Forest Science Project

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TO: Stream Temperature Data Contributors

FROM: Tim Lewis

SUBJECT: Regional Stream Temperature Protocol

Enclosed is a revised and abridged version of Forest Science Project's Regional Stream Temperature Monitoring Protocol. It has been shortened and clarified for easier implementation.

While many of you will continue to deploy sensors to meet the needs of your own monitoring objectives, we hope that you can follow as closely as possible the procedures set forth in the enclosed protocol.

Some of the site-specific attributes that were requested on the field form are now derived in GIS by the Forest Science Project. You can continue to collect these variables for your own in-house use. Providing these values are useful for quality assessment of our GIS-derived values. We will be providing you with the GIS-derived values when we send you back your data package.

Have a great field season!

Stream Temperature Protocol

Forest Science Project
Regional Stream Temperature Assessment

1 Overview

1.1 Background

Stream temperature is one of the most important environmental factors affecting aquatic ecosystems. The vast majority of aquatic organisms are poikilothermic--their body temperatures and hence their metabolic demands are determined by temperature. Temperature has a significant effect on cold-water fish, both from a physiological and behavioral standpoint. Below is a brief list of the physiological and behavioral processes affected by temperature (Spence et al., 1996).

- Metabolism
- Food requirements, appetite, and digestion rates
- Growth rates
- Developmental rates of embryos and alevins
- Timing of life-history events, including adult migrations, fry emergence, and smoltification
- Competitor and predator-prey interactions
- Disease-host and parasite-host relationships

There has been a heightened awareness of the effects of increased stream temperatures on salmon, trout, and other aquatic/riparian species. Several regulatory measures have been promulgated to mitigate impacts of increased water temperatures on aquatic biota. Restoration activities have been initiated, conservation measures developed, and land use practices altered in an attempt to counteract a perceived but undocumented increase in stream temperatures throughout the state of California. One of the goals of the Forest Science Project's temperature monitoring protocol to obtain the consistent and representative data necessary to document thermal regimes in streams across Northern California.

With the onset of continuous temperature sensor technology, large volumes of stream temperature data are now being collected. Despite the wealth of knowledge regarding the effects of temperature on aquatic organisms, particularly fish, there seems to be a lack of a regional understanding of temperature regimes across Northern California. This protocol sets forth a sampling approach that will provide consistent data that can be used to address stream temperature issues at broad regional scales, i.e., watershed, basins, and regions.

1.2 Scope and Application

The field methods described in this protocol are for obtaining representative stream temperatures from perennial streams for regional monitoring. The field methods are specifically applicable for the deployment of continuous monitoring temperature sensors (e.g., Hobo Temps, Temp Mentors, Stowaways, etc.). Possible interferences in the accurate and precise measurement of stream temperature include: 1) exposure of the sensor to ambient air, 2) improper calibration procedures, including date and time settings, 3) improper placement of the sensor in the stream, 4) low battery, 5) inherent malfunctions in the sensor or data logger, and 6) vandalism.

1.3 Summary of Method

All continuous stream temperature monitoring sensors should be calibrated against a National Institute of Standards and Technology (NIST) traceable thermometer. Sensors not meeting precision and accuracy data quality objectives should not be used. Sensors should be placed in a well-mixed zone, e.g., at the end of a riffle or cascade. Monitoring location should represent average conditions — not pockets of cold water refugia or isolated hot spots. Location of sampling points should either avoid or account for confounding factors that influence stream temperatures such as:

- confluence of tributaries
- groundwater inflows
- channel morphology (particularly conditions that create isolated pools or segments)
- springs, wetlands, water withdrawals, effluent discharges, and other hydrologic factors
- beaver ponds and other impoundments

The sensor should be placed toward the thread or thalweg of the channel. Keep in mind that flow will decrease throughout the summer resulting in an exposed sensor. The thermistor portion of the device should not be in contact with the bottom substrate or other substrate that may serve as a heat sink (e.g., bridge abutment or boulder). Secure the sensor unit to the bottom of the channel with aircraft cable, surgical tubing, rebar, or diver's weights. The sensor should be set to record temperatures **at sampling intervals that should not exceed 1.6 hours (96 minutes)**.

2 Equipment and Supplies

2.1 Calibration and Standardization

Prior to deployment of sensors, calibration of each sensor must be performed. The following is a list of equipment and supplies for calibration:

- NIST traceable thermometer - resolution of 0.2°C or better, an accuracy of ±0.2°C or better.
- controlled-temperature water bath, or water-filled thermos or ice chest
- laboratory notebook
- ice

2.2 Field Measurements

There are several useful materials and pieces of equipment that should be taken to the field to install or service temperature sensors. These include:

- securing material such as zip ties, bailing wire, aircraft cable, surgical rubber tubing, locks, rebar, cinder blocks, large rocks with drilled holes, diver's weights
- surveyors marking tape or flagging
- sledge hammer (e.g., two-pound)
- wire cutters and/or pocket knife
- thermistor equipment items (silicone rings, submersible cases, silicone grease, silica packets)
- portable computer or interface for data downloading and launching
- backup batteries and thermistors

- timepiece/watch
- Rite in the Rain field book
- NIST-traceable auditing thermometer
- waders
- camera and film
- brush removal equipment (e.g., safety axe)
- maps and aerial photos
- spray paint
- metal stakes or spikes, rebar

3 Pre- and Post-Deployment Calibration and Standardization

1. A NIST-traceable thermometer must be used to test the accuracy and precision of the temperature sensors. The NIST-traceable thermometer should be calibrated annually, with at least two calibration points between 10°C (50°F) and 25°C (77°F). Calibrations should be performed using a thermally stable mass of water, such as a controlled-temperature water bath, or water-filled thermos or ice chest. The stable temperature of the insulated water mass allows direct comparison of the unit's readout with that of the NIST-traceable thermometer. Accuracy of the NIST-traceable thermometer must be within ±0.5°C.

2. Prior to use, all continuous monitoring devices should be calibrated at room temperature (~25°C, 77°F) and in an ice water bath to insure that they are operating within the accuracy over the manufacture's specified temperature range. Calibrate all continuous monitoring devices with a NIST-traceable laboratory thermometer at two temperatures, room temperature (i.e., ~77°F, 25°C) and near the freezing point of water as follows:

1. When calibrating and prior to deployment, set all units to the same current date and synchronize all devices using an accurate watch/clock that will be used to time the recording intervals of the reference thermometer. Call for the correct time.

2. Set the record interval of each thermograph to a short period, six to 30 seconds.

3. Record the date, sensor serial number, data logger serial number, and analyst's name in a laboratory notebook. Table 1 is an example of a format that can be used for data collection. The same sensor and same data logger should be deployed in the field as they were paired together during calibration.

4. Place the reference thermometer and the continuous monitoring devices in a five-gallon pail filled with about three gallons of water that has reached room temperature overnight or in a controlled-temperature water bath that has reached room temperature (~77°F, 25°C). Make sure the casings of all continuous monitoring devices are completely submerged. Stir the water, just prior to, and during the calibration period to prevent any thermal stratification.

5. After allowing 10 minutes for the continuous monitoring devices to stabilize, begin recording data for a 10-minute interval. Record the time, the reference thermometer temperature, and the continuous monitoring device temperatures measured at the predetermined sampling frequency (e.g., 6 second, 10 second) used during the 10-minute interval. After all readings are completed, calculate the difference between the reference thermometer and each of the continuous monitoring devices for each reading and calculate the mean difference. Record the data using a format similar to that shown in Table 1.

Table 1.Example of Calibration Data Collection Table

4/12/98	Sensor Serial Number = 10043 Data logger S.N. = 2S256S	Analyst: Joe Celsius	Reference Thermometer No. 412
Time (sec)	**NIST Thermometer Reading (°C)**	**Device Reading (°C)**	**Difference (°C)**
0	25.0	24.8	-0.2
10	25.1	25.0	-0.1
20	25.0	24.9	-0.1
30	25.2	25.0	-0.2
40	25.0	24.6	-0.4
50	25.1	24.9	-0.2
60	25.0	25.1	+ 0.1
Etc.		= 24.9	Mean Diff. = -0.16
		S.D. = 0.16	

F. Any continuous monitoring devices not operating within their specified accuracy range should be thoroughly scrutinized. If a particular device returns readings that are outside of the manufacturer's accuracy limits, but is still precise, then a correction factor (addition and/or multiplication) can be applied to the data. Precision should be within 0.2 standard deviations (S.D.) of the mean. Acceptable precision should be observed over the range of temperatures that will be experienced in the field. The correction factor, when applied over the calibration range, should give temperature values that are within the accuracy limits of the device. If units are inaccurate and imprecise they should not be used.

G. Using the same water bath, add enough ice to nearly fill the bucket and bring the temperature down to nearly freezing. Stir the ice bath to achieve and maintain a constant water temperature. Place the reference thermometer and the continuous monitoring devices in the water bath or five gallon pail. Again, make sure that the casings are completely submerged.

H. Repeat steps 2B-D with ice water bath.

I. Also confirm that thermograph batteries have sufficient charges for the entire monitoring period (will the length of the upcoming field season fit into the life expectancy of the unit's lithium batteries?).

J. Calibration should also be repeated when sensors are retrieved at the end of the sampling season (post-deployment calibration). Repeat steps 2A-F.

4 Quality Assurance and Quality Control

4.1 Laboratory

Precision and accuracy should be 0.2 SD and ±0.5°C, respectively for each continuous monitoring device.

Monitoring equipment with detachable sensors must be marked in order to match the sensor with the data logger. This allows instrument and sensor to be calibrated and tested prior to deployment, and also makes malfunctions easier to diagnose and correct. A logbook must be kept that documents each unit's serial number, calibration date, test results, and the reference thermometer used (Table 1).

4.2 Field

In addition to laboratory quality control checks, temperature monitoring equipment should be audited during the field season. A field audit is a comparison between the field sensor and a hand-held NIST-traceable reference thermometer. The purpose of a field audit is to insure the accuracy of the data and provide an occasion for corrective action, if needed. A minimum of two field temperature audits should be taken during the sampling period — one after deployment when the instrument has reached thermal equilibrium with the environment, and ideally one prior to recovery of the device from the field. Reference thermometers used for field audits must meet the same specifications as those used for laboratory calibrations: accuracy of ±0.5°C, resolution of 0.1°C.

A field audit is performed as follows:

1. Place the reference thermometer in close proximity to the continuous monitoring device.

2. Record the reference thermometer temperature and the sensor temperature in a field notebook. A stable reading is usually obtained within 10 thermal response units or time constants. For example, a reference thermometer with a ten-second time constant should give a stable reading in 100 seconds.

> Response time (time constant) is the time required by a sensor to reach 63.2% of a step change in temperature under a specific set of conditions. Response time values should be provided by the manufacturer. Five time constants are required for the sensor to stabilize at 100% of the step change value. Ten time constants are recommended to insure that the reference thermometer has reached equilibrium with the stream temperature.

3. Most general purpose data loggers allow the user to connect a computer in the field and view "real-time" temperature data without disrupting the data logger's scheduled sampling schedule. This feature allows immediate comparison of the data logger's reading with the reference thermometer's reading. Real-time audit accuracy must be within ±1.0°C.

4. Conversely, most brands of miniature data loggers interrupt data collection when the unit is connected to a computer. With this type of unit, field audit data can only be applied by "post-processing", i.e., the stored data are downloaded and later compared to audit values. This does not permit on-site corrective action if the sensor is not within accuracy specifications. For this type of data logger, auditing times should be scheduled reasonably close to the data loggers download time. Otherwise, the sensor/data logger equipment may fail the audit criteria due to rapidly changing water temperatures. Post-processing audit accuracy must be within ±0.5°C .

5. Data loggers typically set date and time based on the set-up computer's clock. It is important that field personnel synchronize their watches to the computer clock's time. Prior to the field audit the computer clock should be set to the correct date and time by calling for the correct time.

5 Procedures

Water temperatures vary through time and space. The temporal and spatial aspects of deploying stream temperature monitoring devices is discussed in the following sections.

5.1 Temporal Considerations of Sensor Deployment

5.1.1 Sampling Window

Launch sensors to capture the hottest period of the field season, which will vary with watershed location. Coastal streams in Humboldt and Del Norte Counties require deployment at least during July, August, and September; whereas Mendocino County and more inland streams may require longer recording periods (June-October) (FFFC, 1996). For consistency **it is recommended that the sampling window be from June 1 to October 1**. This sampling window will ensure that the highest temperatures during the summer will be captured in the data set.

5.1.2 Sampling Frequency

The time interval between successive temperature readings can be adjusted from every few seconds, to every few hours, to every few days, for most continuous monitoring devices. Table 2 shows some of the typical sampling frequencies and the number of days the device can be left in the field prior to data downloading. In most monitoring activities, the primary objective is to determine the highest temperatures attained during the year. Thus, one of the deciding factors in setting the sampling frequency on a device will be to ensure that the daily maximum temperature is not missed.

Table 2. Typical Sampling Frequencies and Storage Capacity of a Hobo® Data Logger Used for Stream Temperature Monitoring

2K Memory / 1,800 Meas.	8K Memory / 7,944 Meas.	32K Memory / 32,520 Meas.	Sample Frequency
37.5 days	165 days	677 days	30 min
45 days	198 days	813 days	36 min
60 days	264 days	1084 days	48 min
75 days	331 days	1355 days	1 Hr
90 days	397 days	1626 days	1.2 Hr

120 days	529 days	2165 days	1.6 Hr
150 days	662 days	2710 days	2 Hr
180 days	799 days	3270 days	2.4 Hr
240 days	1050 days	4300 days	3.2 Hr
360 days	1590 days	6540 days	4.8 Hr

Note: BoxCar and LogBook software's launch menu allows the user to choose from 42 intervals ranging from 0.5 seconds to 4.8 hours. The table shows the most likely settings that may be used for stream temperature monitoring. Mention of trade names does not denote endorsement by the Fish, Farm, and Forests Community Forum, the Forest Science Project, or any of their cooperators.

The sampling frequency will depend on the monitoring question and the statistic to be calculated from the data. If the 7-day moving average of the daily average is to be calculated then a less frequent sampling frequency can be used (e.g., 1.2, 1.6, 2.0 hr) (FSP, 1998). However, if the 7-day moving average of the daily maximum is to calculated, then the daily maximum temperature should be captured. If monitoring data is collected infrequently, the daily maximum temperature is likely to be missed. The sensor should be set to record temperatures **at least every 1.6 hours (96 minutes)**.

The more frequent the monitoring, the more precisely the duration of daily maximum temperature can be characterized. The disadvantage of frequent data collection is reduced number of days of data storage and increased number of data points to be analyzed. Some agencies and other groups have found that an 80-minute sampling interval still captures the daily maximum stream temperatures for sites (OCSRI, 1996). If a less frequent sampling interval is desired, then a pilot study must be performed with monitoring at 30-minute intervals over a one to two week period during the hottest time of the year to determine how rapidly stream temperatures change. Pilot study information can provide information on the time interval most appropriate for capturing the daily maximum.

Selection of appropriate sites for monitoring is dependent upon the purpose and monitoring questions being asked. There are two scales of consideration for the appropriate monitoring site: selection of a sample point or location in the stream which provides representative data and the broader strategy of selecting sites that can provide useful information to answer the questions being asked.

5.1.3 Data Downloading

It is preferable to have the data cover the entire monitoring without interruptions. However, if data must be downloaded during the monitoring period due to insufficient data logger memory, record the date and time the sensor was removed from the stream and the date and time when it was returned to the stream. Some models may allow for downloading of data without interruption or removal of the sensor from the stream. Be sure to return the sensor to the same approximate location and depth after downloading. During a field visit for data downloading or auditing, record in the field notebook whether the sensor was exposed to the air due to low flow, discontinued flow, or vandalism. This information will be valuable for verification and validation of the data in the office.

5.1.4 Mid-Season Field Audit/Calibration Check

If data downloading is performed in mid-season, an opportunity for a mid-season field audit and calibration check presents itself. See Section 4.2 for mid-season field audit and calibration procedures.

5.2 Spatial Considerations of Sensor Deployment

5.2.1 Stream Sample Point Location

The simplest and most specific scale is a sampling point on a stream. Here, the focus is on sample collection methods that will reduce variability and maximize representativeness.

Monitoring must record daily maxima at locations which represent average conditions - - not pockets of cold water refugia or isolated hot spots. Measurements should be made using a sampling protocol appropriate to indicate impact to beneficial uses (OCSRI, 1996). Thus, location of sampling locations should be done in a manner that is representative of the waterbody or stream segment of interest. In order to collect representative temperature data, sampling site selection must minimize the influence of confounding factors, unless the factor is a variable of interest. Some confounding factors include:

- confluence of tributaries
- groundwater inflows
- channel morphology (particularly conditions that create isolated pools or segments)

- springs, wetlands, water withdrawals, effluent discharges, and other hydrologic factors
- beaver ponds and other impoundments

5.2.2 Site Installation

1. All sensors should be placed in the thalweg of riffles to insure a complete mixing of the water and to maintain sufficient water depth for the duration of the sampling window. Alternatively, if riffles are too shallow place the sensor in a pool or glide that exhibits well-mixed conditions. **DO NOT** place the sensor in a deep pool that may stratify during the summer, unless this is the objective of your study. This measure insures that sensors are not selectively placed in cooler areas such as stratified pools, springs, or seeps or in warm, stagnant locations (hot spots) that would misrepresent a stream reach's temperature signature. A hand-held thermometer can be used to document sufficient mixing by making frequent measurements horizontally and vertically across the stream cross section. If stream temperatures are relatively homogenous (±1-2°C) throughout the cross section during summer low-flow conditions, then sufficient mixing exists.

2. Monitoring devices should be installed such that the temperature sensor is completely submerged, but not in contact with the bottom. Place the sensor near the bottom of the stream by attaching it to a rock, large piece of woody debris, or a stake. Use zip ties, surgical tubing, or aircraft cable to attach the sensor to the bottom substrate. Rebar or diver's weights can be used if no suitable fastening substrate is available. For non-wadeable streams, the sensor should be placed one meter below the surface, but not in contact with a large thermal mass, such as a bridge abutment or boulder (ODF, 1994). If the monitoring site is not in a heavily visited area, mark the location of the sensor by attaching flagging marked with the gauge number or site ID number to nearby vegetation.

   Precautions against vandalism, theft, and accidental disturbance should be considered when installing equipment. In areas frequented by the public, it is advisable to secure or camouflage equipment. Visible tethers are not recommended because they attract attention. When equipment cannot be protected from disturbance, an alternative monitoring site should be considered. For external data loggers that are not waterproof, place them above the mean high water line to prevent loss during a freshet. Some data loggers must be housed in a waterproof metal or plastic box that should be locked and chained to a tree. Data logger boxes and cables should be covered with rocks, moss, and wood to hide equipment from passers by.

3. Install the sensor in a shaded location; shade can be provided by canopy cover or some other feature such as large woody debris. If no shaded locations are available, then it may be necessary to construct a shade cover for the sensor (e.g., using a section of large diameter plastic pipe.) The intention for this measure is to avoid direct solar warming of the sensor. The intent **is not** to suggest that sensors should be placed only in shaded thermal reaches.

4. Sensors should be located at the downstream end of a thermal reach, so as to characterize the entire thermal reach, as opposed to local conditions. Protocols for characterizing thermal refugia can be found in FFFC (1996).

A ***thermal reach*** is a reach with similar (relatively homogenous) riparian and channel conditions for a sufficient distance to allow the stream to reach equilibrium with those conditions. The length of reach required to reach equilibrium will depend on stream size (especially water depth) and morphology (TFW, 1993). A deep, slow moving stream responds more slowly to heat inputs and requires a longer thermal reach, while a shallow, faster moving stream will generally respond faster to changing riparian conditions, indicating a shorter thermal reach. Generally, it takes about 300 meters (or 1000 feet) of similar riparian and channel conditions to establish equilibrium with those conditions in fish-bearing streams.

5. The number of thermograph units deployed will vary with 1) drainage area of the watershed, 2) numbers and sizes of inflow tributaries or other transitions in riparian condition, 3) changes in elevation, and 4) proximity to coastal fog zone. In all circumstances, a continuous monitoring device should be located as far downstream as surface water flows during the summer. In watersheds with multiple sensors locate them in a lower/upper or lower/middle/upper distribution.

6. Mark all monitoring site locations on a USGS 1:24,000 topographic map, aerial photo, or GIS map. Clearly show the location of the site with respect to other tributaries entering the stream, e.g., above or below the confluence. Record measured distance to a uniquely distinguishable map feature (i.e., road crossing, specific tributary, etc.) Draw a diagram of the monitoring area. Include details such as: harvest unit boundaries, sensor location and thermal reach length, tributaries with summer flow, description of riparian stand characteristics for each bank, areas where portions of the stream flow become subsurface, beaver pond complexes, roads near the stream, other disturbances to the channel or riparian vegetation (heavy grazing, gold dredging, gravel mining, water withdrawals).

7. Record the serial number of each sensor/data logger combination at each monitoring site. Make an effort to deploy the same sensor/data logger combination at the same site each year.

8. Once a sensor/data logger combination has been deployed at a site, **DO NOT** move the equipment to another location. Adjustments in sensor location may be necessary if the initial location ran dry, and the sensor must be moved to the active, flowing channel. This will necessitate a unique site_id for spatial statistical analysis. Make notes of such relocations in the field notebook.

9. If sensors are used to collect long-term baseline or trend data in specific watersheds, establish fixed-location monitoring stations so that data sets will be comparable.

5.3 Site-Specific Data Collection

Other site-specific data should be collected at the time of sensor deployment or retrieval. These additional attributes will greatly assist in post-stratification and interpretation of status and trends in stream temperatures.

5.3.1 Length of Thermal Reach or Stream Segment

The thermal reach extends 300-600 meters above the site, depending on stream size (TFW, 1993). With a hip chain or measuring tape, measure the length of thermal reach or stream segment (in feet). If the stream has more than one channel, measure along the channel that carries most of the summer flow.

5.3.2 Canopy Closure

Use a spherical densiometer at evenly spaced intervals to determine average canopy closure for the thermal reach above the monitoring site. Take canopy closure measurements at 50-meter intervals along the thermal reach. If the percent canopy cover varies by more than 20% between measurements, then take additional measurements at 25-meter intervals to more accurately determine the average percent canopy closure for the reach. In order to save time, it may be advantageous to determine canopy closure at 25-meter intervals from the start, thus avoiding the need to back-track in cases where the variability exceeds 20%. In addition to calculating the average canopy closure, keep a record in a field notebook of the percent canopy closure at each sampling interval and note the locations on a map or sketch of the reach to document how the shade level varies through the reach. At each 25- or 50-meter interval, stand in the center of the channel and measure canopy closure four times: facing upstream, downstream, right bank, and left bank. Average these four values to obtain canopy closure for the location.

5.3.3 Elevation

Determine the elevation at the midpoint of the thermal reach from a USGS topographic map, or altimeter and record on data sheet to nearest feet.

5.3.4 Average Bankfull Width and Depth

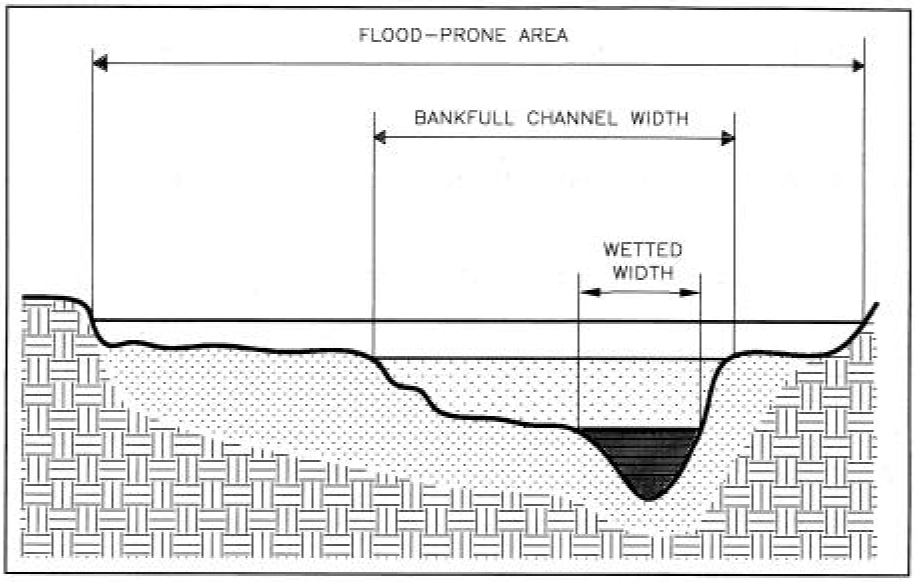
The width and depth of a channel reflect the discharge and sediment load the channel receives, and must convey, from its drainage area. Channels are formed during peak flow events, and channel dimensions typically reflect hydraulic conditions during bankfull (channel-forming) flows.

Bankfull width and depth refer to the width and average depth at bankfull flow. These dimensions are related to discharge at the channel-forming flow, and can be used to characterize the relative size of the stream channel. This characterization will be useful for later post-stratification and assessment of stream temperature data. In addition, the ratio of bankfull width to depth (width:depth ratio) of a stream channel provides information on channel morphology. Width:depth ratio is related to bankfull discharge, sediment load, and resistance to bank erosion (Richards, 1982). For example, channels with large amounts of bedload and sandy, cohesionless banks are typically wide and shallow, while channels with suspended sediment loads and silty erosion-resistant banks are usually deep and narrow. Changes in width:depth ratio indicate morphologic adjustments in response to alteration of one of the controlling factors (Schumm, 1977).

Refer to TFW Ambient Monitoring Manual (1993) for step-by-step procedures for estimating bankfull width and depth.

5.3.5 Average Wetted Width

Measure the wetted channel width at the location where the sensor is placed. This measurement should be collected at the time of deployment and at the time of retrieval. Change in wetted width over the field season will provide information on the change in flow during the monitoring period. Follow the method outlined in Flosi (1998). Figure 3 shows a comparison of wetted width and bankfull channel width dimensions.



5.3.6 Habitat Type

Record the habitat type in which the sensor was placed. Use the following codes for the habitat types:

riffle Shallow reaches with swiftly flowing, turbulent water

run Relatively uniform flowing reaches with little surface agitation

spool Shallow pools less than 2 feet in depth with good flow (no thermal strata)

mpool Mid-sized pools 2 to 4 feet in depth with good flow (no thermal strata)

dpool Deep pools greater than 4 feet in depth or pools suspected of maintaining thermal strata (possible thermal strata)

5.3.7 Stream Class

Record the stream classification as defined by the California Forest Practice Rules.

1 - ***Class I Watercourse:*** Domestic supplies, including springs, on site and/or within 100 feet downstream of the operations area and/or 2) Fish always or seasonally present onsite, includes habitat to sustain fish migration and spawning.

2 - ***Class II Watercourse:*** a) Fish always or seasonally present offsite within 1000 feet downstream and/or 2) Aquatic habitat for nonfish aquatic species. 3) Excludes Class III waters that are tributary to Class I waters.

3 - ***Class III Watercourse:*** No aquatic life present, watercourse showing evidence of being capable of sediment transport to Class I and II waters under normal high water flow conditions after completion of timber operations.

4 - ***Class IV Watercourse:*** Man-made watercourses, usually downstream, established domestic, agricultural, hydroelectric supply or other beneficial use.

For Class I watercourses make a concerted effort to collect fish presence/absence and/or abundance data in the same thermal reaches or stream segments where stream temperature data is being gathered. Conduct fish surveys during the period when stream temperatures are highest (July-August).

6 Data Field Form

To assist in the collection and organization the site-specific information described in Sections 5.3.1 through 5.3.7 a field data form has been developed by the Forest Science Project. The form can be found in Appendix A. Please reduce and photocopy the form onto Write-in-the-Rain paper for data collection activities. Please use a No. 2 pencil.

7 Calculations

It is recommended that only data that meets quality control requirements be used for statistical analyses. Data are considered valid if the instrument's pre- and post-deployment calibration checks are within ±0.5°C of the NIST-traceable reference thermometer, as described in Section 4, and the data are bracketed by field audits which meet the ±1.0°C accuracy criterion (Section 4).

7.1 *Maximum Weekly Average Temperature (MWAT)*

The seven-day moving average of the daily average and the daily maximum can be calculated with most spreadsheet, database, and statistical software. The seven-day moving average of the daily average is simply the sum of seven consecutive daily average temperatures divided by seven. For consistency, it is recommended that the first day's daily average can be used as the first seven-day moving average, the second day's moving average would be the average of day one and day two daily averages, etc. The seven-day moving average of the daily maximum is the sum of seven consecutive daily maximum temperatures divided by seven.

After all the seven-day moving averages have been calculated, the highest of all the moving averages is referred to as the Maximum Weekly Average Temperature (MWAT) for a given site. Different agencies and groups are comparing either the seven-day moving average of the daily average or the seven-day moving average of the daily maximum to various MWAT criteria. The MWAT threshold can be calculated using the following equation:

Install Equation Editor and double-click here to view equation.

where

OT = a reported optimal temperature for the particular life stage or function, and

UUILT = the upper temperature that tolerance does not increase with increasing acclimation temperature.

If the OT is not known, Armour (1991) recommended using the midpoint of a preferred range. The MWAT is interpreted as the upper temperature limit that should not be exceeded during a one-week period in order to prevent chronic lethal effects.

Thus, according to Armour, the MWAT is the threshold against which weekly temperatures are compared. The weekly temperatures are not MWATs.

There is no agreed upon statistic adopted by California state and federal agencies at this time.

8 Acknowledgments

This protocol is based on several existing stream temperature protocols. We would like to acknowledge the states of Oregon and Washington for providing stream temperature monitoring protocols for review and incorporation of sections into the FSP protocol. We would like to thank the Forest Science Project cooperators for their review and helpful comments of this protocol. Also, many insightful suggestions were provided by various reviewers from various state and federal agency personnel in California, Oregon, and Washington.

9 References

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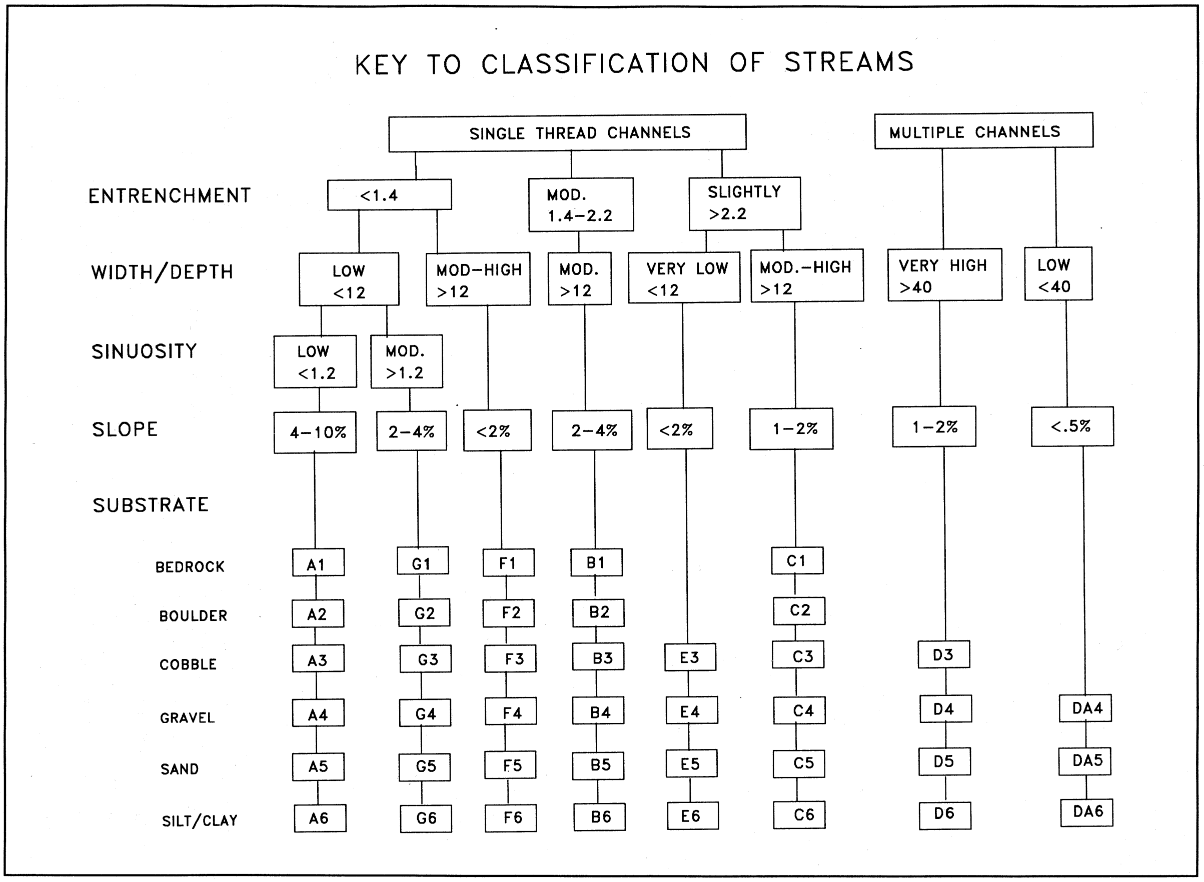
Appendix A

Field Data Form

FSP / FFFC Stream Temperature Field Data Form

Site_ID:	**File Name:**
Stream Name:	
X Coordinate:	**Y Coordinate:**
Projection (UTM Zone 10 NAD 27 preferred):	
Basin Name:	**USGS Quadrangle:**
Describe Placement:	
Surveyor:	**Organization:**
Device ID (serial #):	**Device Type:**
Calibration Date:	**Mid-Season Calibration Date**:
Date Launched:	**Date Retrieved:**
Depth Launched (ft.):	**Depth Retrieved (ft.):**
Wetted Width Launched (ft.):	**Wetted Width Retrieved (ft.):**
Bankfull Width (ft.):	**Diagram or Photo** (optional)
Bankfull Depth (ft.):	
Reach Length (ft.):	
Mean Canopy Closure (%):	
Avg. Gradient (%)[†]:	
Avg. Channel Aspect (degrees)[†]:	
Habitat Type*:	
Channel Type (Flosi et al., 1998):	
Stream Class (I, II, etc.):	
Elevation (ft.)[†]:	
Drainage Area (acres)[†]:	
Comments:	



* **Habitat Types:**	**riffle**	shallow reaches with swiftly flowing, turbulent water
	run	relatively uniform flowing reaches with little surface agitation
	spool	shallow pools less than 2 feet in depth with good water flow (no thermal strata)
	mpool	mid-sized pool 2 to 4 feet in depth with good water flow (no thermal strata)
	dpool	deep pools greater than 4 feet in depth or pools suspect of maintaining thermal strata (possible thermal strata)

†OPTIONAL. This is a FSP GIS-derived variable. Supplying a value will assist with FSP accuracy assessment.

Photocopy the Channel Type description on this page to the back of the Field Data Form.

Appendix B

Data Submission to Forest Science Project

The following attributes and their descriptions are useful to those that would like to submit their stream temperature data to the Forest Science Project for verification and validation and inclusion in stream temperature assessments. Refer to Section 7.2 in the FSP/FFFC Stream Temperature Protocol for more details.

Fields	**Attributes**
SITEID	FSP Site ID (leave blank if you do not know what your FSP id numbers are. These are assigned by the FSP for all new sites.)
SITE	Specific monitoring site descriptor as assigned by the cooperator.
CSNAME	**Cooperators Site Name** as assigned by the cooperator.
FILENAME	Data file name as assigned by the cooperator.
SURVEYOR	Name of field personnel responsible for monitoring device deployment.
ORGID	Cooperator identification code as assigned by FSP.
UTMX	UTM Easting, Zone 10, NAD 27 (horizontal datum).
UTMY	UTM Northing, Zone 10, NAD 27 (vertical datum).
UTMZ	UTM Elevation, NGVD29 (vertical datum). **Optional.** This is FSP GIS derived.
ELEV	**Elevation** of monitoring station in feet from USGS 7.5 min quadrangle.
CAZIMUTH	Average **aspect** channel aspect of thermal reach in degrees from true north. **Optional.** This is FSP GIS derived.
ACRES	**Acres** of watershed contributing stream flow to the monitoring station (if available). Optional. This is FSP GIS derived.
BASIN	Major drainage basin that monitoring device is located within e.g. N. F. Eel, S. F. Eel, S. F. Trinity, etc. Optional. This is FSP GIS Derived.
WAAREA	Watershed area above monitoring station in hectares. **Optional.** This is FSP GIS derived.
HUCID	USGS fourth-field eight-digit hyrologic unit code. **Optional.** This is FSP GIS derived.
HUCNAME	Forth field hydrologic basin name as recorded by USGS. HUC ArcInfo coverage (available from the FSP-FTP site).**Optional.** This is FSP GIS derived.
CALWAID	California Planning Watersheds identification number. **Optional.** This is FSP GIS derived.
RBUASPW	California Planning Watersheds unique hierarchical identification number. **Optional.** This is FSP GIS derived.
CALNAME	Watershed name as recorded by CDF in the California Planning Watersheds ArcInfo coverage (available from the FSP-FTP site). **Optional.** This is FSP GIS derived.
STRMNAME	Stream name as recorded by USGS on 7.5 min. quadrangle.
SITETYPE	Data type collected by cooperator.

water - water temperature monitoring
air - air temperature monitoring.
humidity - humidity temperature monitoring.

DATE Date of record (mm/dd/yy)

TIME Time of record (hh:mm:ss)

TEMPC Water temperature in Celsius.

STRCLASS Stream classification as defined by the California Forest Practice Rules.
1 - Class I Watercourse
2 - Class II Watercourse
3 - Class III Watercourse
4 - Class IV Watercourse

HABITAT Habitat classification

riffle - Shallow reaches with swiftly flowing, turbulent water
run - Relatively uniform flowing reaches with little surface agitation
spool - Shallow pools less than 2 feet in depth (no thermal strata)
mpool - Mid-sized pools 2 to 4 feet in depth (no thermal strata)
dpool - Deep pools greater that 4 feet in depth (possible thermal strata)

CHANTYPE **Channel Type** from Flosi et al, 1998 (see appendix A)

DEVICE Make and model of temperature recording device

hobo - Onset HOBO Temperature Data Logger
hoboxt - Onset HOBO XT Temperature Data Logger
stowxti - Onset stowaway XTI Temperature Data Logger
ostow - Onset Optic stowaway Temperature Logger
stowtid - Onset stowaway tidbit Temperature Data Logger
stowawaytxt - Onset stowaway tidbit XT Temp Data Logger
omnidata - Omnidata Temperature Data Logger
mentor - Ryan Temperature Mentor
other - hourly finger method, etc.

DEVICEID Serial number of the monitoring device.

SETTING Device set to collect temperature data instantaneously or using some method of integration (averaging between readings).

instant - set to collect instantaneous readings (most common).
integrated - set to average between readings.
multimax - set to collect max between readings.

CALDATE **Calibration Date** Date of device calibration.

CANOPY **Avg. Canopy Closure** Average canopy closure in percent for the thermal reach or stream segment above the monitoring station.

CCMETHOD Methodology used for canopy cover estimation.

optical - single optical estimate taken at site.
sdens - single spherical densiometer measurement taken at site.
mdens - multiple spherical densiometer measurement taken along thermal reach..
none - no measurements take.

TRLENGTH	**Reach Length** Length of thermal reach upstream of the site measured in feet.
CLENGTH	**Reach Length** Length of the stream segment in meters for which canopy closure was estimated.
BASEFLOW	Average summer baseflow (cfs) at monitoring site.
LWWIDTH	**Wetted Width Launched** Width of the wetted channel (feet) at sensor deployment.
RWWIDTH	**Wetted Width Retrieved** Width of the wetted channel (feet) at sensor retrieval.
BFWIDTH	**Bank Full Width** Width of the channel (feet) at bankfull flow.
BFDEPTH	**Bank Full depth** Depth of the channel (feet) at bankfull flow.
LDEPTH	**Depth Launched** Depth from water surface to monitoring device (feet) at launch.
RDEPTH	**Depth Retrieved** Depth from water surface to monitoring device (feet) at retrieval.
LDATE	**Launch Date** Date and time of monitoring device launch.
RDATE	**Retrieval Date** Date and time of monitoring device retrieval.
COMMENTS	Comments on site location and placement. To include reference distance from site to well defined 7.5 min quadrangle map location i.e. tributary confluence, road crossing, etc.

Here is an example of relational tables produced in EXCEL developed to prepare stream temperature data for submission to the Forest Science Project. This method will reduce data processing time, reduce transcription errors, and provide consistency. Please call (707) 826-3273 if you need assistance.

stations.xls

id	x	y	elev (ft)	acres	huc name	huc	cal name	calwater	creek	site	str_class	habitat	device	reading	canopy (%)	length (ft)	aspect (deg)	bankfull (ft)
201	401115	4497845	2200	21450	LOWER_EEL	18010105	Palmer	111.110220	My River	**humpty**	1	riffle	hobo	instant	80	500	20	620
202	400720	4497070	1520	126308	LOWER_EEL	18010105	Palmer	111.110220	Lucky River	Lucky Star	1	run	hoboxt	integrat	75	100	80	380
203	414315	4526670	800	12753	MAD-REDWOOD	18010102	Powers Creek	109.100100	Whatever Stream	**dumpty**	1	spool	stowxti	instant	50	500	320	420
204	414480	4525720	832	638932	MAD-REDWOOD	18010102	Powers Creek	109.100100	Blue River	site4	1	mpool	ostow	instant	75	1000	270	500
205	402500	4492200	200	37428	LOWER_EEL	18010105	Newberg	111.110200	Red River	site5	2	dpool	stowtid	instant	90	1200	120	1000
206	402575	4496535	2582	4394	LOWER_EEL	18010105	Alton	111.110210	Green River	site6	3	riffle	stowtidx	integrat	95	600	270	200
207	416620	4528740	1263	486531	MAD-REDWOOD	18010102	Powers Creek	109.100100	Yellow River	site7	4	run	omnidata	instant	90	400	90	120

NOTE: Due to space limitations not all site-specific variables are shown in the table. Refer to the attributes in the previous sections for a complete listing.

humpty.xls

id	**date**	**time**	**temp_c**
201	8/9/96	16:33:00	16.3
201	8/9/96	18:09:00	16.3
201	8/9/96	19:45:00	15.9
201	8/9/96	21:21:00	15.6
201	8/9/96	22:57:00	15.2
201	8/10/96	0:33:00	14.8

dumpty.xls

id	**date**	**time**	**temp_c**
203	8/9/96	11:28:58	14.8
203	8/9/96	13:04:58	16.3
203	8/9/96	14:40:58	17.8
203	8/9/96	16:16:58	18.6
203	8/9/96	17:52:58	17.8
203	8/9/96	19:28:58	17.1
203	8/9/96	21:04:58	16.3