

Pool Characteristics

• Data collection as part of routine monitoring is conducted under all flow conditions including intermittent streams with pools.
• Pool information (maximum depth, maximum width, and pool length) help define attainable and beneficial uses for aquatic life and recreation.
• A pool is defined as anything ≥10 meters long and ≥ to 0.4 meters deep.
Instantaneous Flow Measurement Procedure

Basic method based on USGS publication:
*General Procedure for Gaging Streams, Book 3 Applications of Hydraulics*
Three basic pieces of equipment are needed to measure instantaneous flow:

1. 100 ft measuring tape mark in 0.10 ft increments.

2. Top setting wading rod marked in feet.

3. Mechanical, electronic or Doppler flow meter.

Equipment:
- Pygmy or Price AA-Mechanical
- SonTek FlowTracker-Doppler
- Marsh-McBirney-Electronic
Selecting a Flow Measurement Site

The key to a successful flow measurement is **Site Selection**.

- Avoid sites with back eddies and negative flows.
- Select an even stream bed free of large rocks, protruding obstructions, or vegetation.
- Avoid sites with uneven flow and an irregular bottom.
Selecting a Flow Measurement Site

Select a site with laminar flow

$Laminar \text{ flow} = \text{threads of parallel velocity extending from bank to bank.}$
Where to Measure Flow

Avoid areas with vegetation
Avoid areas with irregular flow
Avoid back eddies with negative flow
Preferred locations

► Bottom free of large obstructions
► Similar depth across the stream width
Key Steps to Measuring Stream Flow

The key steps to measuring stream flow are,

1. Select the flow measurement site.
2. Measure the total width of the stream.
3. Determine the # of cross sections.
4. Find the midpoint of the cross section.

At the midpoint of each cross section:
1. Measure the depth and record.
2. Set the flow sensor at the correct depth.
3. Measure the velocity and record.
4. After completing measurements at all cross sections, calculate flow.

These steps are detailed in this training module.
Measuring the Total Stream Width

Measure and record the stream width between the points where the tape is stretched (water's edge to water's edge). The measuring tape is marked in 0.10 foot increments.

See Chapter 3, page 3-20 for additional information.

Stretch a measuring tape across the width of the stream. The tape is marked in 0.10 foot increments.

Left Bank/Right Bank Orientation is determined by facing downstream.

Total Stream Width = 10 ft

The tape is marked in 0.10 foot increments.
Determine Number of Cross Sections

- Sections should be of equal width
- **Stream width < 5 ft**
  - Cross section width 0.5 feet
- **Stream width > 5 ft but < 10 ft**
  - Minimum 10 cross sections
- **Stream width > 10 ft**
  - Preferred number of cross sections = 20 to 30
Establish the Cross Section Width

Establish cross section width by dividing the total width by the number of cross sections.

Total Stream Width = 10 ft

Number of cross sections = 10; 10/10 = 1.0 ft
Each cross section width = 1.0 ft

Stream width > 5 ft but ≤ 10 ft
Minimum 10 cross sections
Find the Mid-point of the Cross Section

Divide cross section width in half
1.0 ft/2 = 0.50 ft

Start measurements at the first mid-point. Edge of bank is 0.0 so first mid-point is at 0.50 ft

Total Stream Width = 10 ft
Measuring Depth

Measure depth at the midpoint of each cross section using a top setting wading rod.
The top-setting wading rod and flow measurement method were developed by the USGS.
The top setting wading rod is designed to easily set the sensor 20, 60, and 80% of the total depth.
Measuring Depth

Water Depth at D_1 = 1.4 ft

- Each triple line = 1.0 ft
- Each double line = 0.50 ft
- Each single line = 0.10 ft
Measuring Depth

Measure Depth at Each Mid-point

Total Stream Width = 10 ft

Depth = 1.4 ft
Depth = 2.7 ft

Measured Water Depths

Depth
One-Point Velocity Measurement

For depths < 2.5 ft—
Take one velocity measurement at 60% of total depth

Use the water depth, measured at each cross section, to set the flow sensor at the correct depth.

$D_1 = 1.4\text{ ft}$
Setting the Sensor Depth-One Point

Adjust the sliding rod so the “1” foot mark lines up with the “4” on the tenths scale.

Water Depth ($D_1$) = 1.4 ft

Button that releases and holds the sliding rod.

The Sliding Rod has lines marked in feet (0 to 8 ft)

This sets the sensor at 60% of the total depth

The velocity measured is used in the flow calculation for this cross section ($V_1$).

Velocity
Two-Point Velocity Measurement

For Depths > 2.5 ft

Take two velocity measurements at 20% and 80% of the total depth.

D₇ = 2.7 ft
Water Depth ($D_7$) = 2.7 ft

The sliding rod is set at 5.4 feet = 20% of the total depth

The average of the two velocities measured is used in the flow calculation for this cross-section ($V_7$).

2.7 ft / 2 = 1.35 ft

The sliding rod is set at 1.35 feet = 80% of the total depth

2.7 ft x 2 = 5.4 ft
Eddies and backwater areas often produce negative flows. Record these values and include them in the final flow calculation.
Standing at least 1.5 ft downstream and to the side of the flow sensor, at midpoint of each cross section:

► Measure and record the depth using the wading rod.

► Position the flow sensor at the correct depth at the midpoint of the cross section.

► Allow the sensor to adjust to the current.

► Measure and record the velocity.

Using the measuring tape, determine the total stream width.

Determine the number of cross sections.

Find the mid-point of the first cross section.

Flow Measurement Summary
**Stream Flow Data Form**

Stream Width = 10 ft; Cross Section Width (W) = 1.0 ft

<table>
<thead>
<tr>
<th>Section Midpoint (ft)</th>
<th>Section Depth (D) (ft)</th>
<th>Sensor Depth</th>
<th>Velocity (V)</th>
<th>Discharge (Q) (ft³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>At Point (ft/sec)</td>
<td>Average (ft/sec)</td>
</tr>
<tr>
<td>0.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total Stream Width = 10 ft**

**Left Bank**

- W1
- D1
- V1

**Right Bank**

- W10
- D10
- V10

**Flow**

Q

Continued on next slide
<table>
<thead>
<tr>
<th>Section Midpoint (ft)</th>
<th>Section Depth (D) (ft)</th>
<th>Sensor Depth</th>
<th>Velocity (V) At Point (ft/sec)</th>
<th>Average (ft/sec)</th>
<th>Discharge (Q) (ft³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1.4</td>
<td>1.4</td>
<td></td>
<td></td>
<td>Q = (W)(D)(V)</td>
</tr>
<tr>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>1.9</td>
<td>1.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>2.2</td>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>2.1</td>
<td>2.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>2.5</td>
<td>2.5</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td>2.7</td>
<td>5.4</td>
<td>1.8</td>
<td>2.0</td>
<td>1.9</td>
</tr>
<tr>
<td>7.5</td>
<td>1.7</td>
<td>1.7</td>
<td>80%</td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>8.5</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>9.5</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
<td></td>
<td>-0.45</td>
</tr>
</tbody>
</table>

Record the depth and velocity for each mid-point.
Calculating Flow

Flow = Width \times Velocity = Depth \times Width \times Velocity
Calculating Flow

Flow is calculated using the width (W), depth (D), and velocity (V) measured at each cross section.

Total Stream Width = 10 ft

\[ Q_1 = W_1 \times D_1 \times V_1 \]
Calculating Flow

Stream Width = 10 ft; Cross Section Width \((W) = 1.0\) ft

<table>
<thead>
<tr>
<th>Section Midpoint (ft)</th>
<th>Section Depth (D) (ft)</th>
<th>Sensor Depth</th>
<th>Velocity (V)</th>
<th>Discharge (Q) (ft(^3)/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>At Point</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(ft/sec)</td>
<td>(ft/sec)</td>
</tr>
<tr>
<td>0.5</td>
<td>1.4</td>
<td>1.4</td>
<td>0.85</td>
<td>1.19</td>
</tr>
<tr>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>2.5</td>
<td>1.9</td>
<td>1.9</td>
<td>1.3</td>
<td>2.47</td>
</tr>
<tr>
<td>3.5</td>
<td>2.2</td>
<td>2.2</td>
<td>1.7</td>
<td>3.74</td>
</tr>
<tr>
<td>4.5</td>
<td>2.1</td>
<td>2.1</td>
<td>1.8</td>
<td>3.78</td>
</tr>
<tr>
<td>5.5</td>
<td>2.5</td>
<td>2.5</td>
<td>1.8</td>
<td>4.5</td>
</tr>
<tr>
<td>6.5</td>
<td>2.7</td>
<td>5.4</td>
<td>1.8</td>
<td>5.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.35</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.1</td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
<td>0.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-0.45</td>
<td>-0.225</td>
</tr>
</tbody>
</table>

Note: Include negative values in the flow calculation.

Q = 25.2 cfs
Flow Gauging Stations

Gauged flow values may be reported with WQ data if collected within a 0.25 mile of a flow gauge site. This data can be used for a greater distance if there are no dischargers or tributaries between the flow gauge and monitoring site.

Real-Time Flow Data on the Web:


FlowTracker Handheld Acoustic Doppler Velocimeter® (ADV)
The following summarizes the general operation of the FlowTracker. When using the FlowTracker follow the standard instantaneous flow measurement procedure.

For detailed information on operating the FlowTracker refer to the FlowTracker Handheld ADV® Operation Manual.
Flow Measurement Procedure

As described in the instantaneous flow measurement procedure:

- Select an appropriate flow measurement site.
- Stretch a tape across the width of the stream.
- Based on the total width determine the number of cross sections and the midpoint of the cross section.
- Using the top setting wading rod, measure the depth and set the flow sensor at the correct depth.
- Measure velocity.
- The main difference when using the FlowTracker - no data recording or flow calculation in the field.
Mounting the FlowTracker on a Top-Setting Wading Rod

Mount the Doppler flow sensor on the top-setting wading rod using the probe mount adaptor bracket.

Mount the FlowTracker Handheld ADV on the top-setting wading rod.
The FlowTracker is operated using the Handheld Controller.
Positioning the FlowTracker Sensor

Total Stream Width = 10 ft

Water Surface

Flow Direction

Graduated Tag Line

Primary Flow Direction

X Probe Coordinate System

Sampling Volume

Mounting Pin
Details on the key functions are located in Section 2.2-Keypad in the FlowTracker Operations Manual.
Getting Started

To turn FlowTracker **On**: Hold the **On/Off** key for 1 second; the system will open with the **Wake-up Screen**.

Press **Enter** to display the **Main Menu**

- **1**: Setup Parameters
- **2**: System Functions
- **3**: Start Data Run

Press **1** for Setup Parameters Menu
Press **2** for System Functions Menu
Press **3** to Start Data Run

**Note**: Always return to the **Main Menu** before turning the system off to ensure all data has been properly saved.

Rio Grande, Rio Grande Basin, Segment 2306
1: Setup Parameters Menu

From the **Main Menu**, press 1 to access the **Setup Parameters** menu.

Press 1 to set the units to **English** (flow is calculated as cubic feet per second or cfs).

Press 2 to set the **average time (Avg Time)** to 40 seconds.

Press 3 to set the **Mode** to **Discharge**. The **Discharge** mode calculates flow the **General** mode does not.

The Setup Parameters are usually set up once and don’t need to be adjusted with each use. See **Section 2.4** of the **FlowTracker Operations Manual** for detailed information.
2: Systems Function Menu

Main Menu
1: Setup Parameters
2: System Functions
3: Start Data Run

1: View Data File
2: Recorder Status
3: Format Recorder
0 = Exit or Enter = More

4: Temperature Data
5: Battery Data
6: Raw Velocity Data
0 = Exit or Enter = More

7: Auto QC Test
8: Show Config
9: Set System Clock
0 = Exit or Enter = More

The System Functions menu provides access to items that should be checked periodically but are not directly related to data collection.

Press Enter to switch between the 3 screens and 0 to Exit.

To select a System Functions, press the appropriate number on the keypad.

See Section 2.5 of the FlowTracker Operations Manual for detailed information.
3: Start Data Run Menu

From Main Menu, press “3” to Start Data Run.

This will display the Data File Name menu.

- File names have a maximum of 8 characters (letters or numbers).
- For example, use the Station ID and enter “17077” or “Site 17A”

Main Menu
1: Setup Parameters
2: System Functions
3: Start Data Run

Data File Name
1: Name (none)
2: Extension (none)
9: Accept name

Press 1 to enter a file name (required)

If there is an existing file name, press 2 to add a file extension, a maximum of 3 characters.

Devils River, Rio Grande Basin, Segment 2309
Entering a Data File Name
Firmware Version 3.1

To enter a number, type the number on the key pad.

To enter a letter, e.g., for C press 2 four times: 2-A-B-C

Press Enter to complete the file name which will appear in parentheses on the screen.

Data File Name
1: Name (none)
2: Extension (none)
9: Accept name

Press 9: Accept name when ready to start data collection.

See Section 2.2 of the FlowTracker Operations Manual for detailed information.
Start Data Collection

The next screen after pressing **9: Accept Name** will display the starting gauge information.

After entering the file name **Staff** and **Gauge Height** information will be displayed. These values are optional.

On the keypad, Press **Next Station** to continue.

Starting Edge Screen

Starting Edge  
Loc 0.00  Dep 0.00  
LEW CF 1.00  
Next/Prev Stn Key
Set the Starting Edge

1. On the Keypad, Press Set Location key to set the Starting Edge of Water.

2. On the Keypad, Press Set Depth key to set the Starting Edge of Water Depth, Dep.

3. Specify the Starting Edge

The Starting Edge of Water is usually Loc 0.00 and will be Station 0 (Stn 0).

The Starting Edge of Water Depth is usually Dep 0.00

See Section 5 of the FlowTracker Operations Manual for detailed information.
Set the Starting Edge

Starting Edge Screen

Starting Edge
Loc 0.00  Dep 0.00
LEW  CF 1.00
Next/Prev Stn Key

To specify the Starting Edge of Water, Press LEW/REW on the keypad.

LEW = left edge of water
REW = right edge of water

When ready, Press Next Station to continue; the Starting Edge information is complete.

See Section 5 of the FlowTracker Operations Manual for detailed information.

Medina River, San Antonio River Basin, Segment 1903
Station Information

The next screen after pressing **Next Station** will be the station information.

Press **Set Location** to set the first station location (**Loc 1, Stn 1**). Loc 1 will be the midpoint of the first cross section.

Measure the depth at Loc 1. Press **Set Depth** to set the water depth at Loc1.

After pressing **Set Depth**, select a method for determining velocity, **Single Point-Mthd .6D** or **Two-Point-Mthd 2/8**.

Continued on next slide
Setting the Velocity Measurement Method

Station Information

The **Single Point Method-Mthd .6D** measures velocity at 60% of the total depth. Applies to depths < 2.5ft.

The **Two-Point Method-Mthd 2/8** measures velocity at 20 and 80% of the total depth. Applies to depths > 2.5ft.

On the keypad, use the **Method+** or **Method-** keys to select the appropriate method. The method will appear on the **Station Information Screen**.

Continued on next slide
**Keep in mind:**

The velocity measurement method will need to be switched between *Mthd .6D* and *Mthd 2/8* when the depth is > 2.5ft at other stations.

After the station information has been entered correctly, use the top setting wading rod to set the sensor to the correct depth.

Press **Measure** to start data collection.
Velocity Measurement

While the velocity measurement is being made an updating screen shows the velocity and Signal to Noise Ratio (SNR). For best operating conditions the SNR should be 10 decibels (dB), but must be > 4 dB.

**Velocity Average Time** = 40 sec; total measurement time

Note: A low SNR indicates the lack of suspended material in the water. A low SNR can be improved by stirring the sediment upstream of the flow measurement point.

See Section 1.4 of the FlowTracker Operations Manual for detailed information.
Completing a Measurement

When the velocity measurement is complete, a **Summary Screen** appears.

- **Flow Angle <20°**
- **SNR > 4.0 dB**
- **Boundary QC (Bnd) = Good or Best**

If the **QC Checks** pass, press 1 to **Accept** the measurement.

If any of the QC Checks fail, press 2 to **Repeat** the measurement.

Continued on next slide

**Summary Screen**

- Vel 2.25  σV 0.04
- Ang 5°  SNR 15.1
- Spikes 0  Bnd BEST
- 1: Accept  2: Repeat
In addition to the SNR, there are two other important QC Checks that appear on the summary screen. 

Flow Angle (Ang°) and Boundary QC (Bnd)

**Flow Angle:** Correct positioning of the flow sensor-perpendicular to the measuring tape. Zero degrees = perpendicular; Angles < 20° are okay.

**Boundary QC:** An indicator of interference from underwater objects.

See Section 1.4 of the *FlowTracker Operations Manual* for detailed information on QC Checks.
At \textit{Loc 2/Stn 2}, press \textit{Set Location} and enter the cross section width. Location, depth, and method data for the \textit{Next Station} are predicted based on the previous station.

At the second location, \textit{Loc2/Stn2}, the width is changed so that the rest of the measurements are done at the cross section width. This change is made after finishing \textit{Loc1/Stn1}.

At \textit{Loc 2/Stn 2}, press \textit{Set Location} and enter the cross section width. For example, the cross section width is 1.0 ft and the midpoint is 0.5 ft. Set \textit{Loc2/Stn2} at 1.5 ft. When this measurement is accepted the FlowTracker will automatically start using 1.0 ft widths for the rest of the measurements.
Ending Edge Information

1. Press the **End Section** key when all stations are complete.

2. On the keypad Press **Set Location** to set the **Ending Edge of Water**.

3. Press **Set Depth** to set the **Ending Edge of Water Depth**.

4. To specify the **Ending Edge of Water**, Press **LEW/REW** on the **Keypad**. This will depend on the starting edge of water.

   - **LEW** = left edge of water
   - **REW** = right edge of water

See **Section 5** of the *FlowTracker Operations Manual* for detailed information.
When done, to turn the FlowTracker off: Hold the On/Off key for 3 seconds.

Calculating Flow

Press **Calc Disch** to complete the flow calculation.

After calculating flow five screens are available. Use **Enter** to move between the screens.

When done, to turn the FlowTracker off: Hold the On/Off key for 3 seconds.
To run the FlowTracker software, click on the desktop icon

or

Click Start | Programs | SonTek Software | FlowTracker

Click Connect to a FlowTracker

Note: When the connection is established the FlowTracker keypad will display Flow Tracker Under External Control.

Note: FlowTracker does not have to be turned on but batteries must be installed.

Continued on next slide
**Data Display and Export**

**Data Export:** Exports binary FlowTracker files to ASCII text format files that can be read in programs such as Word, Notepad and other text editors.

*Section 6.3 — FlowTracker Technical Manual*
FlowTracker Discharge Data

See Section 6 of the FlowTracker Operations Manual for detailed information on downloading (Section 6.3) and exporting FlowTracker data (Section 6.5).
For the location of monitoring references and resources on the web see Appendix A of the
Surface Water Quality Procedures, Volume 1: Physical and Chemical Monitoring Methods for Water, Sediment, and Tissue
(TCEQ Publications No. RG-415)

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