Washington State Department of Ecology

Environmental Assessment Program

Standard Operating Procedures for continuous temperature monitoring of fresh water rivers and streams conducted in a Total Maximum Daily Load (TMDL) project for stream temperature.

Version 2.3

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Signatures on File

Please note that the Washington State Department of Ecology's Standard Operating Procedures (SOPs) are adapted from published methods, or developed by in-house technical and administrative experts. Their primary purpose is for internal Ecology use, although sampling and administrative SOPs may have a wider utility. Our SOPs do not supplant official published methods. Distribution of these SOPs does not constitute an endorsement of a particular procedure or method.

Any reference to specific equipment, manufacturer, or supplies is for descriptive purposes only and does not constitute an endorsement of a particular product or service by the author or by the Department of Ecology.

Although Ecology follows the SOP in most cases, we occasionally encounter situations where an alternative methodology, procedure, or process is warranted.

SOP Revision History

Revision Date	Rev number	Summary of changes	Sections	Reviser(s)
6/27/06	1.1	First draft incorporating existing SOP		D. Anderson
9/18/06	1.2	Began second draft substantial revision	1,2,3,4,5,6,8	D. Bilhimer
11/27/06	1.3	Minor addition to safety info	7,9,10	D. Bilhimer
3/13/07	2.0	Incorporated Kirk Sinclair and Anita Stohr's comments	1,6, and Appendices mostly	D. Bilhimer
11/29/07	2.1	Changes to address new temperature standards concerning non-summer sampling, to focus on sampling protocol only (not office procedures), and to include standard sample field forms. Incorporate Darrel Anderson's comments. Incorporate S. Brock, J Kardouni, T Swanson, P Pickett comments.	1,3,4,6,7,8,10, Appendix A	A. Stohr
1/15/08	2.2	Incorporate B. Kammin comments. Use standard SOP formatting. Minor update to section 7.2. Complete citations	7.2, 6.13.12, 8.1.1, 10	A. Stohr
9/9/09	2.3	Updated references/discussion to reflect the completion of SOP for in-water piezometers (EAP061)	Various	A. Stohr

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1.0 Purpose and Scope

1.1 The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each waterbody on the 303(d) list. A TMDL identifies how much pollution must be reduced or eliminated to achieve clean water. Ecology works with the local community to develop a strategy to control pollution sources and a monitoring plan to assess the effectiveness of water quality improvement activities.

1.2. The purpose of a Temperature TMDL is to characterize thermal conditions and to establish load and waste load allocations for heat sources that will enable a stream or river to meet surface water temperature criteria and protect beneficial uses. Parameters that influence surface water temperature and are affected by human activity include:

1.2.1 Riparian Vegetation (shade)
1.2.2 Channel morphology (shape, hydraulic geometry)
1.2.3 Hydrology
1.2.4 Temperature (point source and non-point source)

1.3 This protocol covers the monitoring of stream temperature, streambed groundwater temperature, soil, weather stations, as well as air temperature and relative humidity.

1.4 Many temperature TMDL projects continuously monitor temperature within a streambed piezometer. For completeness, this protocol will mention temperature monitoring within a piezometer, however, the detailed instructions for installing and measuring in-water piezometers are contained in SOP EAP061..

2.0 Applicability

2.1 The Standard Operating Procedures (SOP) will be followed during the installation and maintenance of continuous monitoring stations for a temperature TMDL project. The protocols contained in this document reflect in part those outlined in the TFW (Timber, Fish, and Wildlife) Monitoring Program's Method Manual for the Stream Temperature Survey, June 1999.

3.0 Definitions

3.1 7DAD*Max*, 7-day average of the daily maximum temperature
3.2 7DAD*Min*, 7-day average of the daily minimum temperature

3.3 D*Ave*, Daily average temperature
3.4 DEM, Digital Elevation Model
3.6 *DMax*, Daily maximum temperature
3.7 *DMin*, Daily minimum temperature
3.8 *EAP*, Ecology's Environmental Assessment Program
3.9 *EIM*, Ecology's Environmental Information Management database for environmental data
3.10 *EPA*, US Environmental Protection Agency
3.11 *GIS*, Geographical Information System
3.12 *GPS*, Global Position System
3.13 *In-water-Piezometer*, a shallow small diameter well installed within the active stream channel to measure head relationships between a stream or river and near-surface groundwater. These measurements allow one to determine if groundwater is moving up through the streambed into surface water (a gaining stream) or if surface water is moving down through the streambed into groundwater (a losing stream).
3.14 *NAD83 HARN*, Map Projection Coordinate System North American Datum 1983 High Accuracy Resolution Network Washington
3.15 *NIST*, National Institute of Standards and Technology
3.16 *PST*, Pacific Standard Time
3.17 *PDT*, Pacific Daylight savings Time
3.18 *QAPP*, Quality Assurance Project Plan
3.19 *RH*, Relative Humidity
3.20 *Thalweg*, a line defining the lowest points along the length of a stream channel. The thalweg is almost always the line of fastest flow in any river.
3.21 *TI*, an abbreviation for temperature instrument, thermistor, or temperature data logger.

4.0 Personnel Qualifications/Responsibilities

4.1 No certification or license is required to conduct surface water monitoring. However, groundwater monitoring activities involving piezometers have licensing requirements.

4.1.1 Physical installation or decommissioning of instream mini-piezometers must be directly overseen by either a licensed well driller, a well driller apprentice under the supervision of a licensed well driller, or a licensed professional engineer. See SOP EAP061 for detailed instructions on piezometer permit requirements.

4.1.2 Persons involved in the field data collection and analysis must have experience and training in the natural, environmental or physical sciences

4.2 Typical Job Class performing SOP : Natural Resource Scientist 1/2/3, Environmental Engineer 1/2/3/4/5, Environmental Specialist 1/2/3/4/5, Hydrogeologist 1/2/3/4/5, Administrative Intern 1/2/3

Note: The specialized equipment listed does not represent an endorsement by Ecology. Other equipment may be used if it meets the project QA/QC requirements for accuracy and reliability.

5.0 Equipment, Reagents, and Supplies

5.1 All equipment installation events should include a toolbox with all the hand tools you will need including (but not limited to): pipe wrenches, pliers (multiple types), wire cutters, screwdrivers, hammer, nails, rebar pounder, 8lb steel mallet, socket wrench and socket set, and duct tape. Additional items for anchoring thermistors include: fencing wire, rebar, plastic zip ties, steel enforced plastic cable ties, eyebolts, JB weld putty, stainless steel braided cable, or whatever your unique installation situation requires.

5.2 Design specifications for specialized field equipment that is made "in house" can be found in Appendix B.

5.3 Specialized field equipment for each type of field survey:

5.3.1 *Continuously recording thermistors*
5.3.1.1 Onset Hobo© Water Temp Pro v2 (#U22-001), -20°C to +50°C, +/- 0.2C
5.3.1.2 Onset StowAway Tidbits©, -5°C to +37°C model, +/- 0.2C
5.3.1.3 Onset StowAway Tidbits©, -20°C to +50°C model, +/- 0.4C
5.3.1.4 Note: the newer version of the Tidbit, Onset Tidbit v2 (#UTBI-001), has a range (-20°C to 30°C) that is too narrow for most temperature TMDL work
5.3.1.5 Hobo Pro RH/Temp Data Logger
5.3.1.6 Solar radiation shields for Hobo Pro RH/Temp
5.3.1.7 PC communication cables or optic shuttles specific for each instrument type

5.3.2 *Continuously recording thermistors*
5.3.2.1 Onset Hobo Water Level Logger© (#U-20-001-01)
5.3.2.2 Optic USB Base station
5.3.2.3 Special pipe coupler (see Appendix B) for hanging cable inside the piezometer
5.3.2.4 Flexible tubing to fit the MIP fitting on the coupler

5.3.3 *Instantaneous Conductivity and Temperature Measurement*
5.3.3.1 YSI 30 Conductivity, Salinity, and Temperature meter
5.3.3.2 Alcohol thermometer with accuracy of 0.1ºC (optional)
5.3.3.3 Conductivity standard

5.3.4 *Onset Hobo Weather Station© –Instruments*
5.3.4.1 Temperature/Relative Humidity Smart Sensor
5.3.4.2 Wind speed/direction Smart Sensor
5.3.4.3 Barometric Pressure Smart Sensor
5.3.4.4 Rain Gage Smart Sensor
5.3.4.5 Silicon Pyranometer Smart Sensor
5.3.4.6 2m Tripod Kit (includes guy wires, grounding kit, stakes, and tripod level)
5.3.4.7 Pyranometer mounting bracket

5.3.4.8 Wind sensor cross-arm bracket
5.3.4.9 Hobo Weather Station Data Logger
5.3.4.10 Solar radiation shield

5.4 *General Field Equipment includes:*

5.4.1 Field forms on Rite-in-the-rain paper
5.4.2 PC laptop with Boxcar 4.3 or Hoboware software. The newer Hoboware is needed to communicate with v2 data loggers.
5.4.3 Digital Camera (with batteries and memory card)
5.4.4 Metal Clipboard
5.4.5 Waterproof wrist watch or other suitable field clock
5.4.6 Hip belt for small tools
5.4.7 3 mechanical or wooden pencils
5.4.8 3 pens
5.4.9 Black Sharpie pen
5.4.10 Refill lead
5.4.11 Highlighter
5.4.12 Maps
5.4.13 Waterproof field notebook
5.4.14 Extra AA batteries
5.4.15 Hand sanitizer
5.4.16 Rebar pounder tool
5.4.17 5 or 8 lb mallet
5.4.18 Bucket
5.4.19 Cable ties (strong, steel enforced) or Zip ties
5.4.20 Flexible wire (8 or 10 gage smooth fencing wire and thin wire)
5.4.21 1/8th inch diameter braided stainless steel cable and crimps
5.4.22 Crimping tool
5.4.23 Large wire cutters
5.4.24 Small wire cutters
5.4.25 Shade devices for air & water thermistors (PVC pipe works well, see Appendix B)
5.4.26 10-penny stainless nails
5.4.27 Hammer
5.4.28 Steel engineer's tape (with 1/10th and 1/100th foot marks)
5.4.29 GPS unit
5.4.30 Duct tape

5.5 *Piezometer removal equipment includes:*

5.5.1 2 Hi-Lift Jacks
5.5.2 2, 3, or 4 ft lengths of case hardened steel chain link
5.5.3 2 (plus extra) ½inch x 3inch case hardened steel bolts
5.5.4 Gloves
5.5.5 Pipe wrenches

6.0 Summary of Procedure

6.1 *Site Selection Criteria for instream thermistors*

6.1.1 Thermistors should be installed only in well mixed zones such as the stream thalweg. The outside of river bends or the low-flow channels in a riffle are good choices.

6.1.2 Use a reference thermometer to check the stream temperature at several points around the potential thermistor site to make sure the site is truly representative of the well-mixed stream temperature at that location.

6.1.3 Thermistors should be installed at a location and depth where they won't become exposed if stream stage drops. It is often best to install the temperature data loggers (thermistors) at about one-half of the water depth. Periodically check thermistors throughout the study and move them farther down into the water column if necessary as flows drop to base-flow levels during the summer and fall.

6.1.4 If at all possible, do not install thermistors where they must lie directly on the stream bottom since they may be thermally affected by groundwater inflow. However, for shallow depths (<0.5 ft), you may have no choice but to install the thermistor on or near the stream bed. Likewise, avoid installing thermistors in back water eddies or pools that may stratify during low flow conditions.

6.1.5 As the stream stage drops during the summer it may be necessary to move the instream thermistor to keep it in the active stream channel.

6.1.6 Vandalism can be a problem in popular swimming holes and fishing access points, so avoid these locations if possible or find creative ways to camouflage the thermistor.

6.1.7 If necessary, make sure the thermistors are fastened and anchored in the stream sturdy enough to withstand high stream velocities.

6.2 *Site selection criteria for instream mini-piezometers*

6.2.1 Selecting piezometer sites is similar to selecting instream thermistor sites. Select a site with well mixed water that will remain within the active stream channel during summer baseflow conditions. See SOP EAP061 for details.

6.2.2 Where possible, piezometers should be installed within a few feet of the stream bank preferably somewhere near the midpoint of a long well-mixed glide.

6.2.3 Avoid installing piezometers within deep pools which often have backwater eddies and can stratify during baseflow conditions. Do not install piezometers immediately upstream or downstream of steep drops, or near point bars, since these areas often have significant hyporheic exchanges that can complicate our interpretation of regional surface/ground water interactions.

6.3 *Site selection criteria for air thermistors*

6.3.1 The air temperature record has two primary uses:

6.3.1.1 It is used as a measure of air temperature under the riparian canopy adjacent to the stream and is an important input to all temperature models.

6.3.1.2 It is used to compare against the instream temperature record to determine if the stream thermistor was dewatered at any point during its deployment. Keep the instruments paired and in representative places for your monitoring goals.

6.3.2 Always put the air thermistor in a white shade device unless the deployment location does not receive direct solar radiation.

6.3.3 Keep the air thermistor within the same microclimate in which the instream thermistor is located, 1-3 meters into the riparian zone (Schuett-Hames and others, 1999) and about 4-8 feet above the ground (USFS, 2005). Avoid placing the thermistor in areas that are not representative of stream side conditions at your location.

6.3.4 If two stations are located within approximately 0.5 mile of each other and the vegetation and stream side conditions are similar, it is ok to use only one air thermistor to cover both locations.

6.3.5 Relative humidity sensors should be distributed evenly among the number of sensors that you have to deploy and the elevation differences in the watershed or subbasin in which you are working.

6.3.6 Relative humidity sensors should not be deployed such that the sensors will get wet. This will render the sensor useless and if prolonged wetness occurs the instrument will be damaged. Use a solar radiation shield or a rain shield, designs for making your own shields can be found in Appendix B.

6.3.7 Always deploy relative humidity sensors in a solar radiation shield if the area is relatively open with little vegetation and receives direct solar radiation during the day. Relative humidity sensors should be located in the adjacent riparian zone using similar site selection criteria as for the air thermistors.

6.4 *Site selection criteria for soil thermistors*

6.4.1 Soil thermistors are used to measure ground temperature 2-4 ft" below the channel bank surface. Soil temperatures are sometimes used to estimate the temperature of near-stream groundwater. Mean annual air temperature or measurements from piezometers located in gaining stream reaches are other sources of estimates.

6.4.2 Soil thermistors should be distributed so that elevation differences in the watershed are captured.

6.4.3 The hole for the soil thermistor should be located approximately 3 meters into the riparian zone in a location where the ground is shaded. Soil thermistors are generally installed at a depth of 3-4 feet.

6.5 *Site selection criteria for weather stations*

6.5.1 Weather station deployment should help fill in gaps where no other weather data are present. Always check for existing stations in your study area first; look for airports, publicly owned agricultural stations (PAWS), remote automated weather stations (RAWS), and other stations. Use the website for the State Climatologist (http://www.climate.washington.edu/) to locate existing weather stations in your area of interest.

6.5.2 If you do need to deploy and operate a weather station, several considerations must be made.

6.5.2.1 When possible, select a location free of tall trees and buildings to prevent biasing sensor measurements.

6.5.2.2 Provide security against vandalism and theft. Find a landowner who is amenable to you leaving the equipment there and will contact you if anything happens to it.

6.5.2.3 Keep the weather station within a reasonable distance from the stream such that the data still represents near stream conditions.

6.5.2.4 The Hobo Weather Station User's Guide lists other helpful site considerations as well.

6.6 *Instream thermistor deployment options*

6.6.1 It is important to always shade instream and air thermistors to reduce any bias from direct solar radiation.

6.6.1.1 Use a PVC shade device for shade (design is in Appendix B).

6.6.1.2 Rebar (2-3' long by ½" or ¾" diameter) works well as an anchor to attach a stream thermistor. Suitably located piezometers are also a good anchor for in-stream thermistors.

6.6.1.3 Smooth fencing wire (10 or 8 gage whichever is easier for you to work with but is still durable) is the best option for securing thermistors and shade devices to the anchor in stream flows of 50cfs or greater. For stream flows less than 50 cfs, plastic zip ties or steel enforced plastic cable ties may be a viable option to secure the instream thermistor.

6.6.1.4 Stable large woody debris or roots extending into the thalweg of the stream can be used as an anchor for zip tying or wiring a thermistor into an area of swift flow. Exposed large roots that extend into the primary stream flow can often be found in locations where the thalweg is close to one bank.

6.6.1.5 Where it is not possible to get rebar or a piezometer into the streambed due to near-surface bedrock or other consolidated sediments, or where stable large woody debris is not available, use a suitable large rock (~10-15lbs or more) or concrete block as an anchor. Use an epoxy such as JB Weld on a cleaned surface of the rock and a point of attachment such as an L-bracket or eye-bolt from which to attach the stream thermistors. Wire may also be used to secure a thermistor to the rock, but make sure the wire will not slip-off or work free from the rock. This method requires thorough field descriptions to relocate the instrument during monthly field checks.

6.6.2 For large rivers that are deep (accessed by boat) or whose water levels will change widely during deployment, a PVC pipe can be deployed into the stream and the thermistor dropped into the pipe with some stiff wire. The lower end of the pipe is left open and some holes drilled where the thermistor will sit. The upper end can have a bolt put through to hold the deployment wire and a screw down cap installed to discourage casual vandalism. The pipe can be clamped onto a piling or pier or positioned with one end on the stream bottom and anchored to the shore. The depth and length of the pipe will depend on the level where the top will be accessible and the bottom will remain in water during the range of expected flows.

6.6.2.1 An alternative for deep water deployment from the bank is to attach the thermistor to a length of heavy cable. One end is anchored on the bank and the thermistor is then dropped in the water from a boat.

6.6.2.2 Another deployment method is to string thermistors from a buoy. This is useful where no pilings are available or where a string of thermistors is desired for stratified conditions. The main problem with buoy deployment is the likelihood of theft or vandalism. An existing buoy in a monitored area where permission is gained from the owner is best. Otherwise, the likelihood of losing the thermistor is high, especially for long deployments in areas frequented by water-skiers, anglers, and other recreational boaters.

6.6.3 For the cable or buoy deployment, protect the thermistor by suspending it in a small piece of PVC. Take a three-inch piece of pipe, drill holes on opposite sides in the middle, and use a piece of plastic tie to attach the thermistor in the middle. The cable can then also be attached to the holes in the middle.

6.7 *Documentation and General Considerations*

6.7.1 Proper documentation of thermistor and piezometer installation sites and conditions is important for relocating instruments and makes for more efficient use of field time during periodic survey checks and end of season instrument removal. Proper documentation also helps prevent equipment and data loss. A monitoring site can look very different during the spring installation compared to the fall removal if there is any kind of riparian vegetation.

6.7.2 To ensure that the periodic reference measurements can be accurately attributed to the appropriate thermistor record, **ALWAYS** record the **date and time** that each field measurement is made.

6.7.3 Ecology computers that connect to the network should be synchronized to the official US time. The time can be found at: http://www.time.gov/timezone.cgi?Pacific/d/-8/java. Be sure your laptop and wrist watch are synchronized with the official time before heading to the field. All thermistors (air, instream, and groundwater) should be set to record data at 30 minute intervals on the hour and half hour (i.e. 5:00, 5:30, 6:00, 6:30, etc). If you need to replace a lost or malfunctioning thermistor, be sure to set them to record data at 30 minute intervals with a delayed launch for the nearest hour or half hour.

6.7.4 Temperature instruments can be damaged or lost due to vandalism, flooding, animals, or anchors becoming unfastened. Thermistors, weather stations, and instream piezometers should be visited once per month (or more frequently if necessary) to make reference measurements, download station and/or temperature data, and to make sure the data loggers are still present and in working order. Damaged or missing data loggers must be replaced immediately with another calibrated data logger, so bring extra instruments and a laptop computer during these visits.

6.7.5 Always use thermistors that have been properly checked for meeting accuracy requirements as described in section 8.0. Data quality requirements in the QAPP designate the use of properly checked thermistors.

6.8 *Installation of instream thermistors*

6.8.1 Arrive at a station determined by the station network design prescribed in the Quality Assurance Project Plan (QAPP).

6.8.2 Determine the area for the installation attempt based on the site selection criteria in section 6.1. Chose a well-mixed (in regards to temperature) part of the stream. This is usually achieved in the stream thalweg.

6.8.3 Choose a length of rebar appropriate for driving it deep enough into the streambed to stay in place but that also leaves enough rebar in the stream to attach a thermistor at about one-half of the total stream depth. Insert the rebar into the open end of the rebar pounder and use the hand sledge to hammer the rebar into streambed by striking the heavy steel head of the pounder. After you have successfully installed the rebar, leave the pounder on the rebar while you are preparing the thermistor or making other measurements so it will be easy to find again. Additional installation options are outlined in section 6.5.

6.8.4 Write the serial number of the instream thermistor in the appropriate space on the field form. Use a thermistor with an accuracy of 0.2ºC for recording stream temperatures. Attach the flexible wire or cable/zip ties to the thermistor and shade device and attach this unit to the rebar or other anchoring device.

6.8.5 On the field form, fill out the stream name, field crew name, weather, date and time.

6.8.6 Measure the distance from the streambed up to the thermistor and record on the field form; this is the "TI distance from bottom."

6.8.7 Measure the total stream depth at the thermistor; this is the distance from the streambed up to the water surface. Record on the field form as "depth @ TI".

6.8.8 Measure the stream temperature (and also conductivity if groundwater is included in the study) at the location of the thermistor and record on the field form.

6.8.9 Measure the wetted width and bankfull width of the stream and record. The wetted width measurement should be taken at the same transect each time the site is visited. It is preferable to select a permanent stream flow measurement transect and record the wetted width for this transect. An example stream flow form can be found in Appendix A. If stream flow is not being collected during this study, then the wetted width should be taken along a transect that intersects the thermistor.

6.8.10 Take three (or more) digital pictures of the location: 1) a wide angle of the instream thermistor with someone pointing to its location under water; 2) a picture looking upstream from the thermistor; and 3) a picture looking downstream from the thermistor. Record the three image numbers in the appropriate location on the field form. Photographs taken during the installation will be helpful when relocating the instruments later, documenting any changes to the monitoring location during the course of the study, and showing the near stream habitat of the location where the thermistor is deployed.

Figure 1. Instream station documentation photo depicting rebar pounder and field technician pointing at the instream thermistor.

6.8.11 Use the site sketch portion of the instream thermistor installation field form to sketch the installation location of the instrument. Be sure to record important notes such as landmarks or nearby roads, thermistor locations, direction of flow, places to park, paths to the river, and whatever else may be appropriate. Record enough information so that someone other than you could find the thermistor during the next field visit. Driving directions to the site may help as well.

6.8.12 Record the GPS coordinates of the instream thermistor using a hand-held GPS unit using the NAD83 map datum in units of feet.

6.9 *Installation of instream mini-piezometer with thermistors*

6.9.1 Installation should follow the procedures detailed in SOP EAP061.

6.10 *Installation of air thermistors*

6.10.1 Air TIs should be paired with every instream thermistor unless there are two instream stations within a short distance of each other (approximately 0.5 mile) and with similar riparian vegetation types and density.

6.10.2 Select a thermistor with a range of -20ºC to 50ºC (and an accuracy of either +/-0.4ºC or +/-0.2ºC) or a thermistor with a range of-5ºC to 37ºC (and an accuracy of +/-0.2ºC) depending on your thermistor resources and climate, or a relative humidity sensor. If you are working in a watershed where summer air temperatures are likely to exceed 100ºF (37ºC), make sure to use the wider range thermistor.

6.10.3 Use the PC to launch the thermistor or RH sensor to record at 30- minute intervals on the hour and half-hour beginning at the first convenient time.

6.10.4 Record the serial number of the instrument on the field form.

6.10.5 For air thermistors use either wire or zip/cable ties to secure the thermistor inside a white shade device or secure the RH sensor inside a solar radiation shield or rain shield. (Figure 2). Use white PVC shade devices to reduce thermistor heating from thermal absorption due to the color of the material. Dark PVC shade devices are okay to use for water thermistors based on side by side comparisons with different shade device colors.

Figure 2: Air thermistor in a white shade device attached to a tree branch.

6.10.6 Attach the thermistor and shade device or solar radiation shield to the best location (see site selection criteria in section 6.3).

Figure 3: A relative humidity sensor deployed in a solar radiation shield and attached to a tree.

6.10.7 Draw the location of the air thermistor on the site sketch part of the field form for later reference.

6.10.8 Take a wide angle digital picture of the location of the air thermistor (Figure 3).

6.11 *Installation of Soil Thermistors*

6.11.1 Follow the same documentation and instrument calibration instructions as those for air and water thermistors.

6.11.2 Use a post hole digger to dig a hole that is a minimum of 2 feet deep and preferably 3-4 feet deep.

6.11.3 Tie a long wire to the thermistor. Lower the thermistor to the bottom of the hole with the end of the wire extending out onto the ground. Record the depth of the thermistor and location. Fill the hole with soil. Cut the wire so that it extends only 2-3 " above the top of the ground and tie a piece of flagging on it. In some cases it may be advantageous to install two thermistors at different depths.

6.11.4 Camouflage the top so it is not easily assessable to vandals, but can be found by you at the end of the season. Soil thermistors are generally not downloaded in mid-season.

6.12 *Installation of Onset weather stations*

6.12.1 The manual for the Onset Hobo Weather Stations covers the bench testing, construction, and deployment of the various sensors and data logger. Be sure to mark guy lines and stakes with flagging to prevent others from accidentally running into or over them. Figure 4 shows a typical deployment of a weather station.

Figure 4: An Onset Hobo weather station deployed near the East Fork Lewis River.

6.13 *Site visit protocols for a typical station.* If no piezometer is present at your station, ignore that part of the following steps.

6.13.1 Upon arrival at the instream thermistor or piezometer, clear away any accumulated algae or other debris from the station.

6.13.2 Record the well ID tag number and station location on the field data form along with the date/time, names of the field crew, weather conditions, and other header information on the field form (See SOP EAP061 for example piezometer-measurement-field forms).

6.13.3 Remove the well cap and measure the piezometer water level, casing stickup, and other variables per the procedures detailed in SOP EAP061. *Note: You may not be able to measure the surface water level if the piezometer is no longer in the active stream channel. If this is the case, note this on the data form.*

6.13.4 If the well cap is below the water surface, then remove the thermistor string and, add an extension to bring the top of the piezometer pipe out of the water (see SOP EAP061 for additional guidance). You will need to allow time for the water level in the piezometer to equilibrate before taking head measurements. This can take as little as five minutes to multiple hours. This would be a good time to take your stream flow measurement. For reaches with longer recharge equilibration times, it may be advantageous to use a piezometer pipe that will always be above the surface water level. The advantage of the longer pipe should be weighed against the fact that the pipe will absorb heat when above the surface of the water.

6.13.5 Remove the thermistor string from the piezometer, note the removal time on the field form, and set it aside in a safe place for the moment. This may be a good time for one crew member to download the thermistors (including the instream and air thermistors if they were removed for downloading at this time) while the other crew member makes the reference measurements and/or sets up the water quality sampling equipment (see SOP EAP061 for additional guidance).

6.13.6 Record the thermistor serial numbers on the field form. *Note: If it is near the top or bottom of the hour, it is best to leave the thermistors installed in the piezometer and stream until after the instruments record measurements. Now is a good time to take a stream and groundwater temperature/conductivity reading to be synchronized with the thermistors.*

6.13.7 Measure temperature and conductivity of the groundwater at the bottom of the piezometer.

6.13.8 Measure the temperature and conductivity of the stream at the thermistor location and record it on the field form. If you are studying a small and shallow stream (up to 20ft wide) it may also be a good idea to measure the temperature and conductivity of the stream at several locations along a transect at the stream thermistor including the left and right banks and record it in the appropriate space on the piezometer form (see Figure 5 below) or comments section of the temperature form. This will help determine if the instream TI is measuring representative temperatures across the transect and point out any temperature differences across the stream transect.

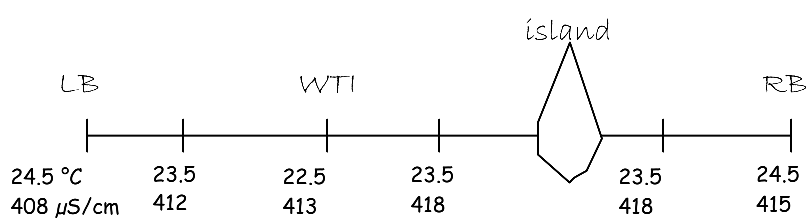


Figure 5: An example thermal transect of a stream at a monitoring station.

6.13.9 **If you are taking groundwater quality samples, start the protocol for sampling groundwater from a piezometer (In development)**.

6.13.10 Reinstall the piezometer thermistor string being sure to push the wire down until you feel it contact the well bottom. Reinstall the instream thermistor. Note the time of redeployment on the field form.

6.13.11 Measure and record the total depth of the water at the location of the instream thermistor. Measure and record the distance from the streambed up to the thermistor.

6.13.12 Measure the flow at the thermistor site using either the Stream Hydrology Unit SOP (Butkus, 2005) or the Water Quality Studies Unit SOP (Sullivan, 2007).

6.13.13 Record the wetted width and bankfull width (installation) along the flow transect or along the transect that intersects the stream thermistor using a flexible fiberglass long tape measure or the laser rangefinder as appropriate.

6.13.14 Check the field form for missing data. If the form is complete, you can recap the well.

6.13.15 If geographic coordinates have not been collected for a particular station yet, then use a handheld GPS unit and record the latitude and longitude of the new monitoring station in decimal degrees (preferable). Record the datum used. The datum should always be NAD83, but check the settings on the GPS unit if you are not sure and adjust it accordingly.

6.13.16 Take a picture of the instream and air instrumentation with a wide angle setting if you do not already have one. Record the file name of all pictures used to document the station and data logger locations. During installations only, sketch the site on the installation form and note important information including walking directions, general location of the tidbit with right and left bank designations, stream flow direction, and easily identifiable local features. It the thermistors need to be moved, sketch the new location if necessary. Also include any special needs information for that station such as notifying the landowner before visiting.

6.14 *Instrument removal*

6.14.1 All rebar or cement blocks should be removed after the data collection period ends. First try using your hands to remove the rebar rocking it back and forth while pulling up. If hands alone were unsuccessful, use pipe wrenches. Grip the rebar with the pipe wrenches and rock it back and forth while pulling upward to loosen the rebar from the streambed sediments. If the rebar is particularly difficult to remove use the procedure for piezometer removal using Hi-Lift jacks. If the aforementioned removal techniques do not work, then carefully step on the rebar to bend it. Bent rebar allows more leverage to wriggle and pivot, thus increasing the chance of removal. Once out of the streambed, bent rebar may be straightened using a sturdy vice that is firmly mounted to a table.

6.14.2 For guidance on removing in-water piezometers see SOP EAP061.

7.0 Records Management

7.1 Field forms for the installation of continuous monitoring stations and for regular site visits can be found in Appendix A. Completed field forms should be kept in a project notebook for entry into the project database and long-term record keeping.

7.2 A Microsoft Access database tool has been developed to aid the organization, analysis, and presentation of both the continuous data and data collected on field forms. This database is being used by Ecology staff but is expected to undergo major revision in 2008. It helps to know a little about how Microsoft Access works, but for ease of use has been designed with a graphical user interface (GUI). Both the database template and manual can be found at Y:\SHARED Files\Temperature TMDLs\Temperature Database\. The database manual covers the entry of continuous temperature data and other field data that is not covered in this document.

8.0 Quality Control and Quality Assurance Section

8.1 The Onset StowAway Tidbits©, Hobo Water Temp Pro©, and Hobo Water Level Logger© instruments must be checked both pre- and post-study to document instrument bias and performance at representative temperatures. A NIST certified reference thermometer must be used for the check. At the completion of the monitoring, the raw data will be assigned a measurement accuracy value based on the pre- and post-study calibration results.

8.1.1 If the average temperature difference for a thermistor, compared against the NIST certified thermometer, is equal to or less than the manufacturer stated accuracy of the instrument (i.e. usually ±0.2°C or ±0.4°C, refer to section 5.2.1 for specific stated accuracy for typically used equipment) the instrument can be used without further qualification. If the average temperature difference for a thermistor is greater than the stated accuracy, then a second check should be performed to ensure there wasn't a problem with the calibration method.

8.1.2 If the second result is still greater than the manufacturer accuracy, and if this is the pre-study check, then *the thermistor should not be used*. If the second result is greater than the manufacturer accuracy, and if this is the post-study check, then *the stated accuracy for the data should be the mean difference of the pre- and post-study calibration values from the NIST thermometer*. If the thermistor is off by a degree or more, a decision should be made whether or not to include the data set from the faulty thermistor.

8.2 Use the following accuracy check lab procedure:

8.2.1 Prepare two insulated coolers for water baths at least 12 hours before the thermistors are actually calibrated and conduct this test in a room where the air temperature can be held constant for the duration of the test. One bath should be at ambient temperature (typically around 16 degrees Celsius) and the other should contain ice and water for a cool bath.

8.2.2 Program the thermistors using a delayed launch so they all begin at the same time and use a 1 minute sample interval to measure temperatures. Keep thermistors at room temperature until the baths are ready. Use a cord or long rubber band to string the thermistors together.

8.2.3 Soak the thermistors in the ambient bath first for 20 minutes before beginning comparison temperature measurements using the NIST calibrated thermometer.

8.2.4 Stir the bath constantly to maintain homogeneous water temperature. After the soak time has lapsed, record the bath temperature using the NIST thermometer every 2 minutes beginning at the time the thermistors record their temperature measurements. Record the time and temperature of the NIST measurement. Keep stirring. An example data logger calibration form can be found in Appendix A. The Access temperature database can also be used to store calibration data.

8.2.5 Record 10 comparison readings in the ambient bath.

8.2.6 Transfer all thermistors to the cool water bath and soak for 20 minutes. Keep the bath stirred to ensure a well-mixed (non-stratified) water bath. You may want to remove most of the ice at the beginning of the soak.

8.2.7 After the soak time has lapsed repeat steps 8.2.4 through 8.2.5.

8.2.8 This procedure should also be used to check the accuracy of the field meter for measuring temperature.

8.3 Variation for field sampling of instream temperatures and potential thermal stratification will be addressed using a field check of stream temperature at all monitoring sites upon deployment, during regular site visits, and during instrument retrieval at the end of the study period. Air temperature data and instream temperature data for each site will be compared to determine if the instream TI was exposed to the air due to stream stage falling below the installed depth of the stream TI.

8.3.1 Field meters for conductivity must be calibrated at the beginning of every day according to the procedure in the manual.

9.0 Safety

9.1. Proper fieldwork safety procedures are outlined in the Environmental Assessment Program Safety Manual for working in rivers and streams, working near traffic and from bridges, and groundwater sampling and water-level measurements (if using instream piezometers). For more unique situations use common sense and follow the general safety procedures in the manual.

10.0 References

10.1 Butkus, Steve. 2005. Quality Assurance Monitoring Plan: Streamflow Gaging Network. Washington State Department of Ecology #05-03-204. updated October 2007.

10.2 Chapra, S.C. and G.J. Pelletier, 2003. QUAL2k: A Modeling Framework for Simulating River and Stream Water Quality: Documentation and Users Manual. Civil and Environmental Engineering Department, Tufts University, Medford, MA.

10.3 Environmental Assessment Program, 2006. Environmental Assessment Program Safety Manual.

10.4 Schuett-Hames, Dave; Pleus, Allen E.; Rashin, Ed; Matthews Jim. 1999. TFW Monitoring Program Method Manual for the Stream Temperature Survey. Washington State Department of Natural Resources and NW Indian Fisheries Commission publication #TFW-AM9-99-005.

10.5 Sinclair, K., and Pitz, C.F., 2009, Standard Operating Procedure for installing, measuring, and decommissioning hand-driven in-water piezometers. Environmental Assessment Program, EAP061, Version 1.0.

10.6 Sullivan, L. 2007. Standard Operating Procedure for Estimating Stream Flows. EAP024.

10.7 USFS, 2005. Weather Station Standards. http://www.fs.fed.us/raws/standards/NFDRS_final_revmay05.pdf

Appendix A

A. This section contains example field forms that should be used for field data collection. Changes to these forms may become necessary in the future so it is okay to modify the form to suit your particular needs. Field forms should be printed on waterproof paper. These forms should be retained for office and archival use. Original electronic versions can be found at Y:\SHARED Files\Temperature TMDLs\Field Protocols\Field Forms. Following are descriptions of each form.

A.1 A regular sized (8½" by 11") field form for installation of air and instream temperature stations.

A.2 A regular sized (8½" by 11") field form for monthly field checks and downloads of water, air, and RH monitors.

A.3 A form to record streamflow measurement data. This form has an optional bankfull depth column that may also be used if taking a bankfull crossection at the same time as the flow measurement.

A.4 Thermistor calibration sample form/spreadsheet

Basin name Temperature Project

A.1

Error Checked by: _____ Date:__/__/__

Station Installation Documentation

Crew: ____________________

Recorder: ______

Station ID: ________ **Stream Name:** ____________________

Date and Time: ____________ GPS: NAD27 or NAD83 ________ **N** decimal ° ________ **W** decimal °

Elevation (ft / m) ________

Water

TI/Prob ID# [ ]

Launch Date ________

Launch Time ________

Air / Rh

TI/Prob ID# [ ]

Launch Date ________

Launch Time ________

TI Installation Date ________

TI Installation Time ________

Site Info — *Circle Units*

Bankfull Width: ________ Meters / Feet

WettedWidth: ________

Water Info

StreamTemperature: ________ degC / degF

Depth @ TI: ________

TI Height (above channel bed): ________

Air Info

Air Temperature: ________

TI Height (above water surface): ________

TI Distance: ________

TI Removal Date ________

TI Removal Time ________

Weather Conditions ________

Digital Images ________

Site Sketch and Map:

A.2

Error Checked by: _____ Date:__/__/__

Data Logger Field Check

Crew: ______________________

Recorder: ________

Station ID: ________ **Stream Name:** ______________________________

Water **TI/Prob ID#**	
Air **TI/Prob ID#**	

STATION CHECK #																
Date																
Time																
SITE	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
Wetted Width																
WATER	degC	degF	degC	degF	degC	degF	degC	degF	degC	degF	degC	degF	degC	degF	degC	degF
Reference Temp.																
Depth @ TI																
TI Dist. From Bottom																
Download (y/n)																
AIR																
Reference Temp.																
TI Height above water																
Download (y/n)																
Relative Humidity																
Weather Conditions																

NOTES								

A.3

Basin name Temperature Project

Error Checked by:____ Date:____/____/____

Flow Measurement Form

Q = ________ *cfs*

Station Name ________________
Date ________________
Time ________________

Stream Name ________________
Surveyors ________________

Air Temp: ________ degC   Water Temp: ________ degC

Weather: ________________________________   *Circle Units*

RB WW: ________   LB WW: ________   *feet meters*

Stage Height: ________

Tape Distance (ft)	Bankfull depth (ft)	Wetted depth (ft)	Flow (f/s)			Comments
			.6x	.8x	.2x	

A.4

Temperature Data Logger Calibration

Crew______

TI/Probe ID#

Data Logger ◯ CELSIUS ◯ FAHRENHEIT
Make ____________
Model ____________
Manu. Accuracy (+/-) ______°

Ref. Therm. ◯ CELSIUS ◯ FAHRENHEIT
Make ____________
Model ____________
Manu. Accuracy (+/-) ______°

PRE
Date ___/___/_____
Bath ◯ Room temp ◯ Ice ◯ ◯

POST
Date ___/___/_____
Bath ◯ Room temp ◯ Ice ◯ ◯

Time	Ref Therm°	TI°	Diff °	Time	Ref Therm°	TI°	Diff °

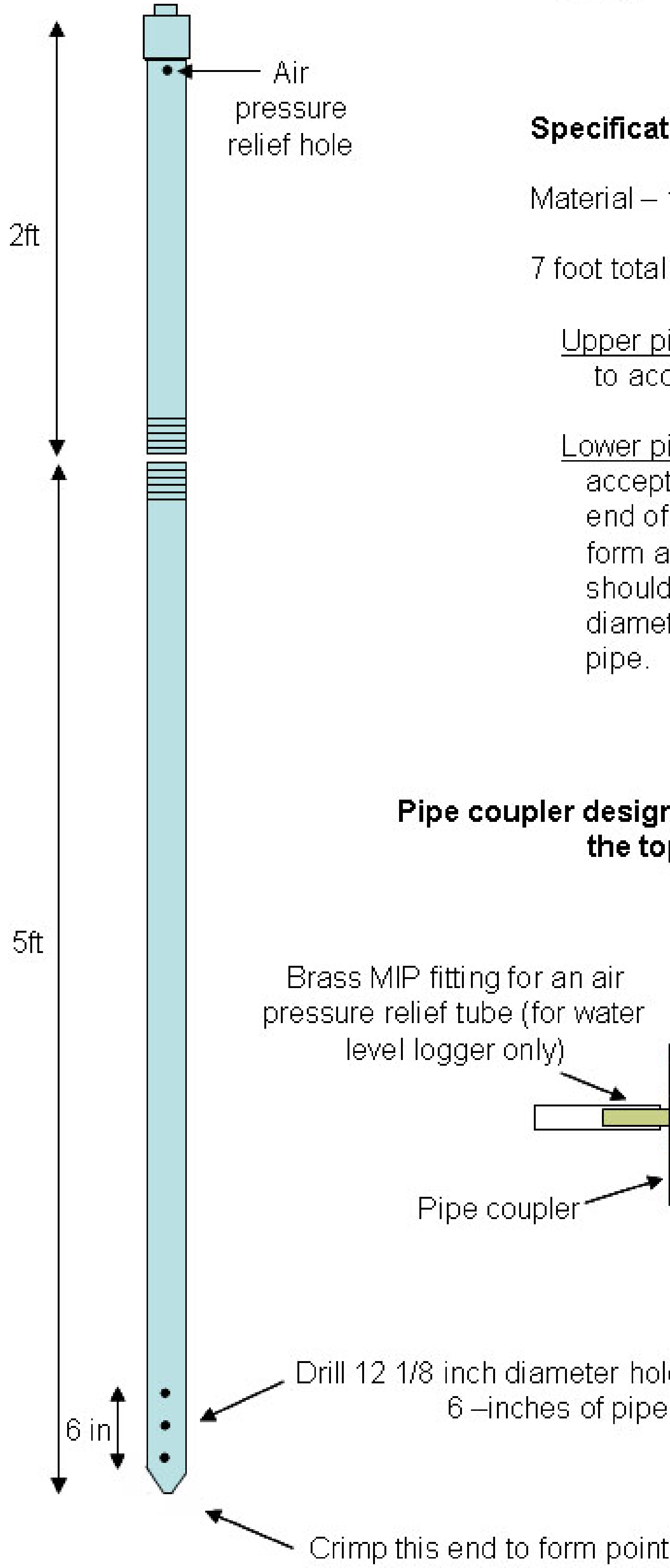
PRE: ◯ Accept ◯ Reject Mean Diff ______

POST: ◯ Accept ◯ Edit/Reject Mean Diff ______

Appendix B

B. This appendix covers the design specifications for the equipment that is made "in-house". These designs have been created to meet specific needs for past field studies, and can be modified as needed. The equipment to make these includes: power saws, drill press, and a pipe threader and other hand tools. Piezometers are crimped and the rebar pounder is manufactured by a contracted welder.

Stream Piezometer used with Onset Stow-away® tidbits



Specifications

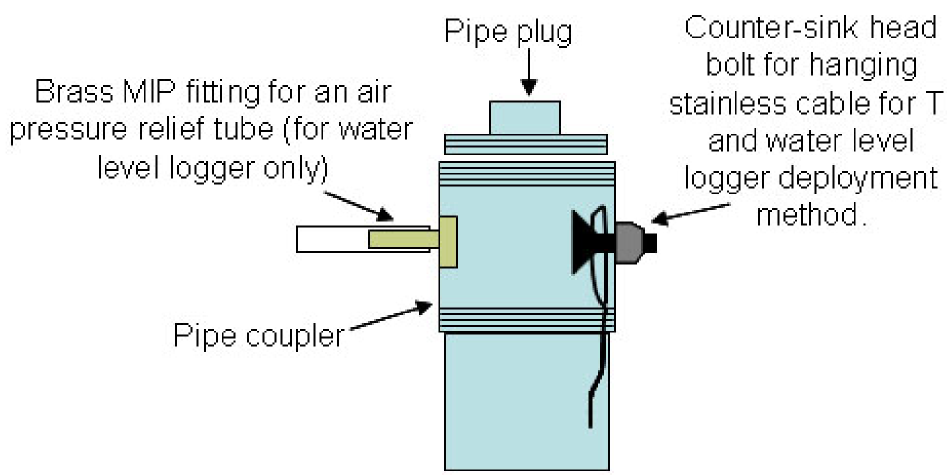
Material – 1.5 inch (ID) galvanized pipe

7 foot total length comprised of two pipe pieces:

<u>Upper piece</u> – 2 ft length threaded both ends to accept standard pipe coupler and end cap

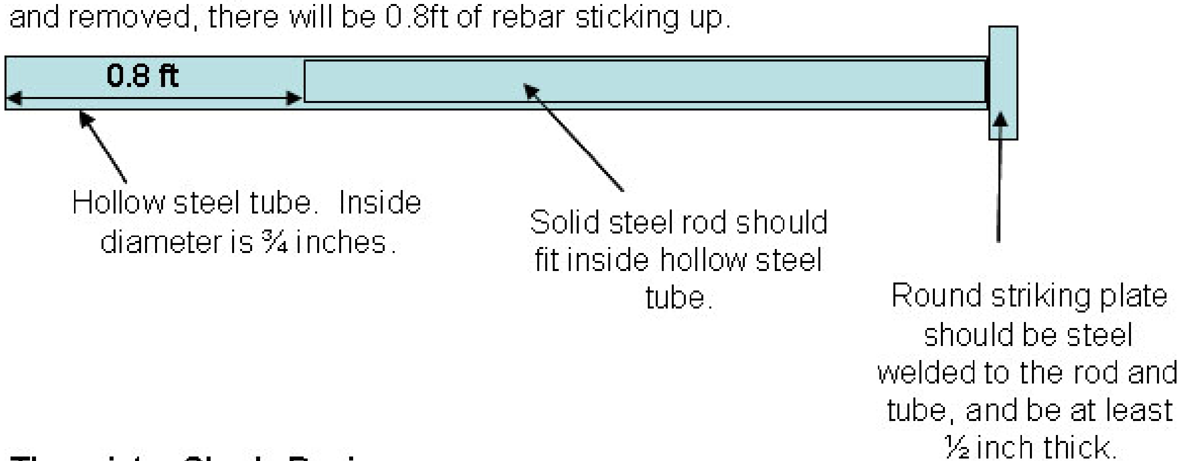
<u>Lower piece</u> – 5 ft length threaded one end to accept standard pipe coupler. The other end of the pipe should be crimped shut to form a point. The pointed end of the pipe should be perforated with 12 -1/8th inch diameter holes drilled in bottom 6 inches of pipe.

Pipe coupler design for hanging instruments from the top of a piezometer



Rebar Pounder Design

The rebar pounder is used for driving rebar sections (2-4ft in length) into the streambed as an anchor for an instream thermistor. The rebar is inserted in the open end so that when the driver reaches the stream bottom and removed, there will be 0.8ft of rebar sticking up.



Thermistor Shade Device

The shade device is typically made from 1.5in (inside diameter) PVC pipe. It can be whatever size is necessary to fit the thermistor type being used, as long as it completely covers the thermistor. This design can be used for both instream thermistors and air thermistors. PVC for the air thermistors should be white so solar radiation absorption is minimized.