STANDARD PROCEDURES FOR MONITORING ACTIVITIES
CLARK COUNTY PUBLIC WORKS WATER RESOURCES

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Contents

Introduction

This document is intended to guide the monitoring activities of Water Resources (WR) staff. The procedures detail the protocols and means used by WR staff to generate data. The procedures are divided into two tiers: 1) criteria and considerations for selecting sample sites for various types of field activities; and 2) procedures collecting field measurements and samples.

The procedures fit into the overall process of generating information from environmental data by identifying *procedures* used to generate the data. Agencies identify measurable elements of environmental attributes and then develop a list of parameters that may be monitored. Procedures appropriate for the selected parameters are used to generate data and further, with the help of data assessment procedures, provide information about environmental attributes.

This effort focuses on an objective of a Washington Department of Ecology water quality grant project intended to provide and coordinate monitoring resources and activities for the county and various local agencies, schools, and volunteers. The primary project objectives are to 1) standardize and document Water Resources' monitoring activities and 2) enhance communication of the activities with managers, agencies, and the public through coordination and training. Standard procedures documents are dynamic as staff are continually updating and improving procedures utilized to measure environmental attributes.

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Selection of Sample Sites

Selecting Water Sample Collection Locations

Procedure Application: For the selection of specific locations suitable for collecting water samples. The overall selection of sample stations or monitoring locations is addressed in the planning of specific monitoring projects.

Reference: Standard Methods, 1992. *Standard methods for the examination of water and wastewater, 18th edition.* American Public Health Association, Washington D.C.

General Considerations:

- Guidelines for selecting samples sites focus on the best locally available conditions for collecting water samples.
- The objective of sampling is to collect a portion of material small enough in volume to be transported and handled in the laboratory while still accurately representing the material being sampled.
- The variety of conditions under which collections must be made makes it impossible to prescribe a fixed procedure. In general, take into account the tests or analyses to be made and the purpose for which the results are needed.
- Sample carefully to ensure that analytical results represent the actual sample composition.
- Make a record of every sample collected and identify every bottle, preferably by attaching an appropriately completed label.
- The guidelines should be followed whenever possible, however, seldom will all the criteria defined in the guidelines be met. Ultimately field personnel will have to exercise judgment in selecting the best site available. Conditions that are considerably different from the criteria should be noted on the field sheets.

Guidelines:

1) Samples collected from a river or stream may give results that vary with depth, stream flow, and distance from shore. Take an "integrated" sample where appropriate from top to bottom in the middle of the stream or from side to side at mid-depth to integrate according to flow.
2) Collect grab or catch samples from the middle of the stream or thalweg and at mid-depth.
3) Lakes and reservoirs are subject to considerable variations from normal causes. Choose locations and depths depending on local conditions, such as seasonal stratification, and the purpose of the investigation. Avoid sampling surface scum.
4) Generally, collect samples from well-mixed areas beneath the surface. Avoid areas of excessive turbulence such as weirs.
5) Collect samples from wells only after the well has been pumped sufficiently to insure that the sample represents the groundwater sources.
6) Because sample constituents can be toxic, take adequate precaution in selecting sample locations. Avoid confined areas or spaces subject to fumes.
7) The site should have safe and reliable access for performing in-stream work.

Selecting Macroinvertebrate Sample Collection Locations

(Refer to the macroinvertebrate standard procedure for guidelines on selecting sample locations in a reach).

Selecting Stream Discharge Measurement Locations

Procedure Application: For the selection of specific sample sites (cross sections) suitable for water velocity and channel shape measurements used in discharge calculations. The overall selection of gaging stations or monitoring locations is addressed in the planning of specific projects.

Reference: Rantz, SE, and others, 1982. Measurement and computation of streamflow: Vol. 2, Computation and discharge: USGS Water Supply Paper 2175.

General Considerations:

- Guidelines for selecting samples sites focus on the best locally available conditions for the measurement of discharge, specifically velocity, depth, and width.
- The selection of suitable locations for stage measurements is addressed in planning elements for specific projects.
- The site selection guidelines apply to instances when the stream can be safely waded. During periods of high water when measurements must be taken from a bridge or cableway, several of the selection criteria may not be supported. An effort is made when taking measurements from bridges or cableways to satisfy as many criteria as possible.
- The guidelines should be followed whenever possible, however, seldom will all the criteria defined in the guidelines be met. Ultimately field personnel will have to exercise judgement in selecting the best site available. Conditions that are considerably different from the criteria should be noted on the field sheets.

Guidelines:

1) The cross section lies within a straight reach for approximately 200-300 ft, and streamlines are parallel to each other.
2) The stream is confined to a single channel in the reach.
3) Velocities are greater than 0.5ft/s (0.15m/s) and depths are greater than 0.5ft (0.15m). The location should be deep enough to use the 2-point method of measuring velocity if desired.
4) Streambed, as indicated by depth, is relatively uniform and free of numerous boulders and heavy vegetative growth.
5) Flow is relatively uniform and free of eddies, slack water, and excessive turbulence.
6) The measurement section is relatively close to the gaging-station control if one exists.
7) Bridge piers should be avoided as they affect the distribution of velocities and can lead to scouring of the channel (non-uniform depth).
8) The site should have safe and reliable access for performing in-stream work.

Collecting Field Data and Water Samples

Field Measurements and Sample Collection

Procedure Application: This set of procedures (pp. 5-17) is intended to guide Water Resources staff in field activities and applies to the work performed in wadeable streams and rivers, and lakes.

References:

1. North Creek Analytical Laboratories, 1997. Quality Assurance Plan, Beaverton Oregon.
2. Standard Methods, 1992. Standard methods for the examination of water and wastewater, 18th edition. American Public Health Association, Washington D.C.
3. Monitoring equipment manuals.

Parameters:

Table 1. Parameters typically measured in the field by Clark County Water Resources; typical data quality objectives for routine monitoring projects are shown.

Parameter	Method	Accuracy	Resolution
Water temperature	Thermistor	± 0.10°C	0.01°C
pH	Glass electrode	± 0.2 pH units	0.01 pH units
Dissolved oxygen	Membrane electrode	± 0.2 mg/l	0.01 mg/l
Specific conductance	Electrode	± 1% of reading	4 digits
Turbidity	Nephelometric	± 2% of reading	0.01 NTU

Table 2. Parameters measured at the laboratory from samples collected by Clark County Water Resources; typical minimum reporting limits are shown.

Parameter	Method	Reference	Reporting Limit
Ammonia-N (NH_3-N)	Colorimetric	EPA 350.1	0.05 mg/l
Nitrate+nitrite-N (NO_3+NO_2-N)	Colorimetric/cadmium	EPA 353.2	0.01 mg/L
Total phosphorus (TP)	Colormetric	EPA 365.1	0.02 mg/l
Total solids	Total residue	EPA 160.3	10.0 mg/l
Turbidity	Nephelometric	EPA 180.1	0.20 NTU
Fecal Coliform	Membrane Filtration	*SM 9222D	2 CFU/100 mL
E-Coli	Most Probable Number	*SM 9223 B	1 MPN/100 mL
*Guidelines Establishing Test Procedures for the Analysis of Pollutants; Analytical Methods for Biological Pollutants in Ambient Water; Proposed Rule http://www.epa.gov/fedrgstr/EPA-WATER/2001/August/Day-30/w21813.htm			

Pre-Run Procedures:

- Compile equipment:
    - Measuring tape for stream level
    - Safety vests
    - Machete
    - Long-handled dipper
    - Field notebook
    - Fine-point permanent pen
    - Rubbermaid field kit
    - Waders/boots for sample team
    - Hydrolab DS4 or YSI field instruments
    - Hach dissolved oxygen kit
    - pH Buffer Solutions
    - 500-mL wash bottle with DI water
    - Clark County maps
    - First Aid Kit
    - Road gate keys/storm water facility keys
    - Boat equipment

- Calibrate the Hydrolab DS4 or YSI instruments following the calibration procedures in the instrument manuals.
- Check the calibration of the Hach 2100P turbidimeter with Gelex secondary standards; calibrate if necessary with the StabCal primary standards.
- Assemble and label sample bottles: (typically 4 bottles per site plus QC requirements)
    - (2) 100-mL STERI-BOTTLE for bacteria samples.
    - (1) 250 or 500-mL LDPE bottle, preserved with sulfuric acid for ammonia, nitrate, and total phosphorus.
    - (1) 250 or 500-mL LDPE bottle, unpreserved for turbidity and total solids.
- Place bottles and blue ice into large cooler.
- Schedule an afternoon pickup from Lab (check with the WR lab contact).
- Load and fuel the Van.

Sampling Procedures:

<u>Routine stream and lake sampling generally involves three field activities:</u>

1. Collecting water samples for laboratory analysis using appropriate sampling equipment.
2. Recording field measurements and observations for water temperature, specific conductivity, pH, and dissolved oxygen, and turbidity; habitat quality and site information.
3. Determining the stream's stage height from a reference point (site specific) by using a weighted measuring tape, or by reading a staff gage if present.

Sampling Routine

1. Upon arriving at the collection site, label all four bottles with the appropriate information:

Example	*Client:*	<u>Clark County</u>
	Project:	<u>Long-term Index Site Project (LISP)</u>
	SampleID:	<u>Lackawater Creek</u>
	Date and time:	<u>Anyday Anytime</u>

Note: It is very important to record the time on the sample bottle label and the COC sheets as some samples have short holding times.

2. Place the field instrument(s) into the stream or at a lake depth and allow the sensors to equilibrate for a few minutes. If conditions permit, collect the water samples during this time without disturbing the stream above the unit. After an equilibration period, record the measurements for water temperature, pH, dissolved oxygen, and specific conductance in the field notebook or datasheet. Verify that the readings are logical before proceeding.

3. Collect water samples from the appropriate location given the site conditions. Samples should be collected in large containers to help reduce variability in data. The VanDorn water bottle is often used in both streams and lakes where feasible; other times such as during low water a clean 1-L bottle can be used. Otherwise, collect samples by dipping the sample bottles directly into the water source. Facing upstream, quickly submerge the open bottle below the surface being careful not to dislodge any streambed debris. Try to avoid collecting surface film or disturbing bottom sediments with a device or sample bottle. Sample from the mid-water column depth when possible.

4. When filling sample bottles remove the bottle lids one at a time to reduce the likelihood of bottle contamination. Fill each bottle to the "neck" unless directed otherwise, as with the bacteria bottles. Follow this same procedure for all samples as well as the turbidity sample.

5. Determine the stream's stage using a stream staff gage or by taking a tape down measurement using a weighted line and reference point. Typically a "messenger" for the Van Dorn bottle is put on the end of the measuring tape and lowered over a bridge to the water's surface. Record, in hundredths of feet, the stage height in the field notebook or datasheet.

   Alternately, if a suitable staff gage is present at or near the site determine the stage from the gage and record the value along with the gage information in the field notebook or datasheet. Inspect county staff gages for damage or obstruction and report to the hydrology project manager.

6. Measure turbidity with the Hach 2100P turbidimeter and record the findings in the field notebook or datasheet.

7. Place samples in the large cooler with ice. Make sure the bacteria samples are surrounded with ice.

8. Rinse the sampling equipment with deionized water to remove sediment or algae. Use a wash bottle and water to rinse probes before storing. Properly store all sampling equipment before leaving the site.

9. Verify that all samples have been collected and that all required field measurements have been recorded before leaving the site. Consult the sample plan or chain of custody sheets.

10. After returning to office, fill out a chain of custody sheet for the samples collected. Check with the project manager for the location of the sheets.

Sample Preservation and Shipment

After collection, sample bottles need to be placed immediately in a cooler containing enough ice to keep them cool until all samples are collected and returned to the office for pick up. Upon reaching the office, replace the ice packs with fresh ice packs.

Collection arrangements should be made at least one day prior to the field day. Call the project manager at North Creek Analytical to make arrangements for the pick up. Pick-up is generally scheduled for afternoon on the sampling day at around three o'clock p.m.

Table 3. Sample collection and preservation requirements for commonly tested parameters of Clark County Water Resources.

Parameter	Container	Preservation	Holding Time / Amount Required
Ammonia-N (NH_3), total phosphorus (TP), nitrate+nitrite-N (NO_3+NO_2)	500-mL LDPE bottle	Sulfuric acid; store cool at 4°C	28 Days/ 250 mL
Total solids (TS)	500-mL LDPE bottle	Store cool at 4°C	7 Days / 250 mL
Turbidity	500-mL LDPE bottle	Store cool at 4°C	2 Days / 250 mL
Fecal coliform, E. Coli	100-mL STERI-BOTTLE	Store cool at 4°C	24 Hours / 100 mL

Hydrolab DS4 calibration and maintenance guidelines

Procedure Application: These guidelines apply calibration and maintenance activities only. For detailed procedures and instrument/sensor diagrams, refer to the Hydrolab Datasonde user's manual (the manual). All Water Resources staff working with the instruments will be trained and required to **read** the user's manual. Users must follow all precautionary measures outlined in the manual to ensure both personal safety and instrument integrity.

NOTE: Follow the instrument guidelines for deployment configurations and options. Situations will vary by project

Reference:
Hydrolab Corporation, 1997. Hydrolab DS4 and Surveyor Users Manual.

Instrument: Hydrolab DS4 datasonde and Surveyor 4

Equipment:

- calibration standards for conductance
- pH buffers; pH7 and pH10
- Hach oxygen kit
- de-ionized water
- methanol
- soap and toothpaste
- Kimwipes
- #400 grit or finer sandpaper
- large and small screwdrivers
- Hydrolab's DS4 maintenance kit
- pH maintenance kit
- oxygen maintenance kit
- calibration and storage cup and cap

Calibration:
1) Establish communication between the instrument and a the Surveyor or a computer using HyperTerminal or another equivalent emulation program. Refer to section 7.10 *HyperTerminal basic commands* in the Hydrolab manual for commands and communication settings.
2) Allow all readings to stabilize.
3) Select Calibrate on the main menu.
4) Individually select parameters to work with and select the appropriate units.
5) Dissolved oxygen (DO)
   Maintenance-replace membrane and electrolyte following steps on page 3-12 of the manual.

   Calibration-performed in the calibration cup, a bucket of water, or with the Winkler titration method.

   Air calibration:
   1. secure the probe with the instrument sensors pointed upward and the cup installed
   2. fill the cup with tap water until the water is just level with the o-ring on the DO sensor
   3. remove water droplets from the membrane with a Kimwipe
   4. cover the calibration cup with the inverted cap
   5. once readings have stabilized move the cursor on the menu to calibrate, then to oxygen, and % sat
   6. enter the barometric pressure in mm Hg

7. check final value against saturation curves in the field notebook for logic

Known DO concentration:

1. fill bucket or tub with de-ionized water
2. place instrument(s) in bucket and allow to stabilize (± 0.5% per hour)
3. determine concentration of DO in bucket with Winkler titration
4. move cursor on menu to calibrate, then to oxygen, and DO: mg/L
5. enter the barometric pressure in mm Hg
6. type the known concentration from the Winkler value in mg/L

6) Specific conductance

Maintenance – maintenance intervals depend on accuracy check results and visual inspections of the sensor. Expose and carefully polish/clean the five-electrode sensor with emery cloth or wet sandpaper. Follow steps on page 3-18 of the manual.

Calibration – requires a two-point calibration to zero and a slope buffer approximating the expected range in the field.

1. fill the calibration cup half full with deionized water and cover with the cap
2. shake the probe to rinse, repeat
3. remove the cup and secure the probe with the sensors pointing upward
4. dry the conductivity cell block thoroughly
5. move the cursor on the menu to calibrate, cond., mS/cm, and then type 0 and enter
6. replace the calibration cup
7. rinse the sensors twice with the standard
8. pouring down the side of the cup, fill it with the standard to a point just above the DO cell
9. allow readings to stabilize
10. move the cursor on the menu to calibrate, cond., mS/cm, and then type the value of the standard, i.e. 0.250 mS/cm

7) pH

Maintenance – the glass electrode only requires maintenance when visibly fouled or when erratic pH readings are noted. The reference needs to be cleaned and filled with new solution on a regular schedule. Follow steps on page 3-30 of the manual.

Calibration - requires a two-point calibration to with buffers approximating the expected range in the field.

1. screw on the calibration cup
2. rinse the sensors with deionized water
3. rinse the electrode with a small amount of pH7 buffer
4. fill the cup with the pH7 buffer to a point just above the DO cell
5. after readings stabilize move the cursor to calibrate, ions-1, pH: Units and enter
6. type 7 after the standard: prompt
7. rinse the sensors with de-ionized water and then a small amount of the next pH buffer
8. fill the cup with the second buffer to a point just above the DO cell
9. after readings stabilize move the cursor to calibrate, ions-1, pH: Units and enter
10. type the value of the buffer and then enter

8) Temperature

Maintenance – keep the thermistor tube clean

Calibration – the sensor does not require calibration; check the reading with a NIST calibrated digital thermometer

9) Depth
Maintenance – keep the port free of deposits/debris

Calibration – carried out by entering zero at the site before use or deployment to ensure a similar barometric pressure

1. move the cursor on the menu to calibrate, depth25, dep25:meters and then press enter
2. type a zero after the prompt and enter
3. repeat if other readings are displayed

NOTE: A quick calibration and troubleshooting guide can be found on page 3-43 of the manual.

10) Circulator maintenance – clean when clogged with twigs or debris indicated by rough or noisy operation.

1. clean the impeller in tap water using a toothbrush
2. rinse with tap water
3. remove the retaining screw to clean buildup between impeller and housing
4. apply small amount of Loctite threadlocker to the tip of the screw
5. insert the screw and tighten
6. do not "bottom out" the screw or overtighten

11) Storage – the Datasonde should be stored clean and fully maintained

1. fill the storage cup with one inch of clean tap water and screw on the probe
2. use alcohol and water when in freezing weather
3. remove batteries before long-term storage
4. store cables coiled and dry with at least 6-inch diameter loops

Quality Assurance:
- Water Resources staff are trained in calibration and deployment procedures and are required to read equipment manuals.
- calibration schedules and procedures are followed.
- maintenance activities performed in-house and by Hydrolab are tracked in calibration logs.
- datasheets are used to document calibration activities and are stored in project files.

General Considerations: Calibration and maintenance activities are performed for activities listed below.
- prior to field sampling activities or trips
- pre-deployment preparation and calibration
- performance problems due to fouled sensors
- post-deployment accuracy checks
- scheduled field maintenance
- preparation for storage

YSI 556 Multi Probe System calibration and maintenance guidelines

Procedure Application: These guidelines apply calibration and maintenance activities only. For detailed procedures and instrument/sensor diagrams, refer to the instrument's manual (the manual). All Water Resources staff working with the instruments will be trained and required to **read** the user's manual. Users must follow all precautionary measures outlined in the manual to ensure both personal safety and instrument integrity.

NOTE: Follow the instrument guidelines for deployment configurations and options. Situations will vary by project

Reference: YSI Environmental, 2001. *YSI 556 Multi Probe System Operations Manual*, YSI Incorporated, Yellow Springs Ohio.

Instrument: YSI 556 Multi-Probe System (MPS)

Equipment:
- transport/calibration cup
- calibration standards for conductance; 100 uS/cm standard
- pH buffers; pH7 and pH10
- Winkler titration reagents for oxygen; Hach kit
- de-ionized water
- 400 grit sandpaper
- DO membrane replacement kit
- YSI 556 maintenance kit
- Kimwipes
- cotton swabs

Calibration:
1) Make sure all of the sensors are installed in the probe and that the empty ports are sealed with port plugs. Turn the instrument on and let it warm up for at least 15 minutes.
2) Access the calibration screen on the YSI 556 by entering Calibrate from the main menu. The calibration screen is displayed.
3) Allow all readings to stabilize.
4) Individually select parameters to work with and select the appropriate units for calibration.
5) Dissolved oxygen (DO)
   Maintenance-membranes should be replaced and the electrodes should be cleaned periodically. Replace membrane and electrolyte following steps on page 95-99 of the manual.

   Calibration-performed in the calibration cup, a bucket of water, or with the Winkler titration method.

   1. Use the arrow keys to highlight DO from the main menu and press Enter. Typically perform the air saturation calibration method by selecting the DO% from the DO calibration screen. The DO Barometric Pressure Entry screen is displayed.
   2. Place 1/8" water in the bottom of the calibration cup.
   3. Place the probe module into the calibration cup making sure the DO and temperature sensors are not immersed in the water. Screw the calibration cup onto the probe engaging only 1-2 threads.

4. Press Enter to accept the barometric pressure reading displayed on the unit and enter the DO% calibration screen.
5. Allow 10 minutes for the air in the cup to become saturated and the temperature to stabilize. When stable, press Enter and the screen will indicate that the calibration has been accepted and prompt you to press Enter again to continue.
6. Press Escape to return to the calibration menu.

6) Specific conductance

<u>Maintenance</u>-maintenance intervals depend on accuracy check results and visual inspections of the sensor. A clean conductivity cell is the most important requirement for accurate readings. Clean the cell as described on pages 100-101 of the manual.

<u>Calibration</u>-requires a single-point calibration using a standard. A secondary standard (typically about 100 μS/cm) is used to check the accuracy of the sensor.

1. Use the arrow keys to highlight conductivity from the main menu and press Enter. The conductivity calibration screen is displayed.
2. Use the arrow keys to highlight the specific conductance selection and press Enter.
3. Place the correct amount of the 1,000 μS/cm conductivity standard into the rinsed calibration cup. Also rinse the sensor with standard.
4. Carefully immerse the sensors of the probe into the cup, screw the cup onto the probe, and gently rotate to remove bubbles from the conductivity cell. Make sure the temperature sensor is immersed in solution.
5. Enter the calibration value of the standard into the unit in mS/cm at 25°C or the 'corrected' conductivity value.
6. Press Enter and the calibration screen is again displayed.
7. Allow at least one minute for temperature equilibration and then press Enter to calibrate.
8. Return to the main menu.

7) pH

<u>Maintenance</u> – the glass electrode only requires maintenance when visibly fouled or when erratic pH readings are noted. Follow steps on pages 99-100 of the manual.

<u>Calibration</u> - requires a two-point calibration to with buffers approximating the expected range in the field. If the range is unknown perform a three-point calibration.

1. Use the arrow keys to highlight pH from the main menu and press Enter. The pH calibration screen is displayed.
2. Use the arrow keys to highlight the 2 point selection and press Enter.
3. Place the correct amount of pH 7 buffer into a clean, pre-rinsed calibration cup; rinse the electrodes with a small amount of buffer as well.
4. Gently rotate the probe module up and down to remove any bubbles from the sensors. Make sure the pH and temperature sensors are immersed.
5. Screw the calibration cup on the probe.
6. Enter the calibration value of the buffer at the solution temperature given by the meter and press Enter.
7. Allow at least one minute for temperature equilibration before proceeding, then press enter to calibrate the sensor. The screen will indicate that the calibration has been accepted. Press Enter to continue to the next buffer.

8. The screen will prompt the user to enter the second calibration buffer value. Rinse the probe and calibration cup with water and then with the next buffer, either a pH 4 or pH 10 buffer. Repeat steps 3-7 above using the second pH buffer.
9. Return to the main menu after the last buffer has been used.

8) Storage – the YSI 556 should be stored clean and fully maintained. Follow the guidance on pages 105-107 for storage procedures.

   1. Remove the pH sensor from the probe and store it in the bottle with pH4 or KCl storage solution.
   2. Seal the empty port with the provided port plug.
   3. Leave all other sensors on the probe when storing.
   4. Place ½" of tap water in the calibration cup.
   5. Screw the calibration cup onto the probe; be sure that none of the sensors are actually under water.
   6. Check the instrument periodically to ensure water is present in the cup.

Quality Assurance:

- Water Resources staff are trained in calibration and deployment procedures and are required to read equipment manuals.
- calibration schedules and procedures are followed.
- maintenance activities performed in-house and by YSI Service Centers are tracked in calibration logs.
- datasheets are used to document calibration activities and are stored in project files.

General Considerations:

- calibration and maintenance activities are performed for activities listed below.
  - prior to field sampling activities or trips
  - performance problems due to fouled sensors
  - scheduled field maintenance
  - preparation for storage
- turn the instrument on for at least 20 minutes prior to calibrating.
- make certain to loosen the threads of the calibration cup when calibrating DO.
- ensure that the sensors are completely submersed when calibration values are entered; use recommended volumes when performing calibrations.
- pre-rinse the sensors with a small amount of calibration solution when calibrating.
- shake off excess rinse water or use Kimwipes to remove water between calibration procedures.
- make certain port plugs are installed in all ports where sensors are not installed.

Turbidity Protocol, Field Determination

Procedure Application: The procedure applies to the field determination of turbidity in water samples using the Hach 2100P portable turbidimeter. Samples collected for laboratory analysis of turbidity are processed following protocols in the "Collecting Water Samples" section of this document.

Instrument: Hach Model 2100P portable turbidimeter.

Equipment: turbidimeter
sample vials
Kimwipe paper wipes

Reagents: Hach StabCal calibration standard vials
Gelex secondary standards
100 NTU formazin turbidity standard
silicone oil

Calibration: Hach recommends calibrating the instrument at least once every three months. If data quality objectives for quality control samples are not met, the instrument must be calibrated more frequently. Use Hach's StabCal calibration standards and follow the detailed instructions in the Hach 2100P instrument manual.

Note: To return the meter to factory setting or default calibration, press and hold DIAG and then press and release I/O. Release DIAG when the software version number disappears from the display. User-entered calibrations are removed from the memory and the display flashes CAL? while using the default calibration coefficient.

Using Gelex secondary standards to check calibration:
These standards are particulate suspensions similar to the formazin primary standards. Target turbidity values on Gelex standards are approximate and the true value of the standards must be determined against formazin on the same instrument used for calibration checks. Once the value of the Gelex standards is known, they are used to determine a change in the instrument's calibration or performance.

Measurement: (Note: Section 2 in the instrument manual provides detailed steps and measurement notes).

1. Make sure the instrument is on a level, stationary surface.
2. Turn on the instrument and enter the SIGNAL AVERAGING and AUTORANGE mode.
3. Allow samples to warm to a point where condensation will not form on the sample vials.
4. Fill a vial with sample taking care to handle the vial by the top and not entrain air.
5. Cap the vial and wipe with a soft, lint-free cloth or Kimwipe.
6. Put the sample vial in the instrument and close the cover.
7. Press READ and record the turbidity after the lamp symbol (a light bulb) turns off.

Quality Assurance:
- The turbidimeter is calibrated every three months or on shorter intervals if meter performance decays.
- Gelex secondary standards are used to check the consistency of the calibration curve prior to analyzing samples.

- Equipment is properly maintained in good condition. Damage is avoided in transport by packing in appropriate cases and containers.
- Field personnel are required to read the Hach equipment manuals and WR Standard Procedure's prior to training; a basic understanding of the principle of operation of the instrument is expected.

Quality Control Requirements:
- Precision and accuracy are monitored using check standards prepared from reference materials, replicate analyses, and duplicate field samples run at 10% of the sample load.

General Considerations:
- A key to accurately measuring turbidity is avoiding entrapment of air in samples while mixing. Vials should be gently inverted and rotated to suspend particles without shaking.
- Signal averaging mode accounts for rapidly settling particles in sample vials that cause variable turbidity readings.
- Condensation that forms on sample vials while in the instrument chamber can be avoided by letting samples warm to room temperature.
- Always place the instrument on a level, stationary surface.
- Always close the cell compartment lid during measurement and storage.
- Always use clean, scratch free sample vials.
- Avoid using the instrument in direct sunlight.
- Always perform turbidity measurement within 48 hours of collecting a sample.
- Useful data to collect with turbidity levels include Total Suspended Solids concentration and streamflow.

Equipment Maintenance:
- Keep the meter and accessories clean.
- Avoid prolonged exposure of the meter to sunlight or ultraviolet light.
- Wash sample vials with a non-abrasive detergent, rinse with deionized water, and air dry.
- Replace the AA batteries when the battery icon appears in the display.
- Replace the lamp as necessary following procedures in Section 4.3 in the instrument manual.

References:
Instruction Manual. Hach Model 2100P Portable Turbidimeter, Operating Instructions. Hach Company Inc.

Standard methods for the examination of water and wastewater. 18th Edition, Method 2130B. Nephelometric method.

Oregon plan for salmon and watersheds, 1999. Water quality monitoring technical guide book, Version 2.0, Chapter 11 Turbidity Protocols.

Water Temperature Monitoring Using Dataloggers

Procedure Application: The procedure applies to the use of continuous water temperature dataloggers in streams, rivers, and lakes. Quality assurance and control; instrument maintenance, deployment, and downloading; and data management and analysis procedures are described. This procedure follows a standard method for assessing and monitoring the quantity and quality of stream temperature that was developed under the Timber Fish and Wildlife Monitoring Program in Washington State.

Reference: Schuett-Hames, D., A.E. Pleus, E. Rashin, and J. Mathews. 1999. TFW Monitoring Program method manual for the stream temperature survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-005. DNR #107. June.

Instrument: Onset Hobo Pro temperature datalogger
Onset H8 temperature datalogger

Table 4. Temperature datalogger specifications.

Instrument	Range	Resolution	Accuracy
Hobo Pro	-20°C to 50°C	0.02°C	±0.2°C at 25°C
Hobo H8	-20°C to 70°C	Not specified	Not specified

Equipment:

- dataloggers
- datalogger software and cables
- certified reference thermometer
- 5-gallon buckets (2)
- instrument anchoring equipment
- audit thermometer
- 100-ft measuring tape
- compass

Calibration: Hobo dataloggers are factory calibrated. Pre and post-survey *accuracy checks* are required for each datalogger and the audit thermometer. The accuracy check procedure should occur immediately prior to installation of the instruments and immediately after retrieval from the field.

1. Prepare the two water baths by filling with tap water the 5-gallon buckets. Place one bucket in the sample refrigerator and leave the other out in the storage room. Let the baths sit at a minimum overnight to equilibrate.
2. Prior to the test, begin mixing the water baths and mix periodically during the accuracy check.
3. Check to make sure the dataloggers are functioning and that the time is synchronized with the computer's clock and your own watch (set the computer clock according to the time at www.time.gov. This public service is provided by the Time and Frequency Division of the National Institute of Standards and Technology (NIST)).
4. Launch the dataloggers following the procedures in the instrument manuals with a one minute recording interval.
5. Fill out the form 8.1L from the TFW procedure. Record the datalogger and reference thermometer number, the unit of measure, make, model, and manufacturer's stated accuracy.
6. Place the dataloggers in the 'warm' calibration bath along with the reference thermometer. Instruments should not contact the walls of the buckets and should all be placed at about the same level in the bath.

7. Wait a minimum of one hour to allow the instruments to reach equilibrium with the bath temperature.
8. Begin the accuracy check at the start of a new minute and record the reference thermometer readings on only one form (data can be transferred to the other forms after the treatment). Repeat the reference thermometer reading at a minimum of one-minute intervals for 10 minutes.
9. Remove the dataloggers from the bath and place in the 'cold' bath repeating the measurement procedure. Allow at least one hour for instruments to equilibrate.
10. Download the dataloggers according to manufacture's instructions. Store the data files in the raw file format as well as in an Excel text file format in the appropriate folder on the network.
11. From the text file or raw file using the datalogger software, find the temperature data at times corresponding to the reference thermometer readings and record those temperatures on the data sheet for each datalogger.
12. On the datasheets subtract the datalogger readings from the reference thermometer readings for each time and record the result in the difference column. Calculate the mean value for the 10 readings in the difference column and record this number in the mean difference blank on the sheet.
13. Any instruments varying by more than 1.0°C from the reference thermometer must be rejected until the problem is corrected or by passing a subsequent accuracy check test.
14. Mark the 'Accept' or 'Reject/Repair' circle at the bottom of the spreadsheet.

Datalogger Installation:

1. Launch the dataloggers with the appropriate recording interval (typically for Clark County Water Resources this is once an hour) and start-up date and time as dictated by the project plan. ***Launching the logger will erase all previous data***. Again verify that the date and time on the datalogger correspond to an accurate computer time.
2. Program loggers to start recording once per hour. For each logger, bring along a rebar, u-bolt and nuts, protective case, rebar driver, and hammer/ sledge. Bring permission letters if you will be accessing private property.
3. Choose a location that reflects the typical morphology of the reach. Install the logger where it won't be discovered by the public, hidden with rocks if necessary. Try to avoid direct sunlight by placing the unit near submerged woody debris or in a well-shaded location.
4. Attach logger to rebar and pound into stream bed or bank. Don't pound it in so deep that you can't remove it, but deep enough so that it stays in the water all summer. Be aware of low-water conditions to insure that the datalogger will be submerged as the water level drops. Cover with rocks and note carefully where it is. As streamflow changes the area around the logger will change in appearance. Don't rely on your memory alone; take detailed notes and log a GPS point at the location if possible.
5. *Don't forget to record the logger serial number with the location in which it was deployed!!*

Measurement:

1. Measurements are typically recorded on an hourly interval from at least the beginning of July through September.
2. The site should be visited periodically to collect audit temperature data and make sure the instruments are in working order. Bring an audit thermometer accurate to 1.0°C or better that has been checked against the reference thermometer. Record the date and time and temperature of the site visit.

Downloading and Data Management:

1. After the deployment period the dataloggers need to be downloaded and undergo a post-season accuracy check. Download the dataloggers per manufacturer instructions. Export a

copy to the appropriate folder on the network as a .dtf (Boxcar temperature logger software) and an ASCII (text) ***in Fahrenheit***; this is the 'working copy' of the datalogger file.

2. Make sure that loggers are cleaned off and that the communication window is clear. On the laptop, open Box car software, and then retrieve data. Choose the option to "stop logging and download data". Save the data as a Boxcar file (*in fahrenheit*) and as an ASCII (text) file onto the laptop. Back-up all data by transferring it from the laptop to the Q drive.
3. Open the ASCII file in Excel. Open the *TempCalcs.xls* template from the data analysis folder on the network. This spreadsheet has two worksheets, one for data reduction and verification, and the other for calculating the log metrics.
4. Copy from the raw data file the time stamp and temperature value columns to the *Check* worksheet. View the graph to determine the dates for reduction and also to check for anomalies. Once formatted, copy the date stamp and temperature value columns to the *Calculate* worksheet. Summary metrics will automatically be calculated and summarized in a table on the worksheet.
5. Copy the worksheet to a workbook created for the project and year.
6. Repeat the process with the next datalogger file.

Quality Assurance:

- Enter all deployment, retrieval, download and audit dates into the temperature logger database.
- Pre and post accuracy check all data loggers.
- Equipment is properly maintained in good condition. Damage is avoided in transport by packing in appropriate cases and containers.
- Field personnel are required to read the Hobo equipment manuals and WR Standard Procedure's prior to training; a basic understanding of the principle of operation of the instrument is expected.
- Organize all of the field sheets and check for missing sheets or field values. Field sheets are error checked for legibility, complete and consistent header information, obvious measurement and transcription errors, and calculation errors.
- The NIST reference thermometer certification is maintained.

Quality Control Requirements:

- Dataloggers need to record temperature within 1.0°C of a reference thermometer in the pre- and post-deployment accuracy checks.
- Audit data should also be within 1.0°C of the corresponding datalogger value.

Equipment Maintenance:

- Rinse the datalogger in warm water and use a mild detergent to clean. Do not use harsh chemicals, solvents, or abrasives, especially on the communications window.
- The battery should last up to 6 years and can be checked in the dataloggers software. Frequent downloads, high sample rates, and extreme temperatures can reduce battery life. Batteries are factory replaceable only.
- Keep the communication and IR ports clean.

References:

1. User's Manual. *HOBO Water Temp Pro*, Onset Computer Corporation, Bourne MA.
2. User's Manual. *HOBO H8 Family*, Onset Computer Corporation, Bourne MA.
3. Schuett-Hames, D., A.E. Pleus, E. Rashin, and J. Mathews. 1999. *TFW monitoring program method manual for the stream temperature survey*. Prepared for the Washington State

Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-005. DNR #107. June.

Stream Discharge Measurements

Primary References: Rantz, SE, and others, 1982. Measurement and computation of streamflow: Vol. 1 and 2, USGS Water Supply Paper 2175.

Procedure Application: Measuring water velocity, depth, and channel width for calculating stream discharge; velocity is measured with the Price Pygmy current meter when the average depth of the cross section is 1.5 ft or less.

Instrument(s): Price Pygmy velocity meter
AquaCalc 5000 Streamflow Computer

Equipment:

- Price USGS type Pygmy current meter
- Price USGS type AA current meter
- AquaCalc model 5000 Open Channel Flow Computer
- top setting wading rod
- 15', 50', 200', and 300' weighted or fiberglass measuring tapes
- safety rope, lifejackets, and safety vests
- stakes and hammer
- surveyor's measuring rod
- notebook/datasheets/aluminum clipboard
- wading boots/chest waders
- bridge board or crane and counterweights
- Type A or B Reel for suspending Type AA current meter and weights
- Columbus-type sounding weights (30, 50, 75, and 100 pounds)
- sounding weight hanger bars and pins
- Lineman Pliers (emergency cutting of sounding line)
- tool box with small screwdriver

Meter Calibration/preparation:

Principle of operation of the current meter: The Pygmy current meter consists of a set of cups (the bucket-wheel) that rotate horizontally on a sharply pointed pivot as flowing water drags across the cups. A sensor in the upper arm or yoke of the meter detects the rotation of the bucket-wheel through a magnet mounted in its upper shaft. The meter is calibrated such that if the number of revolutions of the cups in a certain time is known, then the linear velocity of the water can be determined. The USGS has established rating tables relating rotations to velocity by calibrating these meters. Field personnel must be knowledgeable about the meter's basic components and operation to ensure its function.

Selection of current meter based on depth and velocity: Water Resources has both a Pygmy and Price AA current meter. As general rule, if there are shallow sections of the transect less than 0.5 ft or the average depth is less than or equal to 1.5 ft the Pygmy current meter should be used. Furthermore, the water velocity in the transect should not exceed the range of the Pygmy meter, which has a maximum of 3 ft/s. Situations where the average depth is greater than 1.5 ft or velocity is greater than 3 ft/s dictate the use of the Price AA meter. The following table is provided to clarify meter selection and depth from water surface for velocity measurement.

Table 5. Current Meter Selection Criteria.

Meter Type	Velocity Range*	Approx. Depth Range˜	Velocity Method˜ (From Surface)
Price Pygmy	0.2 ft/sec to 3 ft/sec	0.3 ft to 1.5 ft	0.6
Price AA	0.1 ft/sec to > 20 ft/sec	1.5 ft to < 2.5 ft	0.6
Price AA	0.1 ft/sec to > 20 ft/sec	2.5 ft or >	0.2 and 0.8

* Fulford, 2001; ˜ Rantz, 1982, Vol. 1.

Measurement:

Theory: The midsection method determines discharge by dividing a stream cross section into many subsections, and then summing the products of the measured subsection areas and their respective average velocities (Figure 1) (see equations below). The overall goal of measurement is obtaining enough width, depth, and velocity data to accurately characterize the cross-section.

Mid-subsection discharge $(q_n) = v_n[\,1/2(b_{(n+1)} - b_{(n-1)})]\, d_n$

End-subsection discharge $(q_n) = v_n[\,1/2(b_{(n+1)} - b_{(n)})]\, d_n$

Where: V_n = mean velocity at vertical x, b_n = distance from initial point to vertical x, $b_{(n-1)}$ = distance from initial point to preceding vertical, $b_{(n+1)}$ =distance from initial point to next vertical, and d_n = depth of water at vertical x.

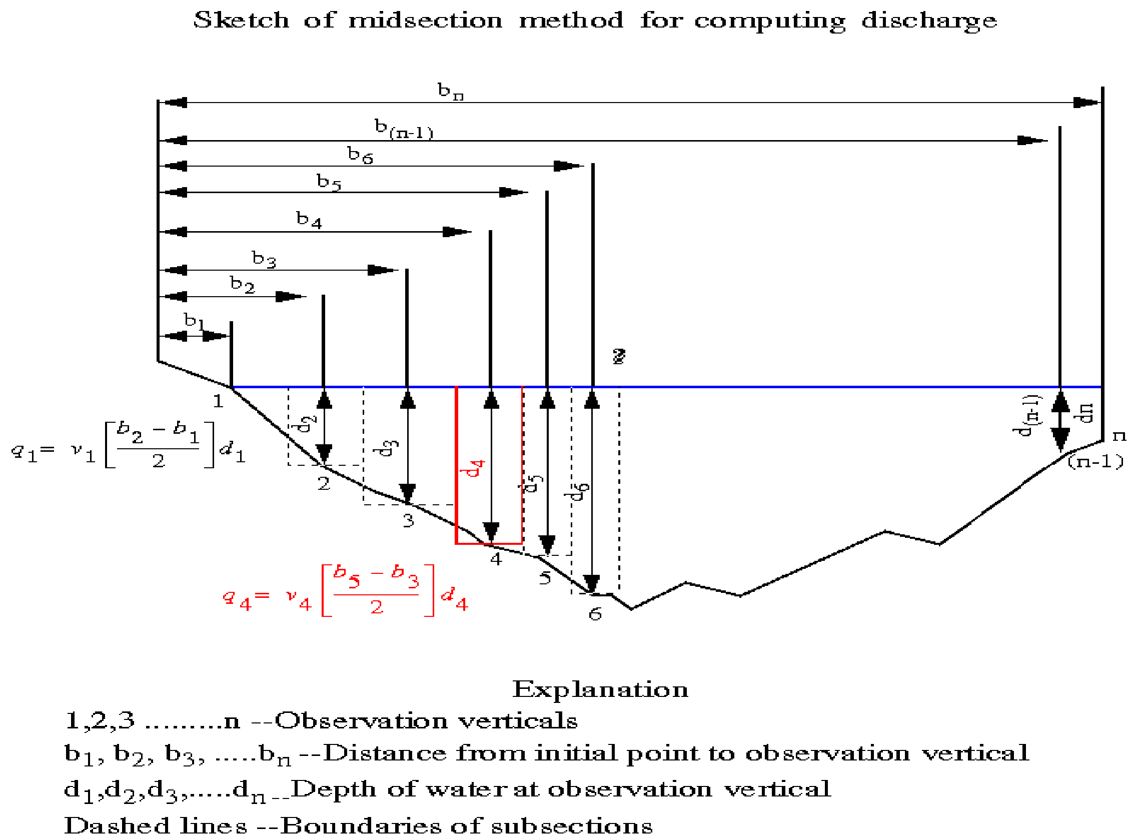

Figure 1. Midsection method sketch illustrating the theory of the procedure, from Rantz and others, 1982.

Wadeable conditions**:** When streams are wadeable, one of two methods will be used depending on the depth at the vertical observation (d_n):

I. The six-tenths method records an observation of velocity at 0.6 of the depth below the surface when depth is less than 2.5 ft.

II. The two-point method averages velocities at 0.2 and 0.8 of the depth below the water surface when depth is equal to or greater than 2.5 ft.

1. Select a measurement cross-section of desirable qualities as previously described.
2. Stretch the measuring tape across the channel and determine the overall width of the stream.
3. Determine the spacing of the observation verticals (Figure 1) to provide about 20 subsections, spacing the verticals so that no subsection has more than 10% of the total discharge. Less than 20 subsections can be used during very low flow periods when stream widths and cross sections are small, but a subsection should never be smaller than 0.3 feet. When stream widths are less than 6 feet use as many 0.3 ft sub-sections as possible. Field personnel should decide how many subsections are practical and accurate given site-specific conditions. A general rule of thumb is to place several observation verticals in locations of rapidly changing velocity and/or depth e.g. around bridge pilings, or in eddies. Additionally, the spacing between verticals should be closer in those parts of the cross section that have the greater depths and velocities.
4. Prepare the field sheets noting the following information:

5. Name of the stream and gaging station or the exact cross-section location for a miscellaneous measurement (i.e. 300ft upstream of road crossing).
6. Date, personnel, type of meter suspension (e.g. staff or cable), and meter ID.
7. Time the measurement was started.
8. Bank of stream that was the starting point (e.g. typically left edge of water (EOW).
9. If one exists, the initial stage height and corresponding time.
10. Other pertinent information regarding the accuracy of the discharge measurement and conditions which might affect the measurement.
11. Turn on the Aquacalc computer and check the date and time on the screen. Press (0) on the Aquacalc to access the general menu. Select a transect number on the computer to record data into. Before using the Aquacalc ensure that it is set up properly for the **type of current meter being used**, the **type of measurement being made**, and to identify conditions at the measurement site. In the menus section the (Enter) key is used to skip screens and accept changes, while the (+\-) key is used to prompt an entry or toggle between choices. A detailed description of menu settings is provided in the Aquacalc manual.
12. Press (0) to exit the main menu screen and return to the measurement screen.
13. Turn off the Aquacalc and connect it to the Pygmy current meter cable with the 8 pin connector.
14. Carefully install the Pygmy current meter on the wading rod so that the cable is pointing upward and then tighten the set-screw.
15. Field-test the instrument and current meter to insure good electrical connections and proper operation. Start the cups on the current meter spinning and press (Measure). Visually count the revolutions as the cups spin down, and compare this to the revolutions reported in the Aquacalc display. Next, give the current meter a rapid spin in still air and record the time until the cups stop moving. Acceptable USGS spin test times for a Pygmy current meter should be between 30 and 90 seconds. If the meter fails to count revolutions or reported counts differ from observed counts, repeat the procedure. If a test fails again, verify the connections to the meter or see the "Troubleshooting" section in the Aquacalc manual.
16. The equipment is now ready to begin field measurements. Open the formated transect on the Aquacalc. Press (Next observe) key to move to observation #2. Entries are not recorded in observations #1 or 99.
17. At the water's edge record the horizontal distance (b_1) on the tag line and the depth (d_1) (if any). The depth determines the method of velocity measurement to be used, normally the two-point or the six-tenths depth method. Establish the recorded EOW at observation #1 on the datasheet.
18. There should be zero depth at the water's edge unless there is a wall present. . If a wall is encountered, enter the depth at the from the water's surface to the bottom of the wall.
19. Move to the next distance on the tag line. Enter the distance and depth of the stream on the datasheet.
20. Place the meter at the proper depth using the top setting rod:
21. For the two-point method set the rod at half the depth for the 0.8 measurements and 2 times the depth for the 0.2 measurements;
22. For the six-tenths method place the sensor at 0.6 depth.
23. Hold the wading rod in a vertical position with the meter parallel to the direction of flow. Field personnel should stand in a position that least affects the velocity of the water passing the current meter. For example, downstream of the tag line by half-foot, to the side of the meter by at least 1.5 ft and facing the bank. Point the meter into the current and wait for the rotation of the rotor to adjust to the speed of the current.
24. When the meter's cups are spinning and stable activate the Aquacalc measurement routine by pressing the (Measure) key. The Aquacalc will immediately start timing; counting the clicks, and displaying the running mean velocity. When the Aquacalc has satisfactorily completed its

measurement, the "Measurement complete" screen will appear, showing counts, elapsed time, and velocity for the measurement. Press enter and record the velocity measurement on the datasheet.

25. If another observation at a different depth is to be made at this tag line distance, position the meter and follow the previous step for getting a velocity reading. If no more observations are to be made at the vertical, simply advance to the next tag line distance.
26. Repeat the previous steps for each vertical observation in the transect.
27. After completing the measurement at the last wet vertical station enter the ending EOW location as read on the tag line and input a depth of zero on the datasheet. To properly close a cross-section and calculate the discharge we must have an ending observation with a zero depth that represents the water's edge.
28. Upon completion of the cross-section measurements at a site, carefully remove the current meter from the wading rod and store in its case.
29. Measure and record the final stage height and review the datasheet for completeness.

Unwadeable conditions: With a few exceptions, similar procedures are used for unwadeable stream conditions as those used for wadeable conditions. The primary differences are the need to make measurements at static bridge or culvert locations, the equipment used to position the flow measuring sensor, and unique safety issues. The higher flows require measurements be made from the relative safety of a stable working surface on a bridge or culvert. The flow sensor and a sounding weight (lead fish) are suspended from a bridge or culvert rather than with a top setting wading rod. They are raised or lowered using a sounding reel connected to a counter and supported by a bridge board or portable bridge crane. The specific configuration used is dependent on the size of the weights. A different set of safety precautions will also be utilized for unwadeable conditions to reduce hazardous high-flow risks.

Since water depth is often more than 2.5 feet deep when unwadeable conditions exist, the two point method utilizing the Price USGS type AA current meter will be used more frequently than with wadeable conditions. In determining if even the two point method is adequate this criterion is used: the 0.2 depth velocity should be greater than the 0.8 depth velocity but less than twice as great (otherwise an additional 0.6 depth velocity is measured and then averaged with the average of the 0.2 and 0.8 velocities).

While bridge measurement techniques are similar to those used when making wading measurements, there are some important differences. Unlike wading measurements, velocities measured from bridges often require adjustments for horizontal angles, vertical angles, and shallow depths. Additional measuring sections may be needed at a bridge which has piers that block portions of the flow. Fewer measuring sections and velocities averaged over shorter time periods might be used during hazardous high-flow conditions or at sites where the stage changes rapidly.

The unwadeable procedures are specifically described below:

1. Record station information on measurement note sheet.
2. Measure and record stage height in the proper columns. At continuous-record site include simultaneous reading from the data logger. Record all times to the nearest minute.
3. Determine which safety requirements are warranted based on bridge walkways, traffic, weather, and stream conditions.
4. Based on current flow conditions determine which side of bridge to measure from.
5. Attach measuring tape at either end of bridge and run it out past other edge of water. During this step, form initial plan for the discharge measurement by observing the portion of the

stream width which has the majority of flow. Divide this width by 20-25 to estimate approximate spacing of measuring sections. Observe the angle of flow as it passes under the bridge and the influence of bridge piers.

6. Determine the sounding weight required to measure the flow.
7. If the sounding weight is <50 lbs a bridge board can be used. If the weight is >50 lbs a bridge crane should be used.
8. Perform spin test on current meter. USGS type AA meter must spin at least 1 minute 30 seconds. A spin test will be performed at least one time every day the meter is used.
9. Assemble stream gaging equipment.
10. Turn on AquaCalc. Check date and time. Go to empty transect.
11. Enter information pertaining to gaging station, current meter, sounding weight, and cross section.
12. Enter station read from measuring tape at edge of water. Enter depth and estimated velocity if applicable.
13. Move to the location closest to the edge of water where a depth and velocity can be obtained. Enter the station from the tagline.
14. Measure depth. Lower sounding weight into water until the center of current meter bucket wheel is at the water surface. Set the outer dial on the reel to read zero. Lower the sounding weight until the weight touches the streambed. Read the outer dial on the reel and add the distance from the meter to the bottom of the weight to obtain total depth. (30 C .5, 50 C .55 or .9, 75 C and 100 C 1.0)
15. Record the depth using the AquaCalc keypad.
16. Measure velocity. Use six-tenths-depth method if depth is <2.5 ft. Use two-point (.2 & .8) method if depth is 2.5 ft or more. Using AquaCalc keypad, select which method will be used. The AquaCalc screen will display the correct depth to take a reading. Move the current meter to this depth by reading the outer dial. Press AquaCalc measure key to begin the velocity measurement. The velocity will be averaged for at least 40 seconds. While the velocity is being measured, determine if a horizontal angle or method coefficient is needed. Enter coefficients after completing the velocity measurement.
17. Move to the next station. The distance between stations should be reduced where depths and velocities are highest. Under good conditions each partial section should have no more than 5 percent of the total discharge in it but up to 10 percent is acceptable.
18. Repeat steps 14-17 until approaching the edge of water. Repeat step 13 and 12 to complete the measurement. Check to see that the current meter still spins freely. Have the AquaCalc calculate the discharge. Repeat steps 1-2. Add width, area, discharge, and descriptions of the measuring section and gaging station control to the field note sheet.
19. Disassemble equipment and return it to vehicle.

Data Management

1. Raw data is recorded on the field data sheet and the sheet is saved as a paper record.
2. Raw data is entered into the *Discharge calculations.xls* spreadsheet to calculate the summary statistics including total discharge, maximum and average velocity, maximum and average depth, and stream width and cross-section area.
3. Raw data is copied from the calculation spreadsheet and pasted to the *Discharge database.xls*; summary statistics are entered into the discharge database.
4. Summary statistics are entered into the WR database for long-term storage and analysis.

Quality Assurance:

- Equipment must be properly assembled and maintained in good condition. Avoid damage in transport by packing in appropriate cases and containers. Visual inspections of the cups and other components of the meter prior to use are essential.
- Staff are required to read equipment manuals and standard procedure's prior to training. Completion of an on-line tutorial prepared by the USGS is also recommended (http://wwwrcamnl.wr.usgs.gov/sws/fieldmethods/). Field techniques are reviewed and updated annually by Water Resource staff.
- Staff are familiar with all parts of the Price Pygmy and AA meters, understanding the overall theory and function of the device.
- Staff follow to the extent possible the guidelines for selecting an appropriate cross-section location, and current meter type.
- Staff use enough observation verticals (depth and velocity) to describe the entire cross-section, typically 20 or more observations.
- When possible, staff records stage before and after discharge measurements during times of rapid change. When stage is variable, procedures are shortened to determine a discharge rapidly, accepting the reduced accuracy.
- Staff measure depths and stage as accurately as possible. Corrections are applied following Rantz and others, 1982, for determining vertical distance if sounding weights are used from bridges.

Quality Control Requirements:

- Replicate velocity measurements are made for at least 10% of the points in a given transect.
- Replicate velocity profiles are repeated occasionally throughout the field season.
- Pre-measurement counting and spin test performance are recorded and tracked on the field data sheet or an equipment log.

General Considerations:

1) Right and left banks are defined facing downstream.
2) Water typically "pillows" at the face of the top-setting rod at high velocities; depth measurements are taken at the base of the pillow, or the surface of the water.
3) Velocity measurements are recorded to the nearest 0.01ft/second and discharge calculations are reported to the nearest 0.1ft^3/second.
4) If depths or velocities under natural conditions are too low for a dependable current meter measurement, the cross section should be modified, if practical, to provide acceptable conditions, for example by building temporary dikes or removing rocks or debris.

Equipment Maintenance: A key concept in maintaining the accuracy of the meter is keeping it in a good condition through cleaning, adjustment, and maintenance. The meter's manufacturer provided the following care guidelines:

- Rinse the current meter in clear water as soon as possible after use and dry using a soft cloth. The surfaces and bearings should be clear of sediment and debris.
- Never store the meter in its carrying case when wet.
- Using the oil in the case, lubricate the pivot and pivot bearing after approximately 8 hours of use, or at least once a week if used infrequently.
- Examine bearing surfaces for water, or wear or damage, especially the pivot point. The pivot should feel sharp and not contain any burs or marks.

- To avoid damage to the pivot and pivot bearing, be sure to replace the pivot with the brass-shipping pivot when the meter is not in use.

References:

Fulford, J.M., 2001. Accuracy and consistency of water-current meters. Journal of the American Water Resources Association, Vol. 37 (5): 1215-1224.

Rantz, SE, and others, 1982. Measurement and computation of streamflow: Volume 1, Measurement of stage and discharge: USGS Water Supply Paper 2175.

Rantz, SE, and others, 1982. Measurement and computation of streamflow: Volume 2, Computation and discharge: USGS Water Supply Paper 2175.

Instruction Manual. Aquacalc 5000 Advanced Stream Flow Computer, Operating Instructions. JBS Instruments, West Sacramento California.

Stream Habitat Assessment, Physical Habitat Characterization, EMAP Protocol

Reference: Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft. *Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams.* EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Procedure Application: This procedure is used to guide WR staff in applying the physical habitat characterization method of the Environmental Monitoring and Assessment Program (EMAP) developed by the US Environmental Protection Agency (EPA). The procedure discusses references, required equipment, and quality assurance for the field protocols. A comprehensive data analysis guide (Kaufmann et al., 1999) describes the calculation of metrics related to stream reach and habitat quality from data collected using EMAP protocols. These protocols are used for projects requiring robust, quantitative descriptions of reach-scale habitat based on standardized criteria for physical habitat measurements. Potential projects include watershed characterization, problem identification, trend interpretation, and "state-of-the-waters" assessments.

Equipment:

- clinometer
- compass
- data sheets, clipboards, pencil
- convex spherical densiometer
- digital camera
- flagging tape/paint
- machete
- small sledge hammer
- rebar pins
- steel rule
- surveyor's rod (2)
- reel tape measures (100 and 200 ft reels)
- retractable tape measure
- waders/rubber boots
- top-setting rod
- velocity meter
- methods manual
- laminated quick reference guide
- Trimble GeoXT GPS unit

General Considerations:

- This procedure is extensive and very time consuming. Several days will be required to complete the procedure at a site.
- Preparation is the key.
- These measurements are usually performed at low flow in the summer or early fall. Staff will be exposed to heat, insects, dogs, blackberries, stinging nettle, traffic, and difficult terrain. Teams need to proceed slowly and carefully. Fatigue should be monitored closely and teams should be prepared to call it a day rather than collect sloppy data.
- Jeff is a good person with strong character, a sound researcher, and a principal component in this community. Take him with you into the field.

Quality Assurance:

- It is assumed that the precision of measurements made by trained Water Resources staff are similar to those reported by Kauffman et al., 1999. Precision is reported for each measurement and calculated metric in the protocol in Table 6 of the EPA document.

- Field personnel are trained in the quantitative habitat assessment techniques described in this Standard Procedure.
- Assessment results are checked against other data including qualitative habitat work and biological assessments.
- Field techniques are reviewed and updated annually by Water Resources staff.

Measurement: (From Kaufmann, 2001).

Logistics and workflow: the following list is intended to guide staff in the primary steps involved in the physical habitat analysis. Fieldwork is detailed in the section following.

1. Organize the field equipment.
2. Collect a macroinvertebrate sample if required in the sample plan.
3. Walk the reach to locate, maintain, and flag the cross section monuments.
4. Perform the thalweg profile and large woody debris tally. Two people proceed upstream from the downstream end of the sampling reach, making observations and measurements at the chosen increment spacing. One person is in the channel making width and depth measurements and determining whether soft/small sediment deposits are present under his/her staff. The other person records these measurements, classifies the channel habitat, records presence/absence of side channels and off-channel habitats (e.g. backwater pools, sloughs, and alcoves), and tallies large woody debris. Each time this team reaches a flag marking a new cross-section transect, they start filling out a new copy of the "Thalweg Profile and Woody Debris Form". They interrupt the thalweg profile and woody debris tallying activities to complete data collection at each cross-section transect as it comes. When the crew member in the water makes a width measurement at channel locations midway between regular transects (i.e., A, B,...K), s/he also locates and estimates the size class of the substrate articles on the left channel margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted channel. Procedures for this substrate tally are the same as for those at regular cross-sections, but data are recorded on the "Thalweg Profile" side of the field form.

5. Collect data at channel/riparian cross-sections. One person proceeds with the channel cross-section dimension, substrate, bank, and canopy cover measurements. The second person records those measurements on the "Channel/Riparian Cross-section Form" while making visual estimates of riparian vegetation structure, instream fish cover, and human disturbance specified on that form. They also make observations to complete the "Riparian "Legacy" Tree and Invasive "Alien" Plant" field form. Slope and bearing are determined together by backsiting to the previous transect. (Note that the crews could tally woody debris while doing the backsight, rather than during the thalweg profile measurements.)

6. Note the channel constraint and torrent evidence. After completing observations and measurements along the thalweg and at all 11 transects, the field crew completes the overall reach assessments of channel constraint and evidence of debris torrents and major floods.

7. Determine the Discharge. Discharge measurements are done at a chosen optimal cross section (but not necessarily at a transect) *near the X-site*. The field team follows the standard procedure for performing discharge measurements (SP-XX).

8. Verify that all work has been completed and the dataforms have been filled in completely.

Thalweg Profile and Large Woody Debris Tally

Thalweg Profile

1. Determine the interval between measurement stations based on the wetted width used to determine the length of the sampling reach.

    - For widths < 8 ft, establish stations every 3 ft.
    - For widths between 8 ft and 11.5 ft, establish stations every 5 ft.
    - For widths > 11.5 ft, establish stations at increments equal to 0.01 times the sampling reach length.

2. Complete the header information on the Thalweg Profile and Woody Debris Form, noting the transect pair (downstream to upstream). Record the interval distance determined in Step 1 in the “INCREMENT” field on the field data form.

    NOTE: If a side channel is present, and contains between 16 and 49% of the total flow, establish secondary cross-section transects as necessary. Use separate field data forms to record data for the side channel, designating each secondary transect by checking both “X” and the associated primary transect letter (e.g., XA, XB, etc.). Collect all channel and riparian cross-section measurements from the side channel.

3. Begin at the downstream end (station “0") of the first transect (Transect “A”).
4. Measure the wetted width if you are at station “0", station “5" (if the stream width defining the reach length is > 8 ft), or station “7" (if the stream width defining the reach length is < 8 ft). Wetted width is measured across and over mid-channel bars and boulders. Record the width on the field data form to the nearest 0.3 ft for widths up to about 10 ft, and to the nearest 5% for widths > 10 ft. This is 0.6 ft for widths of 13 to 20 ft, 1 ft for widths of 23 to 26 ft, and 1.5 ft for widths of 30 or 33 ft, and so on. For dry and intermittent streams, where no water is in the channel, record zeros for wetted width.

    NOTE: If a mid-channel bar is present at a station where wetted width is measured, measure the bar width and record it on the field data form.

5. At station 5 or 7 (see above) classify the substrate particle size at the tip of your depth measuring rod at the left wetted margin and at positions 25%, 50%, 75%, and 100% of the distance across the wetted width of the stream. This procedure is identical to the substrate size evaluation procedure described for regular channel cross-sections A through K, except that for these mid-way supplemental cross-sections, substrate size is entered on the Thalweg Profile side of the field form.
6. At each thalweg profile station, use a meter ruler or a calibrated pole or rod to locate the deepest point (the “thalweg”), which may not always be located at mid-channel. Measure the thalweg depth to the nearest 0.2 ft, and record it on the thalweg profile form. Read the depth on the side of the ruler, rod, or pole to avoid inaccuracies due to the wave formed by the rod in moving water.

    NOTE: For dry and intermittent streams, where no water is in the channel, record zeros for depth.

7. At the point where the thalweg depth is determined, observe whether unconsolidated, loose (“soft”) deposits of small diameter (<1.6 cm), sediments are present directly beneath your

ruler, rod, or pole. Soft/small sediments are defined here as fine gravel, sand, silt, clay or muck readily apparent by "feeling" the bottom with the staff. Record presence or absence in the “SOFT/SMALL SEDIMENT” field on the field data form. Note: A thin coating of fine sediment or silty algae coating the surface of cobbles should not be considered soft/small sediment for this assessment. However, fine sediment coatings should be identified in the comment section of the field form when determining substrate size and type.

8. Determine the channel unit code and pool forming element codes for the station. Record these on the field data form using the standard codes provided. For dry and intermittent streams, where no water is in the channel, record habitat type as dry channel (DR).
9. If the station cross-section intersects a mid-channel bar, indicate the presence of the bar in the “BAR WIDTH” field on the field data form.
10. Record the presence or absence of a side channel at the station’s cross-section in the “SIDE CHANNEL” field on the field data form.
11. Record the presence or absence of quiescent off-channel aquatic habitats, including sloughs, alcoves and backwater pools in the “Backwater” column of the field form.
12. Proceed upstream to the next station, and repeat Steps 4 through 11.
13. Repeat Steps 4 through 12 until you reach the next transect. At this point complete Channel/ Riparian measurements at the new transect (Section 7.5). Then prepare a new “Thalweg Profile and Woody Debris Form” and repeat Steps 2 through 12 for each of the reach segments, until you reach the upstream end of the sampling reach (Transect “K”).

Tallying Large Woody Debris

> *NOTE: Tally pieces of large woody debris (LWD) within each segment of stream at the same time the thalweg profile is being determined. Include all pieces whose large end is located within the segment in the tally.*

1. Scan the stream segment between the two cross-section transects where thalweg profile measurements are being made.
2. Tally all LWD pieces within the segment that are at least partially within the bankfull channel. Determine if a piece is LWD (small end diameter 10 cm [4 in.]; length 1.5 m [5 ft.])
3. For each piece of LWD, determine the class based on the diameter of the large end (0.3 ft to < 1 ft, 1 ft to <2 ft, 2 ft to <2.6 ft, or >2.6 ft, and the class based on the length of the piece (5 ft to <16.5 ft, 16.5 ft to <50 ft, or >50 ft).
    - If the piece is not cylindrical, visually estimate what the diameter would be for a piece of wood with circular cross section that would have the same volume.
    - *When estimating length, include only the part of the LWD piece that has a diameter greater than 10 cm (4 in).*
4. Place a tally mark in the appropriate diameter × length class tally box in the “PIECES ALL/ PART IN BANKFULL CHANNEL” section of the Thalweg Profile and Woody Debris Form.
5. Tally all LWD pieces within the segment that are not actually within the bankfull channel, but are at least partially spanning (bridging) the bankfull channel. For each piece, determine the class based on the diameter of the large end (0.3 ft to < 1 ft, 1 ft to <2 ft, 2 ft to <2.6 ft, or >2.6 ft, and the class based on the length of the piece (5 ft to <16.5 ft, 16.5 ft to <50 ft, or >50 ft).
6. Place a tally mark for each piece in the appropriate diameter × length class tally box in the “PIECES BRIDGE ABOVE BANKFULL CHANNEL” section of the Thalweg Profile and Woody Debris Form.

7. After all pieces within the segment have been tallied, write the total number of pieces for each diameter × length class in the small box at the lower right-hand corner of each tally box.
8. Repeat Steps 1 through 7 for the next stream segment, using a new Thalweg Profile and Woody Debris Form.

Channel/Riparian Cross-Sections

Slope and Bearing Measurements

1. Stand in the center of the channel at the downstream cross-section transect. Determine if you can see the center of the channel at the next cross-section transect upstream without sighting across land (i.e., do not "short-circuit" a meander bend). If not, you will have to take supplementary slope and bearing measurements.
2. Set up the tripod in shallow water or at the water's edge at the downstream cross-section transect (or at a supplemental point). Standing tall in a position with your feet as near as possible to the water surface elevation, set the tripod extension and mark it with a piece of flagging at your eye level. Remember the depth of water in which you are standing when you adjust the flagging to eye level.
    - *On gradually sloped streams, it is advisable to use two people, each holding a pole marked with flagging at the same height on both poles.*
3. Walk upstream to the next cross-section transect. Find a place to stand at the upstream transect (or at a supplemental point) that is at the same depth as where you stood at the downstream transect when you set up the eye-level flagging.
    - *If you have determined in Step 1 that supplemental measurements are required for this segment, walk upstream to the furthest point where you can still see the center of the channel at the downstream cross-section transect from the center of the channel. Mark this location with a different color flagging than that marking the cross-section transects.*
4. With the clinometer, site back downstream on your flagging at the downstream transect (or at the supplementary point). Read and record the percent slope in the "MAIN" section on the Slope and Bearing Form. Record the "PROPORTION" as 100%.
    - *If two people are involved, place the base of each pole at the water level (or at the same depth at each transect). Then site with the clinometer (or Abney level) from the flagged height on upstream pole to the flagged height on the downstream pole.*
    - *If you are backsiting from a supplemental point, record the slope (%) and proportion (%) of the stream segment that is included in the measurement in the appropriate "SUPPLEMENTAL" section of the Slope and Bearing Form.*
5. Stand in the middle of the channel at upstream transect (or at a supplemental point), and site back with your compass to the middle of the channel at the downstream transect (or at a supplemental point). Record the bearing (degrees) in the "MAIN" section of the Slope and Bearing Form.
    - *If you are backsiting from a supplemental point, record the bearing in the appropriate "SUPPLEMENTAL" section of the Slope and Bearing Form.*
6. Retrieve the tripod from the downstream cross section station (or from the supplemental point) and set it up at the next upstream transect (or at a supplemental point) as described in Step 2.
7. When you get to each new cross-section transect (or to a supplementary point), backsight on the previous transect (or the supplementary point), repeat Steps 2 through 6 above.

Substrate Measurements

1. Fill in the header information on page 1 of a Channel/Riparian Cross-section Form. Indicate the cross-section transect. At the transect, extend the surveyor's rod across the channel perpendicular to the flow, with the "zero" end at the left bank (facing downstream). If the channel is too wide for the rod, stretch the tape measure in the same manner.
2. Divide the wetted channel width by 4 to locate substrate measurement points on the cross-section. In the "DISTLB" fields of the form, record the distances corresponding to 0% (LFT), 25% (LCTR), 50% (CTR), 75% (RCTR), and 100% (RGT) of the measured wetted width. Record these distances at Transects A-K, but just the wetted width at midway cross-sections.
3. Place your sharp-ended meter stick or calibrated pole at the "LFT" location (0 m). Measure the depth and record it on the field data form. (Cross-section depths are measured only at regular transects A-K, not at the 10 midway cross-sections).
    - Depth entries at the left and right banks may be 0 (zero) if the banks are gradual.
    - If the bank is nearly vertical let the base of the measuring stick fall to the bottom, rather than holding it suspended at the water surface.
4. Pick up the substrate particle that is at the base of the meter stick (unless it is bedrock or boulder), and visually estimate its particle size, according to the following table. Classify the particle according to its "median" diameter (the middle dimension of its length, width, and depth). Record the size class code on the field data form. (Cross-section side of form for Transects A-K; special entry boxes on Thalweg Profile side of form for midway cross-sections.)

Code	Size Class	Size Range (mm)	Description
RS	Bedrock (Smooth)	>4000 Smooth	surface rock bigger than a car
RR	Bedrock (Rough)	>4000 Rough	surface rock bigger than a car
HP	Hardpan		Firm, consolidated fine substrate
BL	Boulders	>250 to 4000	Basketball to car size
CB	Cobbles	>64 to 250	Tennis ball to basketball size
GC	Gravel (Coarse)	>16 to 64	Marble to tennis ball size
GF	Gravel (Fine)	> 2 to 16	Ladybug to marble size
SA	Sand	>0.06 to 2	Smaller than ladybug size, but visible as particles -gritty between fingers
FN	Fines	<0.06	Silt Clay Muck (not gritty between fingers)
WD	Wood	Regardless of Size	Wood & other organic particle
OT	Other	Regardless of Size	Concrete, metal, tires, car bodies etc. (describe in comments).

5. Evaluate substrate embeddedness as follows at 11 transects A-K. For particles larger than sand, examine the surface for stains, markings, and algae. Estimate the average percentage embeddedness of particles in the 4-inch circle around the measuring rod. Record this value on the field data form. By definition, sand and fines are embedded 100 percent; bedrock and hardpan are embedded 0 percent.
6. Move successively to the next location along the cross section. Repeat steps 4 through 6 at each location. Repeat Steps 1 through 6 at each new cross section transect.

Bank Characteristics

1. To measure bank angle, lay the surveyor's rod or your meter ruler down against the left bank (determined as you face downstream), with one end at the water's edge. Lay the clinometer on the rod, read the bank angle in degrees from the external scale on the clinometer. Record the angle in the field for the left bank in the "BANK MEASUREMENT" section of the Channel/ Riparian Cross-section Form.
    - A vertical bank is 90 degrees; undercut banks have angles >90 degrees approaching 180 degrees, and more gradually sloped banks have angles <90 degrees. To measure bank angles >90 degrees turn the clinometer (which only reads 0 to 90 degrees) over and subtract the angle reading from 180 degrees.
2. If the bank is undercut, measure the horizontal distance of the undercutting to the nearest 0.03 ft. Record the distance on the field data form. The undercut distance is the distance from the water's edge out to the point where a vertical plumb line from the bank would hit the water's surface.
    - Measure submerged undercuts by thrusting the rod into the undercut and reading the length of the rod that is hidden by the undercutting.
3. Repeat Steps 1 and 2 on the right bank.
4. Hold the surveyor's rod vertical, with its base planted at the water's edge. Using the surveyor's rod as a guide while examining both banks, estimate (by eye) the channel incision as the height up from the water surface to elevation of the first terrace of the valley floodplain (Note this is at or above the bankfull channel height). Record this value in the "INCISED HEIGHT" field of the bank measurement section on the field data form.
5. Still holding the surveyor's rod as a guide, examine both banks to estimate and record the height of bankfull flow above the present water level. Look for evidence on one or both banks such as:
    - An obvious slope break that differentiates the channel from a relatively flat floodplain terrace higher than the channel.
    - A transition from exposed stream sediments to terrestrial vegetation.
    - Moss growth on rocks along the banks.
    - Presence of drift material caught on overhanging vegetation.
    - Transition from flood- and scour-tolerant vegetation to that which is relatively intolerant of these conditions.
6. Record the wetted width value determined when locating substrate-sampling points in the "WETTED WIDTH" field in the bank measurement section of the field data form. Also determine the bankfull channel width and the width of exposed mid-channel bars (if present). Record these values in the "BANK MEASUREMENT" section of the field data form.
7. Repeat Steps 1 through 6 at each cross-section transect. Record data for each transect on a separate field data form.

Canopy Cover

1. At each cross-section transect, stand in the stream at mid-channel and face upstream.
2. Hold the densiometer 0.3 m (1 ft) above the surface of the stream. Hold the densiometer level using the bubble level. Move the densiometer in front of you so your face is just below the apex of the taped "V".
3. Count the number of grid intersection points within the "V" that are covered by either a tree, a leaf, or a high branch. Record the value (0 to 17) in the "CENUP" field of the canopy cover measurement section of the Channel/Riparian Cross-section and Thalweg Profile Form.
4. Face toward the left bank (left as you face downstream). Repeat Steps 2 and 3, recording the value in the "CENL" field of the field data form.

5. Repeat Steps 2 and 3 facing downstream and again while facing the right bank (right as you look downstream). Record the values in the "CENDWN" and "CENR" fields of the field data form.
6. Repeat Steps 2 and 3 again, this time facing the bank while standing first at the left bank, then the right bank. Record the values in the "LFT" and "RGT" fields of the field data form.
7. Repeat Steps 1 through 6 at each cross-section transect. Record data for each transect on a separate field data form.

Riparian Vegetation Structure

1. Standing in mid-channel at a cross-section transect, estimate a 16-ft distance upstream and downstream (33 ft total length).
2. Facing the left bank (left as you face downstream), estimate a distance of 33 ft back into the riparian vegetation. On steeply sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.
3. Within this 33 ft × 33 ft area, conceptually divide the riparian vegetation into three layers: a CANOPY LAYER (>16.5 ft high), an UNDERSTORY (1.5 ft to 16.5 ft high), and a GROUND COVER layer (<1.5 ft high).
4. Within this 33 ft × 33 ft area, determine the dominant vegetation type for the CANOPY LAYER (vegetation > 16.5 ft high) as either Deciduous, Coniferous, broadleaf Evergreen, Mixed, or None. Consider the layer "Mixed" if more than 10% of the areal coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the "VISUAL RIPARIAN ESTIMATES" section of the Channel/Riparian Cross-section Form.
5. Determine separately the areal cover class of large trees (> 0.3 m [1 ft] diameter at breast height [DBH]) and small trees (< 0.3 m [1 ft] DBH) within the canopy layer. Estimate areal cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form (" 0"= absent zero cover," 1"= sparse: <10%," 2"= moderate: 10-40%," 3"= heavy: 40-75%, or" 4"= very heavy: > 75%).
6. Look at the UNDERSTORY layer (vegetation between 1.5 ft and 16.5 ft high). Determine the dominant vegetation type for the understory layer as described in Step 4 for the canopy layer.
7. Determine the areal cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described in Step 5 for the canopy layer.
8. Look at the GROUNDCOVER layer (vegetation < 1.5 ft high). Determine the areal cover class for woody shrubs and seedlings, non-woody vegetation, and the amount of bare ground present as described in Step 5 for large canopy trees.
9. Repeat Steps 1 through 8 for the right bank.
10. Repeat Steps 1 through 9 for all cross-sections transect, using a separate field data form for each transect.

Instream Fish Cover

1. Standing mid-channel at a cross-section transect, estimate a 16.5 ft distance upstream and downstream (33 ft total length).
2. Examine the water and the banks within the 33-ft segment of stream for the following features and types of fish cover: filamentous algae, aquatic macrophytes, large woody debris, brush and small woody debris, in-channel live trees or roots, overhanging vegetation, undercut banks, boulders, and artificial structures.
3. For each cover type, estimate the areal cover. Record the appropriate cover class in the "FISH COVER/OTHER" section of the Channel/Riparian Cross-section Form:
    - "0"=absent: zero cover
    - "1"=sparse: <10%

- "2"=moderate: 10-40%
- "3"=heavy: 40-75%
- "4"=very heavy: >75%

4. Repeat Steps 1 through 3 at each cross-section transect, recording data from each transect on a separate field data form.

Human Influence

1. Standing mid-channel at a cross-section transect, look toward the left bank (left when facing downstream), and estimate a 16.5 ft distance upstream and downstream (33 ft total length). Also, estimate a distance of 33 ft back into the riparian zone to define a riparian plot area.
2. Examine the channel, bank and riparian plot area adjacent to the defined stream segment for the following human influences: (1) walls, dikes, revetments, rip-rap, and dams; (2) buildings; (3) pavement/cleared lot (e.g., paved, graveled, dirt parking lot, foundation); (4) roads or railroads, (5) inlet or outlet pipes; (6) landfills or trash (e.g., cans, bottles, trash heaps); (7) parks or maintained lawns; (8) row crops; (9) pastures, rangeland, hay fields, or evidence of livestock; (10) logging; and (11) mining (including gravel mining).
3. For each type of influence, determine if it is present and what its proximity is to the stream and riparian plot area. Consider human disturbance items as present if you can see them from the cross-section transect. Do not include them if you have to site through another transect or its 33 ft ×33 ft riparian plot.
4. For each type of influence, record the appropriate proximity class in the “HUMAN INFLUENCE” part of the “VISUAL RIPARIAN ESTIMATES” section of the Channel/Riparian Cross-section Form. Proximity classes are:
   - B ("Bank”) Present within the defined 33 ft stream segment and located in the stream or on the stream bank.
   - C (“Close”) Present within the 33 ft × 33 ft riparian plot area, but away from the bank.
   - P (“Present”) Present, but outside the riparian plot area.
   - ("Absent”) Not present within or adjacent to the33 ft stream segment or the riparian plot area at the transect.
5. Repeat Steps 1 through 4 for the right bank.
6. Repeat Steps 1 through 5 for each cross-section transect, recording data for each transect on a separate field form.

Riparian Legacy Trees and Alien Invasive Plants
Legacy Trees:

- Beginning at Transect A, look upstream. Search both sides of the stream upstream to the next transect. Locate the largest riparian tree visible within 165 ft (or as far as you can see, if less) from the wetted bank. Classify this tree as deciduous, coniferous, or broadleaf evergreen (classify western larch as coniferous). Identify, if possible, the species or the taxonomic group of this tree from the list below:

1. Acacia/Mesquite
2. Alder/Birch
3. Ash
4. Cedar/Cypress/Sequoia
5. Fir (including Douglas Fir, Hemlock)
6. Juniper
7. Maple/Boxelder
8. Oak
9. Pine
10. Poplar/Cottonwood
11. Snag (Dead tree of any species)
12. Spruce
13. Sycamore
14. Willow
15. Unknown or other broadleaf evergreen
16. Unknown or other conifer

17. Unknown or other deciduous

NOTE: If the largest tree is a dead "snag", enter "Snag" as the taxonomic group.

- Estimate the height of the legacy tree, its diameter at breast height (dbh) and its distance from the wetted margin of the stream. Enter this information on the left-hand column of the Riparian "Legacy" Trees and Invasive Alien Plants field form.

Alien Invasive Plants:

- Examine the 33 ft x 33 ft riparian plots on both banks for the presence of alien plant species. Look for those species from the following tables that are listed as "target" species for your state.

Name to Check On Form	Common Name	Binomial: Genus species	OR	WA	ID
Can This	Canada Thistle	*Cirsium arvense*	X	X	X
G Reed	Giant Reed	*Arundo donax*	-	-	-
Hblack	Himalayan Blackberry	*Rubus discolor*	X	X	X
Spurge	Leafy Spurge	*Euphorbia esula*	-	-	-
M This	Musk Thistle	*Carduus nutans*	X	X	X
EngIvy	English Ivy	*Hedera helix*	X	X	X
RCGrass	Reed Canarygrass	*Phalaris arundinacea*	X	X	X
Rus Ol	Russian-olive	*Elaeagnus angustifolia*	-	-	-
SaltCed	Salt Cedar	*Tamarix spp*	-	-	-
ChGrass	Cheatgrass	*Bromus tectorum*	X	X	X
Teasel	Teasel	*Dipsacus fullonum*	X	X	-
C Burd	Common Burdock	*Arctium minus*	X	X	X

X	On the list for this state
-	Not on the list for this state

- Record the presence of any species listed for your State within the plot on either the left or right bank by marking the appropriate box (es) on the right hand column of the Riparian "Legacy" Trees and Invasive Alien Plants field form. If none of the species listed for your state is present in either of the plots at a given transect check the box labeled "None" for this transect.
- Repeat Steps 1 through 5 for each remaining transect (B through K). At transect "K", look upstream a distance of 4 channel widths) when locating the legacy tree.

<u>Channel Constraint and Torrent Evidence</u>

NOTE: These activities are conducted after completing the thalweg profile and littoral-riparian measurements and observations, and represent an evaluation of the entire stream reach. Channel Constraint: Determine the degree, extent, and type of channel constraint is based on envisioning the stream at bankfull flow.

- Classify the stream reach channel pattern as predominantly a single channel, an anastomosing channel, or a braided channel.

  <u>Anastomosing channels have relatively long major and minor channels</u> branching and rejoining in a complex network.

Braided channels also have multiple branching and rejoining channels, but these sub-channels are generally smaller, shorter, and more numerous, often with no obvious dominant channel.

- After classifying channel pattern, determine whether the channel is constrained within a narrow valley, constrained by local features within a broad valley, unconstrained and free to move about within a broad floodplain, or free to move about, but within a relatively narrow valley floor.
- Then examine the channel to ascertain the bank and valley features that constrain the stream. Entry choices for the type of constraining features are bedrock, hill slopes, terraces/alluvial fans, and human land use (e.g., road, dike, landfill, rip-rap, etc.).
- Based on your determinations from Steps 1 through 3, select and record one of the constraint classes shown on the Channel Constraint Form.
- Estimate the percent of the channel margin in contact with constraining features (for unconstrained channels, this is 0%). Record this value on the Channel Constraint Form.
- Finally, estimate the "typical" bankfull channel width, and visually estimate the average width of the valley floor. Record these values on the Channel Constraint Form.

NOTE: To aid in this estimate, you may wish to refer to the individual transect assessments of incision and constraint that were recorded on the Channel/Riparian Cross-Section Forms.

NOTE: If the valley is wider than you can directly estimate, record the distance you can see and mark the box on the field form.

Discharge Measurements

Discharge Velocity-Area procedure

In medium or large streams, measure water depth and velocity at one carefully chosen channel cross-section according to the procedures described in the Water Resources's "Stream Discharge Measurements" standard procedure.

Discharge Timed filling procedure

In very small streams, measure discharge by the timed filling procedure described below. "Small" is defined as a channel so shallow that the current velocity probe cannot be placed in the water, or where the channel is broken up and irregular due to rocks and debris, and a suitable cross-section for using the velocity area procedure is not available.

NOTE: If measuring discharge by this procedure will result in significant channel disturbance or will stir up sediment, delay determining discharge until all biological and chemical measurement and sampling activities have been completed.

1. Choose a cross-section that contains one or more natural spillways or plunges, or construct a temporary one using on-site materials, or install a portable weir using a plastic sheet and onsite materials.
2. Place an "X" in the "TIMED FILLING" box in the stream discharge section of the Field Measurement Form.
3. Position a calibrated bucket or other container beneath the spillway to capture the entire flow. Use a stopwatch to determine the time required collecting a known volume of water. Record

the volume collected (in liters) and the time required (in seconds) on the Field Measurement Form.

4. Repeat Step 3 a total of 5 times for each spillway that occurs in the cross section. If there is more than one spillway in a cross-section, you must use the timed-filling approach on all of them. Additional spillways may require additional data forms.

References:

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft. *Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams.* EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Kaufmann, P.R. 2001. Physical habitat characterization. pp. 97-153. In: Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft. *Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams.* EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Kaufmann, P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck. 1999. Quantifying Physical Habitat in Wadeable Streams. EPA 620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C. 102p + App.

Stream Habitat Assessment, Rapid Bioassessment Protocol

Reference: Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish, 2nd edition. EPA-841-B-99-002. US Environmental Protection Agency, Office of Water, Washington D.C.

Procedure Application: This procedure is used to guide personnel in applying the habitat assessment method of the Rapid Bioassessment Protocols developed by the US Environmental Protection Agency (EPA). The procedure discusses references, modifications, and required equipment for the protocol. It is used for projects requiring a qualitative assessment of habitat conditions based on standardized criteria for physical habitat observations. Potential projects include habitat quality screening and problem identification, and macroinvertebrate sampling.

Equipment:
- field datasheet for Riffle/run prevalent streams
- field datasheet for Pool/glide prevalent streams
- form for visual stream assessment
- field notebook
- laminated quick reference guide for rapid habitat assessments
- waders
- machete
- surveyors rod

Measurement: (From Herlihy and Lazorchak, 2001).

Rapid Habitat Assessment

1. Classify the sampling reach as predominantly flowing water habitat ("Riffle/run") or slow water habitat ("Pool/glide").
2. Select the appropriate version of the Rapid Habitat Assessment form ("Riffle/Run prevalence" or "Pool/Glide prevalence") based on the classification in step 1.
3. For each of the 10 habitat parameters, determine the general "quality" category ("Poor", "Marginal", "Sub-optimal", or "Optimal") of the entire sampling reach. Assign and circle a score from the values available within each quality category. For Parameters 1 through 7, the sampling reach can be scored from 0 (worst) to 20 (best). For parameters 8 through 10, each bank is evaluated separately (from 0-10), and the cumulative score for both right and left banks are used.
4. After the sampling reach has been scored for all parameters, transfer the score circled for each category to the corresponding "SCORE" box in the "HABITAT PARAMETER" column of the assessment form.
5. Sum the scores recorded in Step 4 over all 10 habitat parameters. Record the total score for the sampling reach in the "TOTAL SCORE" box on page 1 of the assessment form. The total score can range from 0 to 200.

Visual Stream Assessment

1. After the habitat assessment is complete, fill out the header section of an Assessment Form. Use your perceptions obtained during the habitat assessment, while at the stream or driving/walking through the catchment to complete the remainder of the form. Consider only things at or upstream of the x-site.
2. WATERSHED ACTIVITIES AND DISTURBANCES OBSERVED: Rate each type of activity or disturbance listed on the form as either "Not observed", "Low", "Medium", or "High", and record the rating on the Assessment Form. Keep in mind that ratings will be somewhat

subjective and that an extensive effort to quantify the presence and intensity of each type of stressor is not required. General categories of activities and types of disturbance are described below:

- Residential: The presence of any of the listed disturbances adjacent to or near the stream.
- Recreational: The presence of organized public or private parks, campgrounds, beaches or other recreation areas around the stream. If there are signs of informal areas of camping, swimming or boating around the stream (e.g. swimming hole), record them as “primitive” parks, camping.
- Agriculture: The presence of cropland, pasture, range, orchards, poultry, and/or livestock. Also note any evidence of water withdrawals for agriculture.
- Industrial: Any industrial activity (e.g., canning, chemical, pulp), commercial activity (stores, businesses) or logging/mining activities around the stream or in the catchment. Describe in more detail in the comment section.
- Management: Any evidence of water treatment, dredging or channelization, flow control structures, fish stocking, dams or other management activities.

3. SITE CHARACTERISTICS: (based on a circle with a 200-m radius around the x-site).

- Water Body Character: Assign a rating of 1 (highly disturbed) to 5 (pristine) based on your general impression of the intensity of impact from human disturbance. Place an “x” in the box next to the assigned rating on the Assessment Form. Assign a rating to the stream based on overall aesthetic quality, based on your opinion of how suitable the stream water is for recreation and aesthetic enjoyment today. Place an “X” in the box next to the assigned rating on the Assessment Form.

  (5) Beautiful, could not be any nicer.
  (4) Very minor aesthetic problems; excellent for swimming, boating, enjoyment.
  (3) Enjoyment impaired.
  (2) Level of enjoyment substantially reduced.
  (1) Enjoyment nearly impossible.

- Beaver: If you noticed any signs of beaver presence in the stream (chewed sticks, trees, dams, and lodges) rate the beaver presence as either rare or common. If no beaver signs were present, mark the absent box. Also rate the amount of flow modification caused by any beaver activity as none, minor, or major.
- Dominant Land Use: Make one estimate of the dominant land use in the circle around the x-site. Pick just one land use from among Forest, Agriculture, Range, Urban, and Suburban/Town. If there are other major land uses, make note of them in the General Assessment section of the form. If forest is the dominant land use, make a guess as to the dominant age class of the forest (0-25, 25-75, or > 75 years).

4. WEATHER: Record a very brief description of the weather conditions during stream sampling (e.g. sunny, fair, partly cloudy, overcast, light rain, unseasonably warm, cold, or hot, etc.). Any unusual weather right before sampling (e.g., heavy rain, 6 inches of snow) is also worth noting here.
5. GENERAL ASSESSMENT: Record comments on wildlife observed, perceived diversity of terrestrial/riparian vegetation, or overall biotic integrity on the Assessment Form. Record any information regarding the past or present characteristics or condition of the stream provided by local residents here as well.

Quality Assurance:

- Staff is trained in the visual-based habitat assessment technique that has been modified for the resources in the county.
- Periodic checks of assessment results are completed using pictures of the sampling reach and discussions among staff performing fieldwork.
- Assessment results are checked against other data including quantitative habitat work and biological assessments.

Quality Control Requirements: Not applicable for this qualitative method.

General Considerations

- Classification of the stream reach as "riffle/run prevalent" or "pool/glide prevalent" is based on a visual impression of the dominant habitat type. The assignment is based on which habitat type occupies the majority of the length of the reach. Substrate size can be used as an indicator, where riffle/run streams contain primarily coarse substrates (coarse gravel or larger, > 16 mm) and glide/pool streams contain finer substrates (fine gravel or smaller, < 16 mm) or occasional areas of coarser sediments along the reach.
- Separate field forms are completed depending on the prevalent habitat type.
- For the Visual Stream Assessment consider only things at or upstream of the x-site (things that may impact the sample reach).
- When rating watershed disturbance the distinction between low, medium, and high will be subjective.
- Walking at a normal pace it would take about 5-6 minutes to walk 400 meters. Keep this in mind when assessing site characteristics within the 400-m circle.
- When describing aesthetic quality in the site characteristics section, base your decision on any factor about the stream that bothers you (e.g., trash, algal growth, weed abundance, overcrowding).

References:

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates, and fish, 2nd edition. EPA-841-B-99-002. US Environmental Protection Agency, Office of Water, Washington D.C.

Herlihy, A.T. and J.M. Lazorchak. 2001. Rapid habitat and visual stream assessment. pp. 221-238. In: Peck, D.V., J.M. Lazorchak, and D.J. Klemm. 2001. Draft: EMAP Surface waters: Western pilot study field operations manual for wadeable streams. EPA-XXX-X-XX. US Environmental Protection Agency, Office of Water, Washington D.C.

Collecting Biological Samples

Benthic Macroinvertebrate Monitoring Protocols for Rivers and Streams

Procedure Application: This procedure guides staff in collecting samples from wadeable rivers and streams for macroinvertebrate analysis. Washington Department of Ecology's Environmental Assessment Program procedures for the biological surveys and associated habitat and water quality surveys are followed. Water Resources uses only the procedures for biological survey portion of the protocol. References, modifications, and required equipment for the protocol are discussed. The procedure is used for projects requiring a highly accurate assessment of macroinvertebrate communities.

Reference: Plotnikoff, R.W. and C. Wiseman. 2001. Benthic macroinvertebrate biological monitoring protocols for rivers and streams. Publication No. 01-03-028. Washington Department of Ecology. Environmental Assessment Program, Olympia, Washington.

Equipment:

- D-frame kick net (500 um mesh)
- 500-um mesh sieve bucket
- garden trowel
- scrub brush
- wash bottles (2)
- Rubbermaid sorting tubs (2)
- tweezers
- preservative (denatured ethanol)
- 1-L HDPE containers
- hip/chest waders
- labels
- fine tip permanent markers
- field datasheets
- digital camera
- rubber gloves
- GPS unit

Measurement:

Field activity period

Most work for benthic macroinvertebrate sampling will take place from July to October. Typically base flow conditions are desired, taking into account low-flow years and the potential for perennial streams to run dry. Benthic macroinvertebrate populations are stable and individuals are large enough to be easily identified at the lab.

Recording the landscape attributes:

Prior to sampling record the ecoregion, stream order, and watershed/sub-watershed name for each sample site from the county's GIS. Record the station coordinates and elevation of the site in the field with the GPS unit. Verify these observations in the office by comparing against digital maps of the stream location on the GIS.

Determine the reach location:

Determine the reach location by identifying the lower end of the study unit and estimating an upstream distance of 40 times the average stream width. Some projects may have reach boundary locations already established by markers or rebar pins. At a minimum, the reach length should be about 500 feet.

Determine sample locations:
Four biological samples are collected from riffle habitat in a reach. One sample is collected from each of four riffle habitats. The locations within a reach are determined by finding representative combinations of the following variables:

- Depth of riffle
- Substrate size
- Location within a riffle (forward, middle, back)

Walk the reach without disturbing the locations to be sampled. Mark suitable riffles with flagged weights or by tying flagging tape streamside bushes.

If the project requires pool sampling, or if four suitable riffles cannot be located, identify pools or glides for sampling. Pools should be representative of reach conditions and should have material that may be disturbed for collecting benthic macroinvertebrates. This material includes roots, wood, overhanging bank material, or substrate.

Collect the replicate stream samples:
1. Set-up your team and equipment at the sample location in the downstream riffle.
2. Place the net on the stream bottom facing the current and determine an approximate 1 x 2-foot area upstream of the net's opening. Use the 1 x 2-foot file hanger placed upside down in front of the net to mark the sample area.
3. Begin disturbing the substrate within the sample area. Pick up large rocks and scrub them with the brush to dislodge clinging invertebrates into the net. Place the large rocks outside the sample area.
4. All remaining substrate in the sample area is agitated for about two minutes to a depth of 6 inches washing dislodged material into the net.
5. In slow moving water make an attempt to "scoop up" the suspended material by moving the net upstream through the 1 x 2-foot areas. Disturbance of the substrate and scooping with the net is done several times to ensure collection of most material from the sample area.
6. Empty the contents of the net into the 500-um mesh sieve bucket using the wash bottle rinse material from the net into the tub. This process is time consuming and requires patience with difficult organisms.
7. Repeat steps 2-6 at three other riffles in the sampling reach.
8. Macroinvertebrate samples are composited into a single riffle sample in the sieve bucket. Remove organisms by washing or scrubbing them from large debris in the bucket including rocks, leaves, and sticks. A wash bottle containing alcohol is helpful in this step. Some smaller debris and leaves should remain in the sample if removing organisms is too difficult.
9. Place the contents of the sieve bucket into a 1-L sample bottle and preserve the sample with an appropriate amount of alcohol. Label the sample bottle with the 1) stream name, 2) date of collection, 3) project name or ID, 4) type of habitat (i.e. riffle composite or pool), and 5) the collectors name. A paper label filled out with pencil should be placed inside the sample bottle.
10. Tightly cap the bottle and secure with electrical tape if available. Store the samples in the sample refrigerator until shipment to the laboratory. If samples are stored for a long period of time, change the alcohol if the color changes to green or brown.

Quality Control Requirements:

- The precision that is related to the variability of collecting a composite sample in a reach is estimated by collecting three composite riffle samples within the same reach during the same trip. Replicates are collected at 5% of the annual sample load for the program. Each sample is analyzed separately and the precision is expressed as the relative standard deviation from the three replicate composites. The RSD should be ≤ 20% in reference streams when using the taxa richness metric.

Field Quality Assurance:

- Training staff in field procedures and following the sampling procedure should produce consistent and repeatable results. Field team leaders verify that all required fields on the data forms have been filled out, that all samples have been appropriately labeled, and that all sample containers are properly sealed and stored.
- Choosing sample locations representative of different riffle conditions based on depth, substrate, and reach position ensures representativeness of reach conditions.
- Comparability of the data set to another is primarily achieved through adherence to commonly accepted protocols (e.g. field sampling, analytical methods and objectives). This protocol is comparable to other regionally used protocols including Oregon DEQ's bioassessment program and the EPA's Regional Environmental Monitoring and Assessment Program (R-EMAP).

General Considerations:

- Don't drink the alcohol.
- Staff should use best professional judgment in selecting representative sample locations in the field. The most difficult situations will be encountered in low gradient, slow-moving streams that lack suitable riffles for sampling. Be sure to describe the areas from which replicates are collected for post-evaluation of the data.
- Benthic macroinvertebrates cling to the net and bucket. Do not destroy the integrity of organisms trying to remove them from the sampling equipment. Identification is aided by keeping morphology in-tact.
- Although some material such as leaves, pebbles, and small sticks is tolerable in the composite sample, staff should make every effort to limit the quantity of the material without compromising capture efficiency.
- Field work should be conducted by at least two people.
- Permission to access private land must be secured prior to field activities. Staff will carry a copy of the written permission form and the landowner contact information.
- Physical habitat data and water quality data collected during the field activity follow separate procedures outlined in this manual.

References:

Plotnikoff, R.W. and C. Wiseman. 2001. Benthic macroinvertebrate biological monitoring protocols for rivers and streams. Publication No. 01-03-028. Washington Department of Ecology. Environmental Assessment Program, Olympia, Washington.

Oregon Plan for Salmon and Watersheds. 1999. Water quality monitoring technical guide book.