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State of Washington

Standard Operating Procedure

EAP044, Version 4.0

Collecting Data to Support a Temperature Total Maximum Daily Load (TMDL) Study

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Purpose of this Document

The Washington State Department of Ecology develops Standard Operating Procedures (SOPs) to document agency practices related to sampling, field and laboratory analysis, and other aspects of the agency's technical operations.

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Environmental Assessment Program
Standard Operating Procedure EAP044
Version 4.0

Standard Operating Procedures for Collecting Data to Support a Temperature Total Maximum Daily Load (TMDL) Study

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Date – February 16, 2019

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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
8/16/2012	3.0	Removed section on soil temperature sampling, changed pre- and post-thermistor calibration check procedures, and updated figures.	Various	S. Brock
2/11/2013	3.0	Cover Page edits		W. Kammin
2/12/2016	3.1	Three-year review and recertification; removed redundancy with EAP061, updated calibration procedures, updated references and equipment	Various, primarily 6.1.2, 6.3, 6.12	N. Mathieu
1/29/2019	4.0	Three-year review and recertification; removed redundancy with EAP080, added temperature related SOP diagram, updated QA/QC procedures.	Various	N. Mathieu
6/21/2019	4.0	Accessibility and formatting updates.	All	R. Froese

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 local communities 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 wasteload 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 riparian vegetation (shade), channel morphology (shape, hydraulic geometry), hydrology, and temperature (point source and non-point source).

1.3 This protocol provides a general discussion of the data necessary to develop a temperature TMDL. It describes the detailed field procedures for air temperature and relative humidity monitoring, as well as installation of weather stations for additional meteorological parameters. Several data elements collected in Temperature TMDLs are covered in detail by other SOPs (Figure 1).

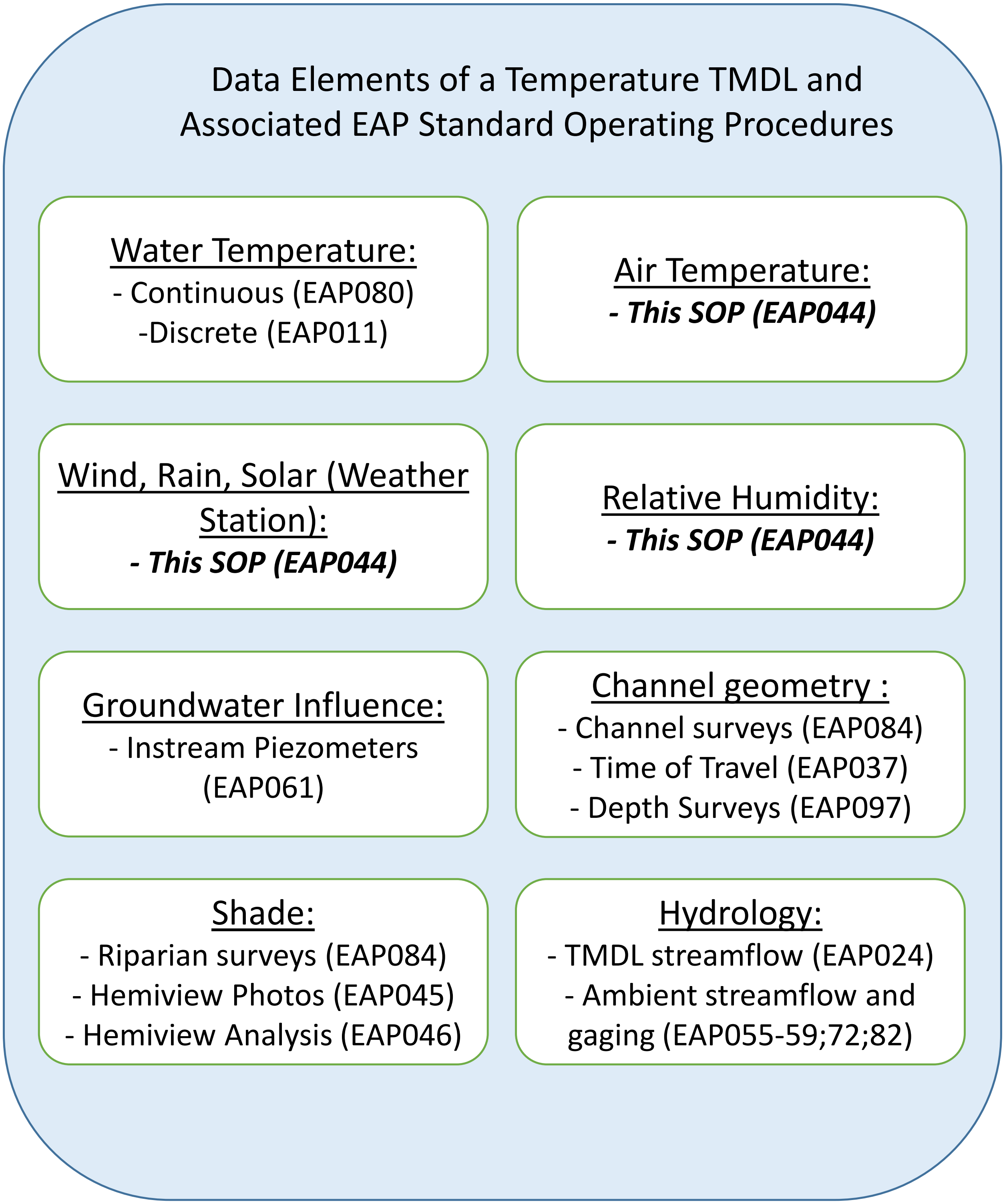

Figure 1. Data typically collected during a Temperature TMDL and the associated SOPs that describe the procedures in detail (see references section for additional information).

2.0 Applicability

2.1 This Standard Operating Procedure (SOP) is intended for monitoring related to a temperature TMDL study. It describes detailed procedures for collecting meteorological data such air temperature, relative humidity, wind speed and direction, barometric and absolute pressure, precipitation, and solar radiation using temperature/humidity loggers and weather stations. It includes references to additional SOPs for other detailed data procedures relating to Temperature TMDLs (Figure 1).

3.0 Definitions

3.1 *Dew point temperature,* A measure of atmospheric moisture. It is the temperature to which air must be cooled in order to reach saturation (assuming air pressure and moisture content are constant). A higher dew point indicates more moisture present in the air. It is sometimes referred to as Dew Point Temperature, and sometimes written as one word (Dewpoint) (NOAA, 2019).

3.2 *EAP*, Ecology's Environmental Assessment Program

3.2 *GPS*, Global Position System

3.3 *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).

3.4 *NAD83 HARN*, Map Projection Coordinate System North American Datum 1983 High Accuracy Resolution Network Washington

3.5 *NIST*, National Institute of Standards and Technology

3.6 *PST*, Pacific Standard Time

3.7 *PDT*, Pacific Daylight savings Time

3.8 *QAPP*, Quality Assurance Project Plan

3.9 *Relative Humidity*, A dimensionless ratio, expressed in percent, of the amount of atmospheric moisture present relative to the amount that would be present if the air were saturated. Since the latter amount is dependent on temperature, relative humidity is a function of both moisture content and temperature. As such, relative humidity by itself does not directly indicate the actual amount of atmospheric moisture present. (NOAA, 2019).

3.10 *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.

3.11 *TI*, an abbreviation for temperature instrument; synonymous with thermistor or temperature data logger.

4.0 Personnel Qualifications/Responsibilities

4.1 Field operations require training specified in EAP's Field Safety Manual (Ecology, 2019), such as First Aid, CPR, and Defensive Driving.

4.2 No certification or license is required to conduct surface water monitoring. However, groundwater monitoring activities involving piezometers have licensing requirements (See SOP EAP061 (Sinclair and Pitz, 2018) for requirements).

4.2.1 Physical installation or decommissioning of instream 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 (Sinclair and Pitz, 2018) for detailed instructions on piezometer permit requirements.

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

4.3 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, Environmental Technician.

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, 8-lb 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 (*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)*:

5.3.1 Continuously recording thermistors

- EAP's programmatic QAPP for water quality impairment studies (McCarthy and Mathieu, 2017) contains a comprehensive list of acceptable field instruments. Additional details can also be found in EAP080 (Ward, 2018).
- Hobo Pro relative humidity/Temp Data Logger
- Solar radiation shields for Hobo Pro relative humidity/Temp
- PC communication cables or optic shuttles specific for each instrument type

5.3.2 *Instantaneous Temperature Measurement:* Field check thermometer or thermistor. See SOP EAP011 "Standard Operating Procedures for Instantaneous Measurements of Temperature in Water" (Dugger, 2019) for additional detail

5.3.3 *Onset Hobo Weather Station© –Instruments*

- EAP's programmatic QAPP for water quality impairment studies (McCarthy and Mathieu, 2017) contains a comprehensive list of acceptable field instruments. Additional details can also be found in EAP080 (Ward, 2018).
- Hobo Pro relative humidity/Temp Data Logger
- Solar radiation shields for Hobo Pro relative humidity/Temp
- PC communication cables or optic shuttles specific for each instrument type
- Temperature/Relative Humidity Smart Sensor
- Wind speed/direction Smart Sensor
- Barometric Pressure Smart Sensor
- Rain Gage Smart Sensor
- Silicon Pyranometer Smart Sensor
- 2m Tripod Kit (includes guy wires, grounding kit, stakes, and tripod level)
- Pyranometer mounting bracket
- Wind sensor cross-arm bracket
- Hobo Weather Station Data Logger
- Solar radiation shield

5.4 *General Field Equipment includes:*

- Field forms on Rite-in-the-rain paper
- PC laptop with appropriate software for temperature and relative humidity loggers).
- Digital Camera (with batteries and memory card)
- Metal Clipboard
- Waterproof wrist watch or other suitable field clock
- Hip belt for small tools
- 3 mechanical or wooden pencils
- 3 pens
- Black Sharpie pen
- Refill lead for mechanical pencil
- Highlighter
- Maps
- Waterproof field notebook
- Extra AA batteries
- Hand sanitizer
- Rebar pounder tool
- 5 or 8 lb mallet
- Bucket
- Cable ties (strong, steel enforced) or Zip ties
- Flexible wire (8 or 10 gage smooth fencing wire and thin wire)
- 1/8th inch diameter braided stainless steel cable and crimps
- Crimping tool
- Large wire cutters
- Small wire cutters
- Shade devices for air & water thermistors (PVC pipe works well, see Appendix B)
- 10-penny stainless nails
- Hammer
- Steel engineer's tape (with 1/10th and 1/100th foot marks)
- GPS unit
- Duct tape

6.0 Summary of Procedure

6.1 *Pre-Deployment Run Preparation*

6.1.1 Assemble equipment. Use list in section 5.0 to ensure all the necessary equipment, supplies, and safety gear are assembled and available in the field.

6.1.2 Calibration checks. All temperature loggers must be calibration checked pre- and post-deployment to document instrument accuracy. Calibration checks should follow the procedures detailed in SOP EAP080 (Ward, 2018).

6.2 *Site Selection Criteria for instream thermistors*

6.2.1 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. Site selection should follow the procedures detailed in SOP EAP080 (Ward, 2018).

6.3 *Site selection criteria for instream mini-piezometers*

6.3.1 Selecting piezometer sites is similar to selecting instream thermistor sites. See SOP EAP061 (Sinclair and Pitz, 2018) for details.

6.4 *Site selection criteria for air thermistors and relative humidity sensors*

6.4.1 The air temperature record has two primary uses:

6.4.1.1 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.

6.4.1.2 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.

6.4.2 Always put the air thermistor in a white shade device unless the deployment location does not receive direct solar radiation (i.e., the north side of the tree trunk).

6.4.3 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 (NWCG, 2014). Avoid placing the thermistor in areas that are not representative of stream side conditions at your location.

6.4.4 If two stations are located within approximately 0.5 miles 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.

6.4.5 Relative humidity sensors should be distributed evenly among the sites and the elevation differences in the watershed or subbasin.

6.4.6 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.

6.4.7 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.

6.5 *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 (Onset, 2011).

6.6 *Instream thermistor deployment options*

6.6.2 Instream deployment should follow the procedures outlined in SOP EAP080 (Ward, 2018).

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 computer, 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, installation equipment (shade devices, rebar, ties, etc.), 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 Installation should follow the procedures outlined in SOP EAP080 (Ward, 2018).

6.9 *Installation of instream mini-piezometer with thermistors*

6.9.1 Installation should follow the procedures detailed in SOP EAP061 (Sinclair and Pitz, 2018).

6.10 *Installation of air thermistors and relative humidity sensors*

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 designated for air use (temperature loggers with an accuracy of ±0.5°C from calibration test) or a relative humidity sensor (relative humidity loggers with an accuracy of ±2.5% from the pre-deployment test).

6.10.3 Record the serial number of the instrument and the launch date and time on the field form (Appendix A.1).

6.10.4 For air thermistors, use either wire or zip/cable ties to secure the thermistor inside a white or light gray shade device (Figure 2) or secure the relative humidity sensor inside a solar radiation shield or rain shield (Figure 3). Use white or light gray 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.

6.10.5 Attach the thermistor and shade device or solar radiation shield to the best location (see site selection criteria in section 6.4).

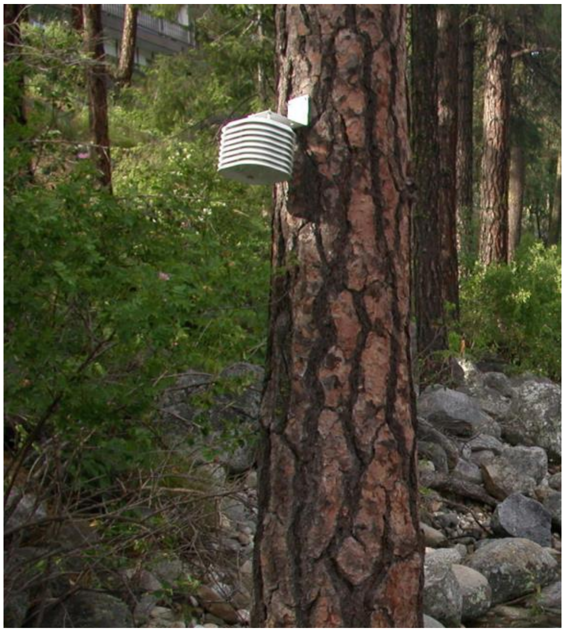

Figure 3. A relative humidity sensor deployed in a solar radiation shield and attached to a tree.

6.10.6 Draw the location of the air or relative humidity thermistor on the site sketch part of the field form for later reference.

6.10.7 Take a wide angle digital picture of the location of the air thermistor, making sure to capture significant landmarks to identify the instruments location during future visits (Figure 3).

6.11 *Installation of Onset weather stations*

6.11.1 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.

6.12 *Site visit protocols for a typical station.* (If piezometer is present at your station, refer to SOP EAP061 (Sinclair and Pitz, 2018) for additional steps.)

6.12.1 If air temperature or relative humidity loggers are deployed at the site, field checks may be completed using either an instantaneous temperature instrument or another logger set up to continuously record every 5 minutes. Hang the field check instrument or logger/s immediately upon arrival at a location as close to the deployed sensor as feasible. This will allow for maximum instrument response time.

6.12.1.1 For instantaneous air check measurements follow the general guidelines in EAP SOP 011 (Dugger, 2019). It is important to keep the instrument dry, shielded from direct solar radiation, and in an area with moderate air flow in order to get an accurate air temperature reading.

6.12.1.2 For logged air temperature/relative humidity check measurements, the logged check values can be matched to the deployed logger values later using the field visit time.

- For quick site visits where only air temperature is needed a fast response logger, such as the Hobo U12-015-02, is preferable which has a 90% response time of 2.25 minutes (with ~2 mph wind/airflow).
- For checking both air temperature and relative humidity, the Onset U23-002 logger provides good accuracy measurements for both parameters, with a reasonable response time of 5 minutes in ~2mph wind/air flow.
- Note, it is not recommended to use a temperature logger such as the Tidbit V2 for air temperature field checks as it has a slow response time of up to 20 minutes in ~2mph wind/air flow.

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

6.12.3 Record the station location on the field data form (Appendix A.2) along with the date/time, names of the field crew, weather conditions, and other header information on the field form. Record the instream and air thermistor serial numbers on the Data Logger Field Check Form (Appendix A.2). Download the thermistors to the appropriate device.

6.12.4 Measure the temperature of the stream at the thermistor location and record it and the date and time on the field form (Appendix A.2). If you are studying a small and shallow stream (up to 20 ft wide) it may also be a good idea to measure the temperature and other water quality parameters 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 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.

6.12.5 Reinstall the instream and air thermistors. Note the time of redeployment on the appropriate field form.

6.12.6 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.

6.12.7 Measure the flow at the thermistor site using either the Stream Hydrology Unit SOP EAP056 (Shedd, 2018) or the water quality impairment studies SOP EAP024 (Mathieu, 2016).

6.12.8 Measure and 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.

6.12.9 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.

6.12.10 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. If the thermistors need to be moved, sketch the new location. Also include any special needs information for that station, such as notifying the landowner before visiting.

6.12.11 As a final step before leaving the site, record the air temperature and/or relative humidity from the field check measurement if taking an instantaneous instrument. By collecting this measurement last, the instrument has the maximum amount of response time, generally at least 15 minutes. Ideally, the check measurement should be collected at or near the logged measurement time (every 30 mins) of the deployed logger. If using a logger for field checks, record the time the check logger was removed.

6.12.12 Check the field form for missing data. If the form is complete, you can recap the piezometer (if applicable).

6.13 *Final reference check and instrument removal*

6.13.1 During the final site visit in which the instruments will be removed, repeat steps 6.12.1 – 6.12.13. However, do not reinstall the thermistors. Record the date and time the instruments were removed on the appropriate field sheet (Appendix A.1, A.2, and SOP EAP061 (Sinclair and Pitz, 2018)).

6.13.2 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.

6.13.3 For guidance on removing in-water piezometers see SOP EAP061 (Sinclair and Pitz, 2018).

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. 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 on the EAP SharePoint site. The database manual covers the entry of continuous temperature data and other field data that is not covered in this document.

7.3 A new internal EAP database is currently under development and will be available soon to store and review continuous water and air temperature data. The database will also include the capability to upload finalized data directly to Ecology's EIM database.

8.0 Quality Control and Quality Assurance Section

8.1 For submersible temperature loggers that are deployed for either water or air temperature, pre- and post-deployment checks are conducted using an NIST certified thermometer and stable temperature water baths, see EAP SOP080 (Ward, 2018).

8.1.1 If the average temperature difference for a thermistor, compared against the NIST certified thermometer, is equal to or less than ±0.2°C then the instrument can be used without further qualification. If the average temperature difference for a thermistor is greater than the ±0.2°C, 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 ±0.2°C, 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 data should either be qualified or rejected, based on the average difference from the post-check and the criteria in Table 1.

8.2 For non-submersible loggers such as the Hobo U23-002 Temperature/Relative Humidity logger, the following procedure is recommended:

8.2.1 Pre-deployment, setup all non-submersible loggers (a minimum of 5) to log every 30 minutes for a minimum 24-hour period in a safe location.

8.2.2 All loggers should be deployed in a side-by-side manner that does not insulate nearby loggers or restrict air flow. The loggers must either be deployed in complete shade or in identical solar radiation shields.

8.2.3 Select one submersible logger that passed the pre-deployment check and deploy as a reference measure of air temperature.

8.2.4 For relative humidity, compare each logger's record to the median of all deployed loggers. If the average difference between the two is greater than 2.5%, then the loggers should ideally not be deployed in the study. The errant loggers should be sent to the manufacturer for repair or replacement.

8.2.5 For air temperature, each logger's record should be compared to the deployed reference logger. If the average difference between the two is greater than 0.5°C, then the loggers should ideally not be deployed in the study. The errant loggers should be sent to the manufacturer for repair or replacement.

8.2.6 The same procedure should be repeated post-deployment. The average differences are then compared to the criteria in Table 1 to determine whether the data is accepted, qualified, or rejected.

Table 1. Measurement Quality Objectives for Temperature and Relative Humidity Loggers.

Parameter	Unit	Accept	Qualify	Reject
Water Temperature	°C	≤ ± 0.2	> ± 0.2 and ≤ ± 0.8	> ± 0.8
Air Temperature	°C	≤ ± 0.5	> ± 0.5 and ≤ ± 1.5	> ± 1.5
Relative Humidity-General study	%	≤ ± 2.5%	> ± 2.5 and ≤ ± 10%	> ± 10%
Relative Humidity-Model input*	%	≤ ± 1%	> ± 1 and ≤ ± 5%	> ± 5%

*See section 8.3

8.3 Table 1 contains more stringent requirements for temperature TMDL model input data because ±3% relative humidity corresponds to >2°C change in dew point temperatures. Given that most temperature models are sensitive to dew point temperatures, it is recommended to either verify relative humidity accuracy is <1% or use data from the closest meteorological station data from an acceptable weather source (McCarthy and Mathieu, 2017).

8.4 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.

8.5 Field check values (described in sections 6.12.1 and 6.12.4) should be presented in data plots and evaluated by the project manager to further evaluate bias and identify potential drift issues. Data may be qualified or rejected based on a field check values, subject to best professional judgement; however, the measurement quality objectives in Table 1 apply only to the procedures described in 8.1 and 8.2 and are not intended for comparison to field checks. When comparing check values to deployed logger values, it may be necessary to interpolate between the deployed (every 30 minute) measurements in order to get an accurate comparison.

8.6 Note: it is recommended that air temperature data collected using an enclosed, slower-response logger such as the Tidbit V2 (UTBI-001) or Hobo Water Temp Pro V2 (U22-001) only be used for the purpose of conducting a paired deployment check on a water logger to determine periods when the submerged logger may have been exposed to air. This air temperature data is not recommended for use as an input to a temperature TMDL model. It is preferable to use a logger with an external sensor and an air temperature response time of 5 minutes or less (90% response at ~2 mph wind/air flow), such as the HOBO U12 Stainless 5-inch Probe Temperature Data Logger (U12-015-02) or the HOBO Pro v2 External Temperature/Relative Humidity Data Logger (U23-002).

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 (EAP, 2019).

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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 on EAP's Y drive. The 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 relative humidity 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 cross section at the same time as the flow measurement (See EAP084 for detail).

A.1

Basin name Temperature Project

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								

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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	