FIELD PROCEDURE: FLOW

Note: The main procedure described here primarily follows the discharge measurement procedure described in the 1994 TFW Ambient Monitoring Program *(Schuett-Hames et al., 1994).* Some modifications were suggested by the Washington State Department of Ecology. The 1999 TFW protocol calls for more cells and longer velocity averages, but Streamkeepers' technical advisors consider the 1994 TFW protocols to have adequate accuracy for our program purposes.

EQUIPMENT NEEDED:

- Swoffer 2100 velocity meter and staff
- flexible measuring tape marked in tenths of a foot
- 2 stakes
- pocket calculator
- watch to note time of day
- sand-bags and ties
- small shovel
- extra 9-volt battery
- data sheet, clipboard, pencil

In this procedure, you will measure depth and velocity at 15-20 points across your stream. Back at the office, we will use your measurements to calculate the amount of water that the stream is discharging, recorded in cubic feet per second ("cfs"). For informational purposes, to better understand how discharge is calculated, see the illustration on the last page of this protocol. This procedure is best performed by two people: one taking measurements and the other recording.

When to measure: Generally, you'll measure flow each time you monitor each reach. If possible, wait until a day or two after major storms, to give the stream time to return to its baseflow. Also keep safety in mind—think twice about going into water above your knees.

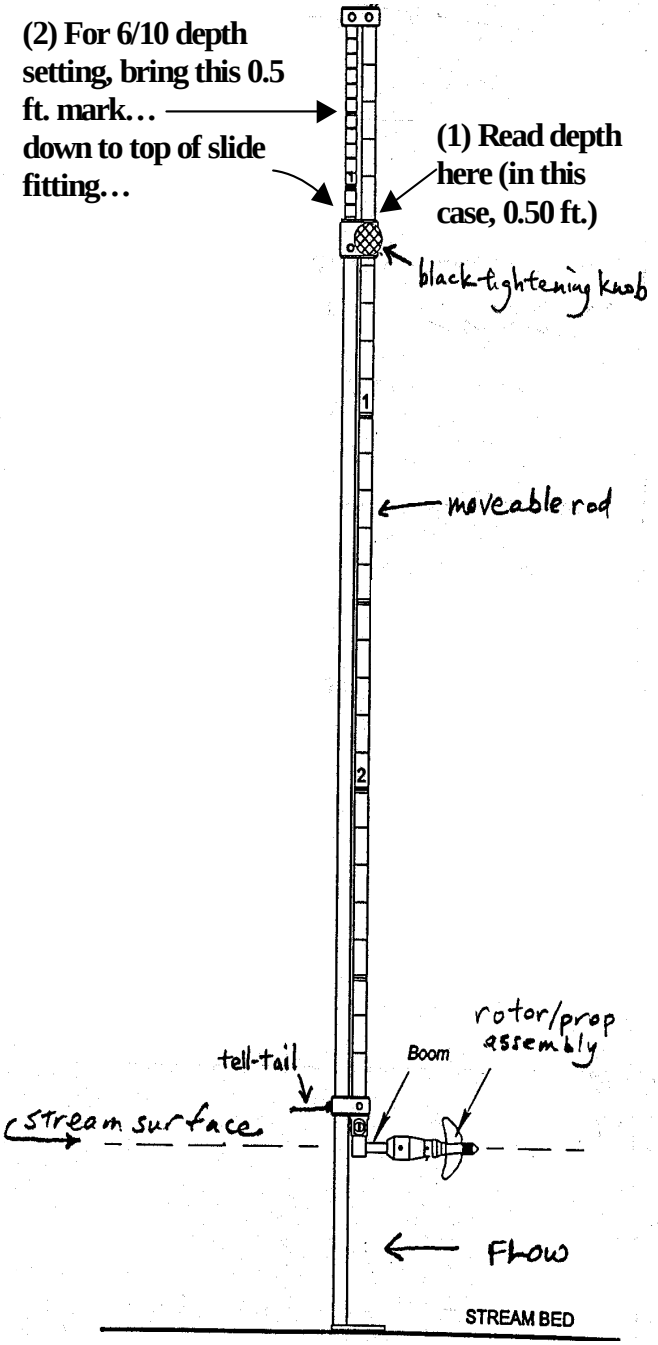
Where to measure: Streamkeepers has established permanent flow monitoring markers at some of its monitoring reaches. In many cases they are the cross-section monuments, but in other cases they are separate monuments. (Check your reach maps, team leader, or program staff for more information.) If your site has such monuments, use them. If it does not, you should pick the best spot on that day:

- The ideal site would be at least 5' across, at least 3" deep, and have water that is flowing straight and not turbulently at ≥ 1 ft/sec.
- If you can't find an ideal site (as is likely to happen with smaller streams in the summer), find or create a site where the water is at least 3" deep and moving at ≥ 0.5 ft/sec. (I.e., compromise on width if you have to.) You can "create" such a site by making temporary "peninsulas" on the sides of the creek to concentrate the flow, using rocks/gravel/sand, or the sandbags in your field kit.
- Look for variations in the amount of water you see flowing along the length of your reach, and measure at a spot where the flow is maximized and not running underground.
- A suitable site should not have side-channels, undercut banks, or flow obstructions such as boulders, logs, or aquatic vegetation. If a few large rocks are in the way, you can move them about six feet downstream.
- You may walk outside your reach IF no water leaves or enters the stream in between.

PREPARING THE METER AND STAFF:

1. While still on dry land, remove the velocity meter staff from its plastic-pipe case (see picture on next page). Move the moveable rod up slightly. (Loosen or tighten the black knob on the slide fitting at the top, so that the sliding rod moves snugly.) At the bottom of the moveable rod is a boom that swivels. Swivel the boom to the 90° position. Take the orange protective cap from the boom and put it in your pocket.

SWOFFER 2100 STAFF:



2. Take the "PRIMARY" rotor/propeller bag from the "treasure box" in your kit. ***Record the rotor number, calibration number, and calibration date on your data sheet.***

3. Take the rotor/prop unit out of the bag. Make sure the number etched into the side of the unit is the same as that on the bag. If not, check the other bag, or write down the numbers on both the bag and the unit. Make sure the knurled nut on the end is snug. Then perform a hand-spin test: Hold the unit vertically by the steel rotor shaft with the prop facing up, and give a super-fast spin to the nut on top of the prop by "snapping" your fingers. If you hear a buzz, the rotor needs to be replaced—switch to the "SPARE" and return to Step 2. IF ANY ROTOR FAILS THE HAND-SPIN TEST, NOTE IT ON THE DATA SHEET AND INFORM THE PROGRAM MANAGERS UPON RETURNING THE EQUIPMENT. On your data sheet, mark the results of the test <u>for the rotor you used</u>.

4. Insert the rotor/prop assembly into the sensor boom on the staff. Use the 1/16" Allen wrench from the same bag as the rotor/prop to tighten the tiny set screw at the ***tip*** of the boom, ***just enough*** so that the rotor/prop assembly cannot be pulled off of the boom, plus a tiny bit extra. The prop should spin freely. Put the Allen wrench in your pocket.

5. Connect the cables on the meter and staff. The connector is "keyed" and only mates one way, so **be very careful that you are aligning the connector ends properly**. Push the connector ends together, and then twist clockwise until the connector clicks into the lock position.

6. Switch to the "CALIBRATE" position. The display should read the same calibration number as that given for the primary rotor/prop assembly. If the number is not the same but is within 10%, proceed—the computer will compensate for the difference. If the difference is >10%, try a fresh battery (see "Meter Troubleshooting" at the end of this section), and if that doesn't work, start over with the spare rotor/prop. Record the meter calibration number on your data sheet.

7. Perform a count test: Rotate the switch to the "COUNT" position. Turn the prop slowly and confirm that the count increases by one for every quarter-turn of the prop. If not, try a fresh battery. On your data sheet, mark the results of the count test.

8. Perform a blow-spin test: Hold the rotor/prop assembly with the prop facing up, and blow a strong, steady, sustained breath of air to give the 3" prop a chance to overcome inertia. (If you are using an older 2" prop, use a short hard puff.) Right after you <u>stop</u> blowing, hit the "RESET" button on the meter and allow the rotor to coast to a stop. If the count is less than 300 consistently or if the prop stops abruptly instead of coasting slowly to a halt, either take apart the rotor, rinse it in clean water and try again, or switch to the "SPARE" and return to

Step 2. On your data sheet, record the results of the blow-spin test for the rotor you use. IF ANY ROTOR FAILS THE BLOW-SPIN TEST, INFORM THE PROGRAM MANAGERS UPON RETURNING THE EQUIPMENT.

9. When satisfied that the flow meter is operating correctly, turn the switch "OFF".

MEASURING FLOW:

1. Record on your data sheet:
   a. the time, and
   b. the bank you'll be starting at *(**NOTE**: left and right are always facing downstream).*
2. Determine the nominal interval for your measurements:
   a. At the point where you have decided to measure flow, stretch a tape across and above the wetted portion of the stream channel perpendicular to the direction of flow. (This may not be exactly perpendicular to the stream banks.) Use spring clamps to secure the tape around vegetation, large rocks, or stakes.
   b. On your data sheet, note the tape readings for the wetted edges to the nearest 0.1'. Calculate and record the wetted width of the stream by subtracting one wetted edge from the other. Divide the wetted width by 10 to find the MAXIMIUM INTERVAL and record it on the data sheet. Do not exceed the MAXIMIUM INTERVAL between measurements even outside of the "prop-turning" portion (see below).
   c. Determine the area along this line where the prop turns—i.e., don't include portions where the stream is too shallow or the water isn't moving. On your data sheet, note the distances on the tape corresponding to the edges of the "prop-turning" portion. Calculate and record the "prop-turning" width on the data sheet by subtracting one from the other.
   d. On your data sheet, divide this "prop-turning distance" by 20, then round UP any decimals to the nearest tenth of a foot. This will give you an average interval that will yield 15-20 measuring-point cells across the "prop-turning" area.

   (For example, if the area is 12.2' wide, 12.2'/20 = 0.61'. If you round UP to 0.7', you will have about 12.2/0.7 or 17 cells.)

   ***NOTE:** The MINIMIUM INTERVAL distance is 0.3', regardless of what you rounded up to. So in a creek smaller than 4.5' across, you'll have fewer than 15 cells.*
3. ***Zero readings at wetted edges:*** At both wetted edges, you'll need to record the tape reading in the first and last blank in the flow data table (as recorded above on the data sheet in step 2a); the depth (zero), and the velocity (also zero) have already been recorded on the data sheet for you. If the bank is undercut (try to avoid this!), you'll have to estimate how far back the water goes. (You can do this by putting a stick into the undercut and then measuring this distance on the stick.)
4. ***Proper stance:*** Put the velocity meter's strap around your neck and enter the stream downstream of the tape. When taking measurements, stand with the wading rod at arm's length and your feet upstream and downstream of each other, off to the side of where the water flows past the rod. You will be facing upstream at about a 45° angle. Hold the rod so the propeller faces into the flow.
5. ***Intervals for measurements:*** Your nominal interval will be the one you calculated on your data sheet. However, your actual intervals should be:
   - larger in non-prop-turning areas or places where water depth or velocity are relatively small or uniform
   - smaller in places where water depth or velocity are relatively large or are changing rapidly

   Intervals should be:
   - no greater than 1/10 the wetted width of the stream (MAXIMIUM INTERVAL)
   - no smaller than 0.3' (MINIMIUM INTERVAL)

   You need to take readings even in non-prop-turning areas, where you'll just record distance, depth, and in the velocity field either: "insf/d" for insufficient depth, "insf/v" for insufficient velocity or "insf/dv" for both (see "Low-Velocity Conditions" below).

BE SURE TO TAKE READINGS 0.3' TO EITHER SIDE OF "PROP-TURNING" EDGES, unless those edges are right next to the wetted edges.

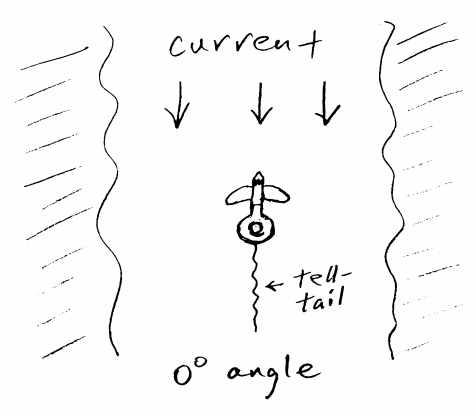
6. ***Taking readings—general procedure for water between 0.3 and 2.5 feet deep:***

   a. Set the rod on the stream bottom and record the tape reading on your data sheet, to the nearest tenth of a foot.

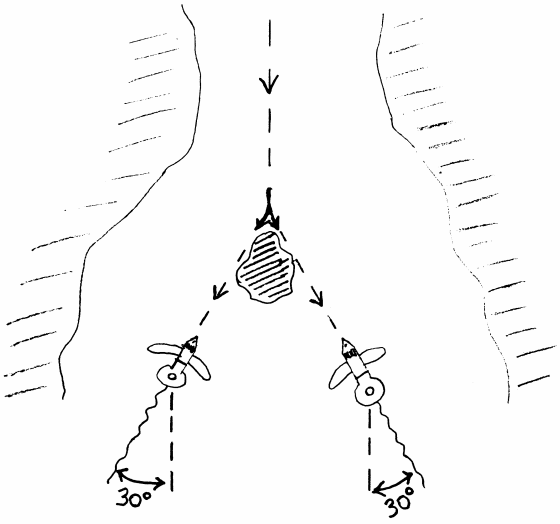
   b. Adjust the moveable rod as needed to set the tip of the prop at water level. The staff should be vertical, which you can determine by briefly letting go of it. Read the stream depth from the large scale on the moveable rod, at the point where it enters the top of the slide fitting. (See picture earlier in this section.) Note that the scale reads downward, intervals are in tenths of a foot, and foot-marks are triple lines. Record the water depth from the staff, to the nearest hundredth of a foot. (You will have to estimate between the 0.1' markings on the staff.)

   c. Place the prop at 6/10 the distance from the water surface to the stream bottom. You can do this easily by lowering the moveable rod until the top of the slide fitting matches the marking for your stream depth on the smaller rod. For example, if your depth is 0.4 feet, slide the rod down to the fourth notch on the smaller rod. (Exception: do not go so far that the prop hits the stream bottom.)

   d. The tell-tail (piece of colored twine attached to the back of the prop/rotor fitting) will ordinarily point downstream in line with the axis of the prop (see sketch below).



   If it does not, then rotate the rod to one side or the other, until the prop faces directly into the current with the tell-tail straight out behind it (see sketch below). Take your measurement with the prop turned into the current at this angle.



   Estimate, to the nearest 10°, the angle you rotated the rod, and record it on the data sheet. (It doesn't matter whether you rotated the rod left or right—just record the number of degrees you had to rotate it.) If you did not need to rotate it at all, write 0. (If the stream flow were completely reversed at your point of measurement, i.e. flowing back upstream, and you had to turn the rod completely around, you would record an angle of 180°.)

   NOTE: *If the water is turbid and you can't see the tell-tail, you should be able to feel the "sweet spot" where the current isn't trying to push the rod to either the left or right. Then compare the angle you see on the double-rod to the angle of the overall current.*

   e. Turn the meter switch to "DISPLAY AVERAGING" (between the Min and Max settings). Press and release the RESET button to zero the display. After approximately 25 seconds, the meter will display a velocity. Record this reading in the "velocity" column on your data sheet.

   f. Proceed across the stream, taking your readings, ending at the far wetted edge.

g. If any velocity reading is different by a factor of 2 than the previous one, the recorder should ask the sampler to confirm that reading.

h. COMMON SENSE & FLOW READINGS: Use your common sense to consider whether the velocity on the meter jibes with how fast the water seems to be moving. Certain conditions can cause the meter to mis-read. If you doubt a reading, take another, then a third to confirm. If possible, record all of these data points along with an explanation of which ones you think should be ignored, and why. If problems persist, see the "Troubleshooting" section later in this protocol.

i. In the "Sampler's Initials" box to the right of the data boxes, put all the initials of one sampler taking responsibility for the data, which will generally be the person with the most experience or knowledge.

j. Recheck the meter calibration number (switch to "CALIBRATE"). If the number has changed, record the new number alongside the first number on your data sheet.

k. Turn the meter off when finished taking readings, and see storage and transport instructions at the end of this section.

7. ***Procedure for water >2.5 feet deep:*** First, seriously consider whether it's safe for you to be in the stream! If you're sure it is (you'll need chest waders), you will need to take two velocity and angle measurements, at 2/10 & 8/10 of total depth. To do this:

   i) Put slashes across the velocity and angle boxes, to make room for the two readings you will take.

   ii) For the 2/10-of-depth reading, take the depth you measured and multiply it by 0.2, then lower the rotor assembly by this amount on the larger rod. An easy way to calculate this in your head is to double the depth number and move the decimal one place to the left. For example, if your depth shows 2.8, doubled is 5.6, and moving the decimal left makes it 0.56. You would drop the rotor assembly by this amount on the larger rod scale to 2.24 (i.e., 2.8 minus 0.56). Record velocity and angle at this point, as described above.

   iii) For the 8/10-of-depth reading, drop the rotor to 0.2 of the water's depth, the same number you calculated above. Move the slide fitting to that point on the large rod. In the example above, the rotor would drop to 0.56 feet. Record velocity and angle at this point, as described above.

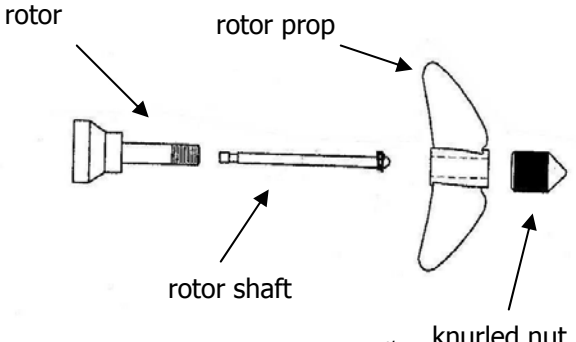
8. ***Procedures for low-velocity conditions:***

   a. If at a given measuring point, the water isn't moving fast enough to turn the prop, write "insf/v" ("insufficient velocity") on the data sheet.

   b. If the prop turns, but erratically, measure the velocity a second time. If the difference is <20%, keep the first reading. If the difference is >20%, take a third reading, and record the average of all three.

9. ***Procedure for water <0.3 feet deep:*** For very shallow water, don't worry about the depth at which you set the prop—put it at any depth where the prop will turn. Record distance, water depth, and velocity as usual. (Note if the prop is partway out of the water.) However, if the shallowness is clearly impacting your velocity measurements, try one of the alternative low flow methods on the next page suggested by the U.S. Bureau of Reclamation (Perry, 2003)

10. ***Gunk on the prop:*** If there is a lot of organic matter in the stream (particularly filamentous algae and particulates), you may find the prop becoming impeded and turning erratically or not at all. The rotor/prop unit may have become dirty inside. Take off the rotor/prop unit using the 1/16" Allen wrench and try rinsing it in clean water or squirting clean water up the rotor shaft. If that doesn't help, unscrew the knurled knob, remove the rotor shaft, and ***gently clean both it and the bore hole*** in clean water. You may have to do this several times in certain conditions.



ALTERNATE LOW-FLOW PROCEDURES:

BUCKET METHOD: If you can capture the flow (from a culvert or waterfall) in a bucket or other container, simply time how many seconds it takes to fill it. Record 3 reps, and then record the average. Measure the volume of the container and convert to cu.ft. (128 oz. = 1 gal. = 0.134 cu. ft.). Record the results with every step labeled clearly so office staff can verify the results.

ONE-POINT "HYDRAULIC" METHOD: Find or create a small ditch that confines the water, using rocks or sandbags as needed, creating a section as rectangular in cross-section as possible, a few feet long if possible, and deep enough to submerge the prop of the meter. (Also ensure you're measuring at a spot where significant amounts of water aren't flowing under the gravel; you may have to walk several hundred yards to determine this.) Then:

1. Find <u>one</u> good spot for a velocity reading:
   a) halfway between the upstream and downstream ends of your ditch;
   b) at a place where the tell-tail points straight back; and
   c) at halfway depth.
   If the prop does not turn freely at this point, try to find a spot at which it does.
2. Take a velocity measurement at that point: set the meter to "Velocity/Max," take 3 readings, record and average them. (If you still can't get the prop to work, estimate the velocity by marking off the length of your ditch and floating a small twig down its length ten times. Divide the number of feet by the average number of seconds to get the velocity [all to the nearest tenth].)
3. Measure and record the channel depth and width at the spot you measured.
4. Multiply velocity x depth x width and round to the nearest tenth or else to the first digit with an actual number (e.g., .04 or .003). This is your flow measure. *(Note: this method is a way to estimate flow under poor conditions and does not account for friction so it may result in an overstated flow value. Provide all relevant information so a determination can be made in the office as whether to apply a correction factor.)*

STREAM GAGES:

Your stream may have a water-level gage installed on it, or we may be able to install one if you're willing to do the leg-work. Over the course of time, dual readings from both the flow meter and gage yield a formula that enables us to estimate discharge simply by reading the gage. (We also have to calibrate the gage by periodically making dual readings and measuring the channel cross section.)

If you have a gage at your site, simply record the water height and units on your flow field sheet. Read the gage both before and after measuring flow, if possible.

Please see Streamkeepers staff if you think a gage is or can be installed near your reach.

MONITORING FLOW BETWEEN SESSIONS:

You might want to measure flow between quarterly monitoring sessions, to learn more about extreme high and low flows in a stream, or about how flow changes during a storm. Therefore, if:

- you want to perform additional flow sampling,
- a field kit is available,
- it is **SAFE** to monitor, and
- you have a team of at least two,

you are welcome to borrow a field kit and data sheet at any time.

METER TROUBLESHOOTING:

- If the meter falls in the water, open the battery compartment on the back as soon as possible by twisting the set screws loose by hand. Dry the battery terminals and cable connections, and let the compartment air dry as much as possible before replacing the cover. Hand-tighten the set screws.
- If the prop isn't spinning freely:
    - You may be at a spot in the stream with no current (or almost none). A sign of this would be that the tell-tail is drooping. If the tell-tail is pointing to the side, you may need to rotate the staff to face into the current.
    - If the tell-tail indicates current and the prop isn't spinning, try the "Gunk on the prop" cleaning procedure described earlier.
    - Try the hand-spin and blow-spin tests again. If a test fails, switch to the spare prop and start the flow measurement procedure over again from the begining. Note problems and how you dealt with them on your data sheet.
- If the velocity readings appear inconsistent or illogical as you're proceeding across the stream, try the following fixes and test them by turning the meter to "Count" and letting the prop turn in the stream; the numbers shouldn't skip or stop (unless the current is very slow).
    1. Try turning the meter on and off again. Sometimes this will reset the circuits.
    2. Examine the cords and connectors for wetness, bad connections, or any other obvious problems, taking corrective action where possible.
    3. Try taking the battery out from the back panel, checking for wetness or corrosion, and putting it back in if it looks okay. Sometimes this simple step can reset the circuits. If this doesn't work, try replacing the battery.
    4. Try the blow test again. If it fails, you can either take apart the rotor and rinse all the parts, or switch to the spare rotor.
    5. IF YOU CONTINUE TO EXPERIENCE DIFFICULTIES, NOTE THE NATURE OF THE PROBLEMS ON THE DATA SHEET AND DISCONTINUE FLOW MONITORING. INFORM PROGRAM STAFF UPON RETURNING THE EQUIPMENT.

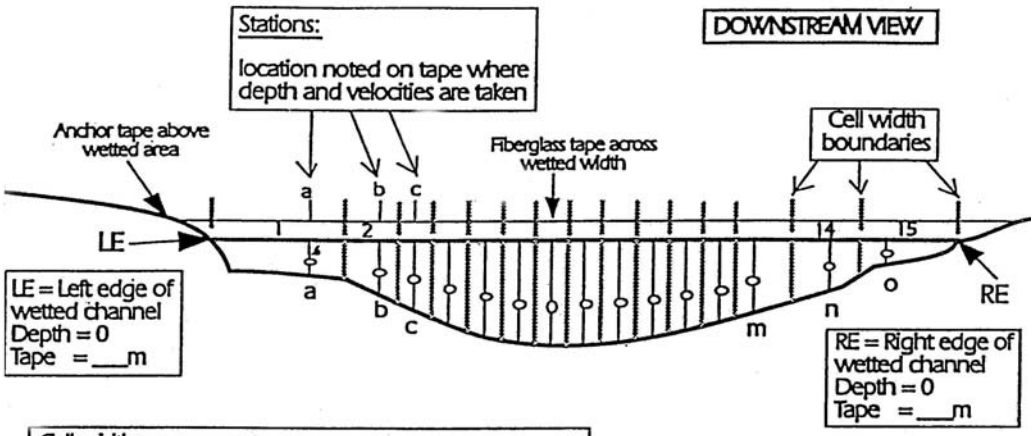
TIPS FOR DATA RECORDING

- Write legibly and be sure to record the data in the units and number of decimal places called for on the data sheet.
- The data recorder should repeat measurements back out loud to the flow sampler to avoid mistakes.
- The data recorder should be alert for inconsistencies in the progression of the numbers and bring any suspect sudden changes to the attention of the flow sampler for verification and resampling if necessary.
- Use common sense when recording readings. If the water appears to be moving faster or slower than the meter is reading, consider going over the METER TROUBLESHOOTING steps in the prior section.

METER STORAGE AND TRANSPORT:

- When swiveling the boom mechanism, always hold it by its base and not by the rotor assembly.
- **NEVER** transport the staff with the rotor/prop attached. Take off the rotor assembly, and replace the orange protective cap between sites. Return rotor/prop unit and Allen wrench to the treasure box. If you are going to another monitoring reach that day, you can keep the rotor/prop and Allen wrench in your pocket.
- **DO NOT** wrap the cord around the wand before storing in the plastic tube to avoid causing shorts in the electrical cables. The preferred method of storage is to place the wand in the tube "head" first and drop the cord down inside when the wand is about halfway in, then insert the rest of the wand with the "foot" part at the top and the tell-tail tucked under so it does not get frayed.
- At the end of each monitoring day, always be sure to remove the rotor/prop assembly and store staff, meter, rotor/prop assembly, protective cap and Allen wrench in their proper places. If possible, dry these parts with the rags in your field kit before storing.

How Flow is Calculated using TFW protocols



Cell width:

Edge cells - distance from wetted edge to first station + 1/2 the distance to the next station
for example: cell 1 = LE - a + 1/2 a - b
cell 15 = 1/2 n - o + o - RE

Middle cells - split the difference between stations
for example: cell 2 = 1/2 a - b + 1/2 b - c
cell 14 = 1/2 m - n + 1/2 n - o

NOTE: To capture high flow areas of stream, take smaller cell measurements in those locations.

Velocity:

Station depth of water < 2.5 ft/.6m: take one velocity at .6 of depth (from surface) at stations

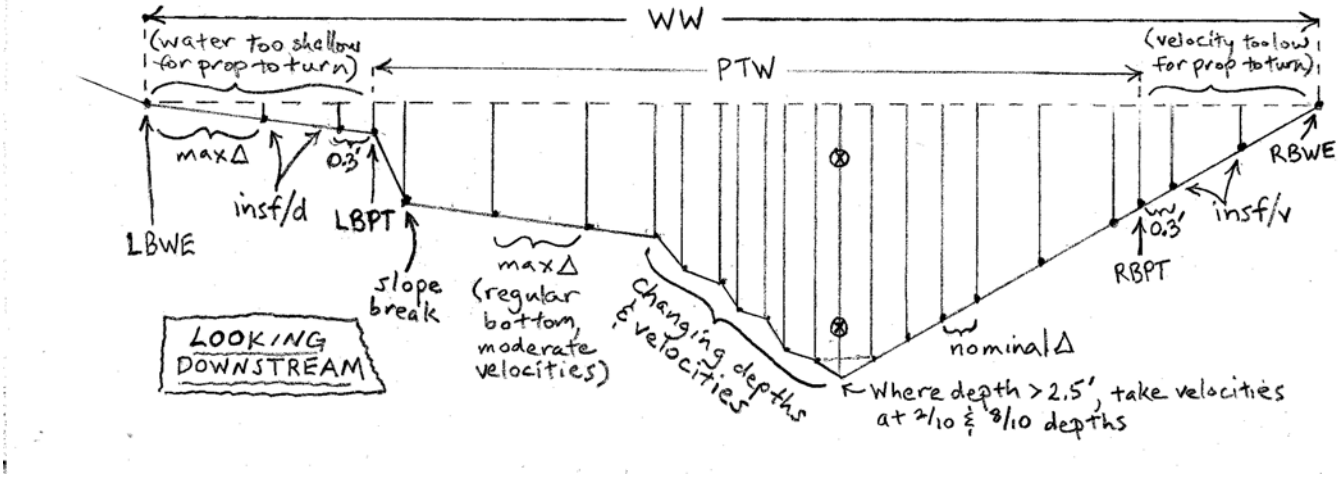
Station depth ≥ 2.5 ft/.6m: take velocities at .2 and .8 of depth at stations and average together

Cell Discharge = Cell Width X Cell Depth X Cell Velocity

Stream Discharge = The sum of all cell discharges

Average cell depth:

Depth at station from surface of substrate to stream's surface



Streamkeepers flow abbreviation definitions

LBWE = Left Bank wetted edge of dry land.
RBWE = Right Bank wetted edge of dry land.
WW = Wetted width; the difference between wetted edges.
MaxΔ = MAXIMUM INTERVAL; 1/10th the wetted width.
LBPT = Tape measurement at LB "prop-turning" edge.
RBPT = Tape measurement at RB "prop-turning" edge.
PTW = "Prop-turning" width; the difference between "prop-turning" edges.
NomΔ = NOMINAL INTERVAL; the "prop-turning" width divided by 20.
Insf/d = Insufficient depth, water too shallow for prop to turn.
Insf/v = Insufficient velocity, water too slow for prop to turn.