City of Corvallis
In-Stream Temperature Monitoring Protocol

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Utilities Division
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Table of Contents

Table of Contents 2
Acknowledgements 3

Introduction 4
Project Overview 4
Background 4

Methods 6
Monitoring Plan Development 6
Project Oversight 6
Data Logger Selection 6
Site Selection 6
Collection Interval 7
Quality Assurance/Quality Control 8
Level of Data Quality 8
Precision 8
Accuracy 8
Field Audits 9
Data Collection 10
Logger Placement/Locality Documentation 10
Equipment Installation 10
Field Audit Procedures 11
Offloading Data in the Field 12
Project Completion 13
Data Logger Retrieval 13
Data Analysis/Reporting 13

References 16

Appendix A. HOBOware® Pro Specifications 17
Appendix B. Map of Corvallis with In-Stream Temperature Monitoring Sites 18
Appendix C. Data Logger Accuracy Check Form 19
Appendix D. Field Audit Form 20
Appendix E. Suggested Equipment List 21

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Disclaimer

This protocol is intended to act as a guide for the placement, retrieval, and documentation of temperature data loggers at individual stream sites and subsequent temperature data handling. In-stream temperature monitoring is not currently required by the City of Corvallis according to state or federal regulations. It is within the City's discretion to make adjustments to this protocol at any time.

Introduction

Project Overview

This document is intended to establish protocol for in-stream temperature monitoring conducted by the City of Corvallis. The purpose of this protocol is to describe guidelines for the placement of data loggers at stream sites, data collection procedures, and subsequent temperature data organization and analysis. It provides background information, methods, data reporting instructions, and a suggested equipment list for in-stream temperature monitoring. An 'In-Stream Temperature Monitoring Binder' (*see references section*) which contains comprehensive site descriptions, photos and sketches as well as field equipment guides and data forms, has been created and should be utilized by project personnel in conjunction with this protocol for replicating this project in the future.

Background

The federal Clean Water Act requires the Oregon Department of Environmental Quality (DEQ) to develop and submit to the U.S. Environmental Protection Agency (EPA) a 303(d) list of state waters that do not meet applicable water quality standards for various beneficial uses, including recreation, fish consumption, and fish rearing. The state is then responsible for developing a Total Maximum Daily Load (TMDL) for the affected water bodies. River miles (RM) 119.7 to 148.8 of the Willamette River, which includes the section that runs through Corvallis, and some Corvallis tributaries are included in the 303(d) listing by DEQ as water quality limited due to bacteria levels, mercury, iron and manganese, and elevated summer temperatures. The Willamette is also listed for depressed levels of dissolved oxygen between RM 54-8 and RM 186.5, another section that runs through Corvallis.

The Upper Willamette River Spring-run Chinook salmon are listed as a threatened species under the federal Endangered Species Act (ESA). Salmon are a temperature sensitive species and require optimal temperatures for reproductive success. Temperature ranges of 4.4-18.8 degrees Celsius support healthy life stages in salmonids; temperatures outside of this range can result in stunted growth and can even be lethal (*DEQ 1999*). The amount of dissolved oxygen (DO) available to aquatic biota decreases as water temperature increases. Depressed DO levels can metabolically stress salmonids, enhancing their susceptibility to disease and mortality (*DEQ 1999*).

In compliance with the ESA protection regulations, the City of Corvallis initiated the Salmon Response Plan in the summer of 2000. The purpose of this plan was to identify citizen and city-sponsored activities that negatively impact Chinook salmon habitat in Corvallis, and to develop protocol which would prevent further degradation to salmon habitat and restore the health of impaired waters (*Dillinger and Jones 2004*). In-stream temperature monitoring was initiated in 2001 to help accomplish one of many goals outlined in the Salmon Response Plan. The monitoring plan, along with other measures,

helped the City to assess progress toward meeting its salmon habitat goals and compliance requirements. More recently, the City of Corvallis TMDL Implementation Plan approved by the DEQ in 2009, identified management priorities to reduce heat pollution in local 303(d) listed waterbodies. In addition, the City of Corvallis has a DEQ National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit, granted in 2007, to guide efforts to improve water quality within the City's jurisdiction.

Due to the increasingly stringent requirements set forth by the EPA and the DEQ, the City of Corvallis is pursuing various options for further reducing heat pollution into the Willamette River. The goal of the in-stream temperature monitoring project is to collect baseline water temperature data to inform future water quality management decisions for the City of Corvallis.

Methods

Monitoring Plan Development

Project Oversight

The 2010 in-stream temperature monitoring pilot project for the City of Corvallis was designed and implemented by AmeriCorps LINKS volunteer Miranda Adams, under the guidance of Public Works Stormwater Program Specialist, Gwenn Kubeck.

Data Logger Selection

The HOBO® U22 Water Temp Pro v2 Logger (*Fig. 1*), manufactured by Onset®, was selected for in-stream temperature data collection based on recommendations from the DEQ as well as surrounding municipalities currently engaged in in-stream temperature monitoring. This data logger is able to continuously record data for weeks or even months; this feature maximizes the likelihood of detecting maximum daily temperatures during the critical stream temperature season. It has a precision sensor for ±0.2°C accuracy over a wide temperature range and is equipped with an Optic USB interface for data offload in the field (*Appendix A, HOBOware® Pro Specifications*).

Fig. 1 HOBO® U22 Water Temp Pro v2 Logger

It is imperative to familiarize oneself with the data loggers and the HOBOware® Pro software prior to installing the equipment in the field. At a minimum, persons operating the equipment must read the HOBOware® 'Getting Started Guide' (refer to the 'In-Stream Temperature Monitoring Binder' to review this document). Pre-deployment accuracy checks must be performed before installing the data loggers in the field and prior to collecting data. The procedure for conducting these accuracy checks is discussed on page 8 of the 'Methods' section of this protocol.

Site Selection

The City of Corvallis previously collected in-stream water temperature data from 14 sites on four streams within Corvallis as part of the City of Corvallis Salmon Response Plan (*2004*). These sites were visited by project personnel in the spring of 2010 to assess the suitability of these locations for continued in-stream temperature data collection.

Site selection for logger placement will ideally be representative in terms of the goal and objectives of the monitoring activity (*Zaroban 2000*). The sites were selected to assess non-point source temperature influences. Locations were chosen to maximize stream

water mixing and minimize the influence of localized warm or cool water sources, such as ground water inflow, point sources, and direct sunlight (*DEQ 1999*). In order to collect representative data, sites were selected to minimize the influence of these potential confounding factors. Further considerations such as ease and safety of site access by project personnel, and likelihood of vandalism (distance away from roads, bike paths, etc.) were taken into account when deciding on site locations.

Thirteen sites were selected for the 2010 monitoring season, closely mirroring the sites previously monitored as part of the City of Corvallis Salmon Response Plan. One of the formerly monitored sites, Oak Creek at Morris Ave. and Hwy 20/34, was inaccessible due to prohibitively deep water, and was omitted from this project. Each site is assigned with a site ID, which correspond(s) to the ID of the data logger(s) placed there. See *Table 1* for brief descriptions and GPS coordinates of each site and *Appendix B* for a map of site locations. Comprehensive descriptions of each monitoring site, including navigation directions, photos, and site sketches, are available in the 'In-Stream Temperature Monitoring Binder'.

Table 1. Data collection sites

Stream Name	**Site ID/ Logger ID**	**Latitude**	**Longitude**	**Location Description**
Dixon Creek	01	44.59234	-123.29768	Walnut Pl. off Walnut Blvd.
	02	44.59393	-123.28448	Walnut Blvd. & 29th St. @ Timberhill Park
	03	44.57809	-123.26991	Beca St. and 16th St.
	04, 05	44.57468	-123.25329	Waterworks Ave and 2nd St. (Wastewater Reclamation Plant)
Dunawi Creek	06	44.54848	-123.29863	Starker Arts Park, downstream of culvert
	07	44.55224	-123.27992	Brooklane Dr. south of Philomath Blvd.
	08	44.55738	-123.30104	North Fork Dunawi Creek, West Hills Rd. First Congregational Church of Christ parking area
Oak Creek	09	44.57717	-123.30788	~1/4 mile upstream of Bald Hill recreation area off Harrison Blvd.
	10	44.58689	-123.30788	North Fork Oak Creek, Walnut Blvd. near Fire Station #5, downstream of bridge
	11, 12	44.57173	-123.31140	Harrison and 53rd/Walnut Blvd., downstream of bridge
	13	44.55841	-123.28454	30th St. off Western near OSU, downstream of bridge
Sequoia Creek	14	44.60005	-123.26182	Meadowridge Pl. off Highland Dr.
	15, 16	44.59000	-123.24483	Conser Dr. at railroad tracks, downstream of bridge

Collection Interval

For assessing maximum stream temperature, temperature monitoring is generally conducted from June through September when solar angles are high and stream flow is low. Based on previous years data, as well as observations made during the 2010 pilot project season, subsequent data collection will begin in early May and will continue through late October.

The HOBO® data loggers have temperature recorders that can be set to record at regular intervals, which allows them to capture the shape of water temperature changes throughout a day. As recommended by DEQ, the monitoring frequency will be set for continuous temperature recordings at 30-minute intervals to best capture the peak daily temperatures of each stream and to improve field audit data interpretations. Using the delay-start function, all of the data loggers will be initially programmed to start recording at the same time and on the same day. For instructions on utilizing this function, refer to the HOBO® *User's Guide* (see references section).

Quality Assurance/Quality Control

Level of Data Quality

Quality assurance/quality control protocols are key components in collecting accurate and meaningful water quality data for any monitoring plan. According to DEQ's *Volunteer Water Quality Monitoring*, Quality Assurance Project Plan (*DEQ 2009*), Level A data is the highest quality data and can be used to assess compliance with state water quality standards, permitting requirements, and/or other regulatory activities. Level B data is the next highest level of data quality and can be used as an early warning of potential problems or for screening information. The data collected for this project will meet DEQ's standard for Level B data or better.

Precision

Precision (*P*), or the amount of agreement among repeated measurements of the same parameter, is an important objective in any water quality monitoring project and is determined by collecting duplicate samples. To meet requirements for Level A or Level B data, *P*= ±1.0°C. DEQ's *The Oregon Plan for Salmon and Watersheds*, Water Quality Monitoring Guidebook (*DEQ 1999*) recommends that two loggers be launched simultaneously at the same location for every ten loggers placed in the field (a 10% precision rate). The data loggers should be placed as close to each other as possible, ensuring that they are in similar in-stream habitat types, at the same depth, and that they will receive similar sunlight influences. Refer to page 11 of this document for specific information regarding the installation of duplicate data loggers.

Accuracy

Accuracy (*A*), or how close the results are to the true/expected value, are determined by conducting pre- and post-deployment accuracy checks. As previously noted, all data loggers must be tested for accuracy before being deployed in the field and after being retrieved from the field.

To determine data logger and field audit thermometer accuracy, prepare a room-temperature water bath ('High Temp') and an ice water bath ('Low Temp') and use a calibrated and maintained National Institute of Standards and Technology (NIST) thermometer accurate to ±0.2°C to perform accuracy checks. To meet requirements for Level A data, *A*= ±0.5°C; to meet Level B standards, *A*= ±2.0°C *(DEQ 1999)*.

Set up the water baths several hours prior to conducting the accuracy checks, allowing ample time for the bath temperatures to stabilize. Program the data loggers to collect temperature readings at one minute intervals.

For the 'High Temp' accuracy check, place the data loggers in the room-temperature bath. After allowing the loggers to equilibrate for 15 minutes or more, record the temperature given by the NIST thermometer every minute for at least five minutes, for a total of six temperature readings. During this procedure, you will also need to check the field audit thermometer by placing it in the water bath with the data loggers and recording the temperature reading once it achieves a stable reading. Record the field audit thermometer temperature and time. Compare the field audit thermometer temperature to the NIST thermometer reading. Once the six 'High-Temp' readings have been taken, remove the data loggers from the warm water bath and place them in the ice-water bath to conduct the 'Low-Temp' accuracy check. Allow them to equilibrate for 15 minutes or more. Record the temperature given by the NIST thermometer every minute for at least five minutes, for a total of six temperature readings. You will need to check the field audit thermometer once again by placing it in the ice-water bath with the data loggers and recording the temperature reading once it achieves a stable reading. After a total of 12 NIST readings are taken (six 'High-Temp' and six 'Low-Temp' readings), remove the data loggers from the water and attach them one-by-one to the coupler to offload and save the data.

Note: It is important to synchronize your watch to the computer's clock (or use the computer's clock) so there are no discrepancies in the time which the accuracy checks occurred.

When the accuracy checks are complete, transfer the data logger temperature readings to the Data Logger Accuracy Check Form (*Appendix C*) and enter the NIST thermometer readings into the appropriate columns on the same spreadsheet. The spreadsheet contains formulae which will automatically calculate and display the audit results. A grade of 'LEVEL A', 'LEVEL B', or 'Fail' will appear for each reading in the 'status' column of the audit form. If the data logger fails the accuracy test, it is outside the range of acceptable criteria and must be retested for correctness. Repeat the accuracy check procedure with the data logger that failed. Equipment failures are most often due to user error. For example, allowing an insufficient amount of time for the data loggers to equilibrate to the water bath can give a faulty result. However, if the data logger continues to fail, a new data logger may be needed, which will have to undergo the same accuracy check procedure. Newly purchased equipment which fails the pre-deployment accuracy check more than once may be defective and should be returned to the manufacturer and exchanged for a properly functioning unit.

Field Audits

Monthly field audits serve several purposes, including ascertaining data logger functionality and documenting changes in the physical characteristics of the sample site. See the 'Field Audit Procedures' section on page 11 of this document for guidance on conducting field audits.

Data Collection

Logger Placement/Locality Documentation

Place the data loggers in an area of the stream where turbulence and mixing occur, preferably in a riffle, run or cascade (*DEQ 1999*). Place the equipment in the main channel, where it appears flow is greatest, and at the lowest point of the channel bed (the "thalweg"), where the data logger will be completely submerged, even as flow naturally decreases during the summer months. To the extent possible, the data logger should be suspended half-way in the water column, where it is not coming into contact with the channel bed (*Fig. 2*). This may become more difficult to achieve as water levels decrease over the monitoring period. The data loggers also need to be fitted with a protective boot to help minimize possible wear and tear that often occurs in the water channel. Data loggers commonly become coated with algae or silt and may be difficult to find during field audits; if the data logger becomes covered in debris or buried in the substrate, the data may be compromised and should be carefully scrutinized for abnormalities. Recording thorough field notes can help explain abnormalities found in data sets.

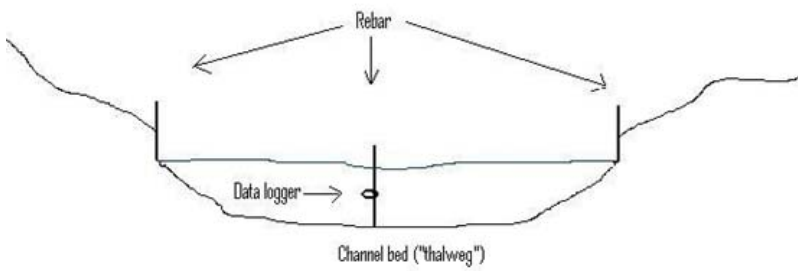

Fig. 2 Data logger placement in the stream channel

Equipment Installation

Field conditions can be unpredictable and challenging. To streamline the equipment installation process, program the data loggers prior to going into the field. To do this, follow the manufacturer's directions closely. Connect the data logger to the laptop, launch the software, and set the equipment to start recording temperature readings at 30-minute intervals. Use the delay-start function so that all the data loggers begin collecting data at the same exact time (see page 13 of the *Getting Started Guide*, included in the 'In-Stream Temperature Monitoring Binder'). Once all of the data loggers are programmed, you are ready to install them in the field.

Refer to the 'Suggested Equipment List' (*Appendix E*) and gather the necessary installation equipment for the monitoring project. Navigate to each site using all of the resources provided in the 'In-Stream Temperature Monitoring Binder'. This binder

includes driving directions, GPS coordinates, photos, a map of site locations, and other useful information pertaining to this project. Once a suitable location is chosen for data logger placement, drive a 3-ft. long piece of rebar into the stream bed using a sledge hammer or mallet. At sites with duplicate loggers, drive two 3-ft. long pieces of rebar into the stream bed approximately 3 inches apart. The rebar should be deep enough in the substrate to resist movement, but should remain visible (if only slightly) above the water to help locate it during field audits (*Fig. 3, 4*). Drive a 1-ft. long piece of rebar into each side of the channel, so that there are a total of three pieces of rebar forming a straight line across the stream channel (*Fig. 2*). The two pieces of rebar on the banks of the stream will help locate the data logger in case of higher flows and can also be used to secure the tape measure when measuring the wetted width during field audits. Each data logger is assigned its own unique identification number, which corresponds with the stream where it will be installed (see *Table 1* for site/logger IDs). This identification number is written on the side of data logger.

Submerge the data logger and secure it to the rebar using several zip-ties; making sure it is about mid-way in the water column. At sites with two data loggers, secure one logger to each of the two pieces of rebar at equal depths.

Fig. 3, 4 Installing rebar in the stream channel (May 2010)

Field Audit Procedures

During monthly site visits, specific physical parameters pertaining to the site, such as water temperature, channel width (wetted-width) and depth, and weather conditions are to be recorded on the Field Audit Form (*Appendix D*). Carefully observe and note any disturbances to the monitoring site, such as vandalism or significant changes in stream flow in the comments column of the form. Using a tape measure, determine and record the wetted-width, by attaching the measuring tape to the rebar on one side of the stream and extending it to the other bank. Wetted width is defined as the distance between the wetted portions of the two stream banks. Measure and record the water depth by placing a depth-rod or yard stick in the channel next to the rebar.

To perform the temperature audit as previously mentioned in the 'Field Audits' section of this protocol, place the NIST-calibrated field audit thermometer in the stream as close as possible to the data logger's sensor. After a stable reading is observed, record the

temperature and the time on the Field Audit Form (*Appendix C*). The logger data will not be immediately available to compare with the temperature audit data; therefore, it is important that there are no discrepancies in the time in which the audit occurred. To minimize discrepancies in otherwise valid data, project personnel must set their watch according to the computer's clock.

Offloading Data in the Field

Follow the procedures below to offload data from the data logger to a laptop in the field.

1) Turn on the laptop and open the HOBOware® Pro software.
2) Locate and detach the data logger from the rebar. Remove it from the stream channel. Remove the protective boot.
3) Using a soft, absorbent cloth, wipe the data logger clean of any algae or excess water.
4) Plug the HOBO coupler into the laptop using the USB cable. Attach the data logger to the coupler.
5) Download the data, closely following the protocol outlined in the 'Getting Started Guide' (page 16), available in the 'In-Stream Temperature Monitoring Binder'.
6) When the download is complete, the program will prompt you to save your data.
7) At this point, you can view the data in graphical form. This is helpful to ensure the logger is functioning properly. If there are any unusual trends such as extended periods of no temperature change, the logger may not be functioning properly and should be replaced with a new one.
8) Re-program the data logger to begin recording at the next time interval, allowing at least 15 minutes for it to equilibrate to the stream temperature. (TIP: Try to time your audits so that there are no 'holes' in the data. For example, if you remove the data logger and download the data at 11:35 a.m., you will have ample time to re-deploy the logger so that the next data point is included at 12:00 pm.)
9) Disconnect the coupler from the laptop and from the data logger and return the data logger to the water, securing it to the rebar with zip-ties.
10) Upon returning to the office, upload the data from the laptop to the City's hard drive using a desktop computer which contains the HOBOware® Pro software.
11) Export and save the data files to Excel. Data files should be saved separately for ease of data organization and interpretation.

Note: DO NOT expose the laptop to inclement weather (i.e. rain). In case of inclement weather, take the data logger back to the truck to download the data.

More detailed information regarding viewing, analyzing, customizing, exporting, and printing data is available electronically in the system folder X:\Divisions\Utilities\Storm Water\Program_Specialist_Files\Stream Health and Data\Temp Monitoring\2010_ Temp_Monitoring_Project\HOBO_Temp_loggers (HOBOware *User's Guide).*

After each field audit, project personnel will need to review the data files to complete the accuracy check. This is done by finding the data point from the time the audit took place and comparing it to the temperature taken with the field audit thermometer during the

field audit. This ensures that the loggers and the field audit thermometer are accurately recording stream temperatures throughout the monitoring season. This is also a good time to look for abnormalities in the data sets.

Project Completion

Data Logger Retrieval

Around late October, when the monitoring period has come to an end, project personnel will visit the field sites to retrieve the data loggers and download the remaining data. Because final accuracy checks will be performed after retrieving the loggers, it is not necessary to perform a final temperature audit, although project personnel may choose to do so. The rest of the Field Audit Form should be completed as normal. Document the condition of the site and the data logger; taking note of whether the logger is still in the water, whether there are any signs of vandalism or disturbance, and any notes about the overall integrity of the logger. Record the date and time accurately. Before leaving the site, gather all the field equipment. For public safety and flood prevention reasons, the rebar should be removed from the stream channel, if it is feasible to do so. Photos may be taken to help document changes in the stream's character over the course of the monitoring period.

Return to the office to download the final data set from the temperature loggers. Conduct the post-retrieval accuracy checks on the data loggers and the field audit thermometer, using the same procedures as described in the pre-deployment accuracy checks. If any of the loggers fail the post-retrieval accuracy checks, first re-test them. If they continue to fail, the data may be compromised and must be omitted from the data set. Finally, clean and organize the equipment and store it in a designated place for future monitoring seasons.

Data Analysis/Reporting

Open each data file individually and chose the preferred parameters to plot in the 'Select Internal Logger Events to Plot' window. Temperature should always be viewed and recorded in degrees Celsius. Refer to the 'Plot Setup Window' section of the HOBOware® 'Getting Started Guide' (page 17) for additional instructions in performing this task. Once you've chosen the parameters you wish to plot, click on the 'plot' box; the HOBOware® Pro software will generate a graph of the data points contained within the data file.

Review the graphs for errors prior to analyzing the data. Scrutinize the plotted data for invalid or irrational segments. Portions of data which show little or no change in temperature, extremely high or low blips, and excessive 'noise', etc. are likely to be erroneous, and need to be omitted from the data set before data analysis begins. After reviewing the data for errors, export all data sets to excel spreadsheets for data analysis. Refer to the '2010 In-Stream Temperature Monitoring Report' (*Adams 2010*) for examples of omitted data sets due to temperature logger disturbance.

Organize the data in a clear and concise manner for ease of interpretation and analysis. Statistical parameters to consider when summarizing stream temperature data are as follows:

1) Mean- calculate daily average temperatures, daily average maximum temperatures and daily average minimum temperatures.
2) Delta (T)- calculate the daily fluctuations in temperature by taking the difference between the daily maximum temperature and the daily minimum temperature.
3) Skew- measure the asymmetry of the distribution of data values. The skewness value can be positive or negative, or even undefined. A negative skew indicates that the majority of the values (including the median) lie to the right of the mean. A positive skew indicates that the majority of the values lie to the left of the mean; positive skewness is statistically more common than negative skewness. For example mode<median<mean indicates a positive skew. A zero value indicates that the values are relatively evenly distributed on both sides of the mean, typically but not necessarily implying a symmetric distribution. Excel has a function which will calculate the skew.
4) Kurtosis- measure the "peakedness" of the probability distribution of the data points. Higher kurtosis means more of the variance is the result of infrequent extreme deviations, as opposed to frequent modestly sized deviations. Excel has a function which will calculate the kurtosis.
5) Seven-Day Moving Average- calculate the seven-day moving average by taking the average temperature from the proceeding three days and the following three days of the day you begin with. For example, if data collection began on May 15, you would calculate the seven-day moving average for May 18 by adding the maximum temperatures from May 15 to May 21 and dividing the result by seven. Do this for the minimum average and the maximum average temperatures.
6) Precision- calculate the precision of the data by plotting the temperature data from those sites that had duplicate data loggers on the same graph and check for conformity.
7) Upstream vs. Downstream Temperatures- graph the seven-day moving maximum average temperatures for each stream site for the entire monitoring season onto the same graph. The temperatures recorded at downstream locations are often generally warmer than upstream locations.

In addition to the parameters discussed above, note the frequency of temperature exceedances according to the DEQ's Water Quality Criteria (*Oregon Administrative Rules*) for designated fish uses, which are as follows:

1) salmon/ trout rearing and migration, 18.0°C
2) core cold water habitat identification, 16.0°C
3) salmon and steelhead spawning, 13.0°C.

Draft a preliminary analysis and report of the temperature data for City records. The '2010 In-Stream Temperature Monitoring Report' (*Adams 2010*) contains the first year's data results and findings using this protocol. Because the 2010 season was the pilot

season for this project, minor deviations from the final protocol occurred. Additional information pertaining to this pilot project, including deviations from the protocol, field forms, accuracy check notes and accuracy check results can be found in the system folder X:\Divisions\Utilities\Storm Water\Program_Specialist_Files\Stream Health and Data\Temp Monitoring\2010_Temp_Monitoring_Project\Report\Relevant_Info. Recommendations for streamlining data collection in subsequent years can also be found in this folder. Some of these recommendations have been incorporated into this protocol, others will need to be considered and decided on by City managers.

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Appendix A. HOBOware® Pro Specifications

HOBO® U22 Water Temp Pro v2
(Part # U22-001)

Inside this package:

- HOBO U22 Water Temp Pro v2 logger

Thank you for purchasing a HOBO data logger. With proper care, it will give you years of accurate and reliable measurements.

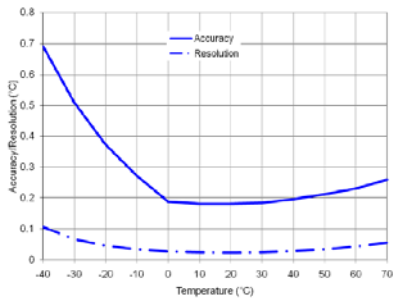
The HOBO Water Temp Pro v2 logger is designed with a durable, streamlined, UV-stable case for extended deployments measuring temperature in fresh or salt water. The small size of the logger allows it to be easily mounted and/or hidden in the field. It is waterproof up to 120 m (400 feet) and rugged enough to withstand years of use, even in stream conditions. It has enough memory to record over 42,000 12-bit temperature measurements.

The logger uses an optical USB communications interface (USB-Optic Base Station, Part # BASE-U-4, with COUPLER2-C) for launching and reading out the logger. The optical interface allows the logger to be offloaded without compromising the integrity of the seals. The USB compatibility allows for easy setup and fast downloads.

HOBOware® software is also required for logger operation. Visit www.onsetcomp.com for compatible software.

Specifications

Temperature Sensor	
Operation range	-40° to 70°C (-40° to 158°F) in air; maximum sustained temperature of 50°C (122°F) in water
Accuracy	0.2°C over 0° to 50°C (0.36°F over 32° to 122°F), see Plot A
Resolution	0.02°C at 25°C (0.04°F at 77°F), see Plot A
Response time (90%)	5 minutes in water; 12 minutes in air moving 2 m/sec (typical)
Stability (drift)	0.1°C (0.18°F) per year
Logger	
Real-time clock	± 1 minute per month 0° to 50°C (32° to 122°F)
Battery	2/3 AA, 3.6 Volt Lithium, factory-replaceable ONLY
Battery life (typical use)	6 years with 1 minute or greater logging interval
Memory (non-volatile)	64K bytes memory (approx. 42,000 12-bit temperature measurements)
Weight	42 g (1.5 oz)
Dimensions	3.0 cm (1.19 in.) maximum diameter, 11.4 cm (4.5 in.) length; mounting hole 6.3 mm (0.25 inches) diameter
Wetted materials	Polypropylene case, EPDM o-rings, stainless steel retaining ring
Buoyancy (fresh water)	+13 g (0.5 oz.) in fresh water at 25°C (77°F); +17 g (0.6 oz.) with optional boot
Waterproof	To 120 m (400 ft.)
Shock/drop	1.5 m (5 ft.) drop at 0°C to 70°C (32°F to 150°F)
Logging interval	Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to HOBOware software manual.
Launch modes	Immediate start and delayed start
Offload modes	Offload while logging; stop and offload
Battery indication	Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
NIST certificate	Available for additional charge
CE	The CE Marking identifies this product as complying with the relevant directives in the European Union (EU).



Plot A

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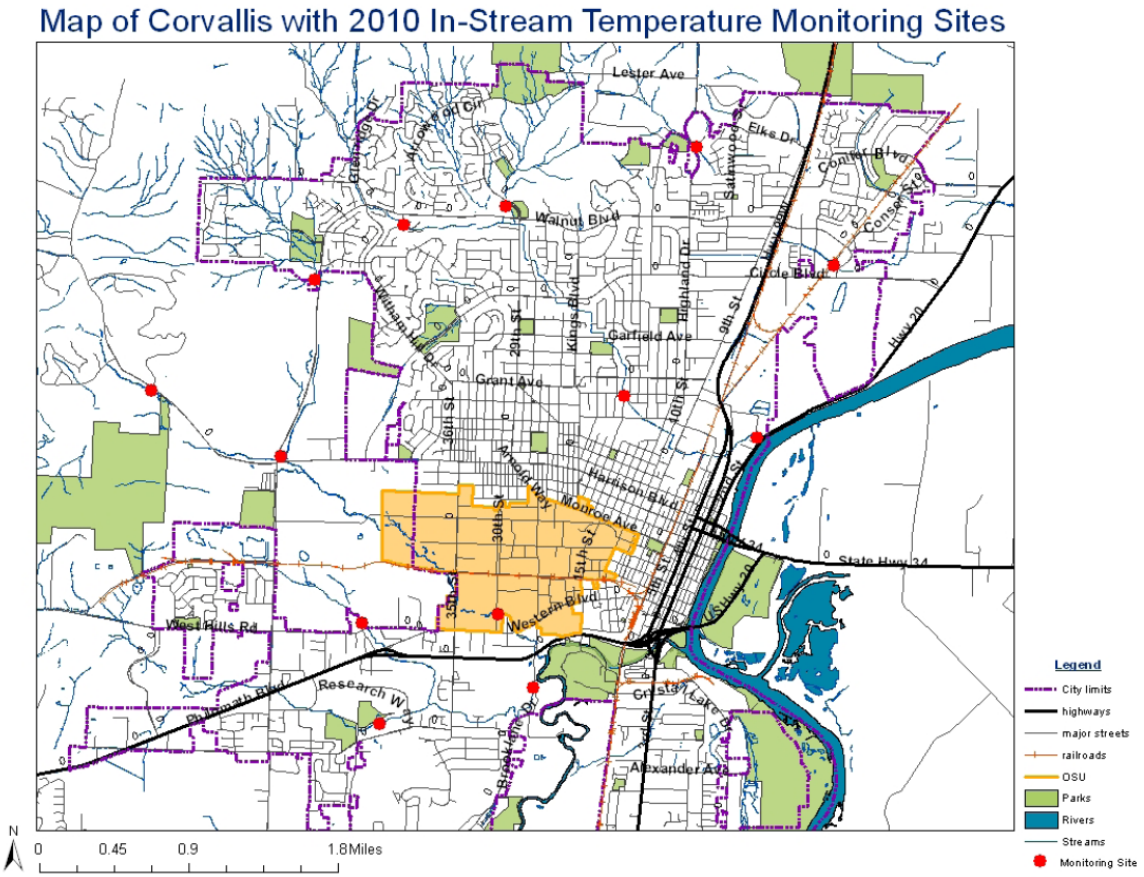
Appendix B. Map of Corvallis with In-Stream Temperature Monitoring Sites



Appendix C. Data Logger Accuracy Check Form

DATA LOGGER ACCURACY CHECK FORM

Pre-Deployment Temperature Check

Data Logger ID# _____ Date: _____
Initials: _____

High Temp

TIME (00:00)	NIST Temp	Unit Temp	Difference	Status
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A

Low Temp Initials: _____

TIME (00:00)	NIST Temp	Unit Temp	Difference	Status
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A

Post-Deployment Temperature Check

Date: _____
Initials: _____

High Temp

TIME (00:00)	NIST Temp	Unit Temp	Difference	Status
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A

Low Temp Initials: _____

TIME (00:00)	NIST Temp	Unit Temp	Difference	Status
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A
			0	LEVEL A

Field Audit Thermometer Accuracy Check

Thermometer ID# _____ Date: _____
Initials: _____

High Temp _____ TIME _____
Low Temp _____ TIME _____

Date: _____
Initials: _____

High Temp _____ TIME _____
Low Temp _____ TIME _____

Appendix D. Field Audit Form

FIELD AUDIT FORM

Site Name: _____

Logger ID#(s): _____

Audit Date	Temp (C)	Time (00:00)	Wetted Width (ft.)	Depth (in.)	Weather Conditions	Comments/Notes

Site Name: _____

Logger ID#(s): _____

Audit Date	Temp (C)	Time (00:00)	Wetted Width (ft.)	Depth (in.)	Weather Conditions	Comments/Notes

Site Name: _____

Logger ID#(s): _____

Audit Date	Temp (C)	Time (00:00)	Wetted Width (ft.)	Depth (in.)	Weather Conditions	Comments/Notes

Site Name: _____

Logger ID#(s): _____

Audit Date	Temp (C)	Time (00:00)	Wetted Width (ft.)	Depth (in.)	Weather Conditions	Comments/Notes

Site Name: _____

Logger ID#(s): _____

Audit Date	Temp (C)	Time (00:00)	Wetted Width (ft.)	Depth (in.)	Weather Conditions	Comments/Notes

Appendix E. Suggested Equipment List

- HOBO U22 Water Temp Pro v2 loggers with protective boots
- Laptop computer w/ HOBOware® Pro software
- Tape measure (preferably metric)
- Yard stick or depth rod
- GPS Receiver
- Calibrated digital thermometer
- Rebar
- Sledge Hammer
- Zip-ties
- Flagging
- Digital Camera
- Waterproof Boots (Waders recommended)
- Raincoat
- Soft cloth
- Pencils, Sharpies, Grease Pens
- Safety gear
    - First Aid Kit
    - Sunscreen and hat
    - cell phone
- In-Stream Temperature Monitoring Binder
    - Salmon Response Plan Executive Summary
    - City of Corvallis TMDL Implementation Plan
    - HOBO® Specifications
    - HOBOware® Getting Started Guide
    - Suggested Equipment List
    - In-Stream Temperature Monitoring Protocol
    - Pre & Post-Deployment Accuracy Check Notes
    - 2010 Deviations from Final Protocol
    - 2010 Field Audit Information
    - 2010 Field Notes
    - Recommendations for Future Monitoring
    - Map of Corvallis with 2010 Monitoring Sites
    - Directions to Sites
    - Site Information/Logger Placement Sheets
    - Site Descriptions w/GPS coordinates
    - Field Audit Forms (printed on '*Rite-in-the-Rain*' paper)
    - Accuracy Check Form
    - List of Helpful Resources