Prepared in cooperation with the National Park Service

Monitoring Stream Temperatures—A Guide for Non-Specialists

Chapter 25 of
Section A, Surface-Water Techniques
Book 3, Applications of Hydraulics

Techniques and Methods 3–A25

U.S. Department of the Interior
U.S. Geological Survey

Cover:
Upper left: East Pinnacles Creek looking north along The Pinnacles, Sierra National Forest, California.
Center: Sycan River looking upstream, Fremont National Forest, Oregon.
Lower right: Big Sawmill Creek looking upstream, Arc Dome Wilderness, Toiyabe National Forest, Nevada.
All photographs by Michael Heck, U.S. Geological Survey.

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
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exercising the authority of the Director

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
	Volume	
ounce, fluid (fl. oz)	0.02957	liter (L)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$°F = (1.8 \times °C) + 32.$

Monitoring Stream Temperatures—A Guide for Non-Specialists

By Michael P. Heck[1], Luke D. Schultz[1], David Hockman-Wert[1], Eric C. Dinger[2], and Jason B. Dunham[1]

Executive Summary

Water temperature influences most physical and biological processes in streams, and along with streamflows is a major driver of ecosystem processes. Collecting data to measure water temperature is therefore imperative, and relatively straightforward. Several protocols exist for collecting stream temperature data, but these are frequently directed towards specialists. This document was developed to address the need for a protocol intended for non-specialists (non-aquatic) staff. It provides specific step-by-step procedures on (1) how to launch data loggers, (2) check the factory calibration of data loggers prior to field use, (3) how to install data loggers in streams for year-round monitoring, (4) how to download and retrieve data loggers from the field, and (5) how to input project data into organizational databases.

Section 1. Getting Started—Why, What, Where, When?

Is This Protocol for You?

Measuring stream temperature seems like a simple task, but in our experience the details matter. Accordingly, several protocols are available for measuring stream temperatures that provide guidelines to help avoid common pitfalls, including Dunham and others (2005), Isaak and Horan (2011), Sowder and Steel (2013), U.S. Environmental Protection Agency (2014), and Mauger and others (2015). Although thorough, these previous protocols lack the clear guidance for implementation for non-specialists. Our objective in this report is to provide a simplified distillation of this advice for non-specialists who may not have experience in monitoring stream temperature, as well as providing standardized techniques and basic reporting. After reading through this protocol, non-specialists with an interest in monitoring streams and water quality will have the capability to effectively install stream temperature data loggers to remotely record water temperatures.

Why Monitor Water Temperature?

In streams, temperature represents the collective influence of many factors that influence heat exchanges (Caissie, 2006), including heat gains from solar radiation, inflows of groundwater or tributaries, and losses of heat from evaporation or radiation to the atmosphere. Changes in streamflows, stream shading, and other factors can significantly influence stream temperatures. Increasingly, changing precipitation patterns, decreasing snow cover and glaciers, and warming air temperatures, among other factors, have led to concerns about warming temperatures in streams (Isaak, Young, and others, 2016). Collectively, temperatures in streams reflect all of these influences.

Temperature also is a central force behind just about every biological process that takes place within stream ecosystems (Magnuson and others, 1979), ranging from the speed of chemical reactions to ecosystem productivity. Across the United States, altered stream temperatures are a leading source of water quality impairment, leading to loss of cold water for species like Pacific salmon (*Oncorhynchus spp.*) and steelhead (*Oncorhynchus mykiss*; Poole and others, 2001) and native trout from the west to east coast (Shepard and others, 2016). In short, simply measuring stream temperature can help us identify locations were restoration actions are needed, provide us insight about how and why temperatures change over time or vary in different locations, and help us anticipate the consequences of these changes for water quality and species distributions.

[1]U.S. Geological Survey.

[2]National Park Service.

Identifying the Key Questions about Water Temperature

The most important step in designing a temperature monitoring effort is to clearly identify the questions that information from monitoring will answer (Nichols and Williams, 2006). Common research questions regarding water temperature include the following:

- *How are temperatures in streams changing over time?* This could be related to an interest in daily fluctuations in temperature, the seasonality of temperature or thermal regimes, or changes across years or longer periods of time—up to 30 years or longer in the case of tracking climate-related changes.

- *How do temperatures relate to potential causes of heating or cooling?* This could be related to the importance of changes to shading of streams from solar radiation, influences of heat exchanges with groundwater, lakes, or runoff from glaciers and snowfields, or an interest in how stream temperatures track air temperatures.

- *How do stream biota respond to temperature?* This could involve relating temperature to the presence, abundance, or growth of species. Summaries of temperature such as magnitude, variability, frequency, duration, and timing could drive biotic processes.

The following sections provide guidance on how to frame specific questions of interest for any monitoring effort.

Status.—The simplest question that can be asked about temperature is "what is it?" This relates to the *status* of temperature in a location and time sampled within a given stream. As with many aspects of temperature, status can have many meanings.

Because temperature is a continuous phenomenon, status can refer to many characteristics. Variation in temperature over time can be framed in terms of the magnitude, frequency, duration, and timing of events (Arismendi and others, 2013a).

- *Magnitude* simply refers to how warm or cold temperatures are. Understanding magnitude can be important for addressing questions about water quality, for example, where water-quality criteria are often specified in terms of magnitudes (Falke and others, 2016).

- *Variability* refers to temporal fluctuations in temperature across a given time period. Although stream fishes have adapted to withstand temperatures fluctuating on a daily basis, the magnitude of that fluctuation must remain within their range of biological tolerances.

- *Frequency* refers to how many times a given thermal condition is observed. For example, there may be an interest in how many times water temperatures exceeded thresholds that might cause biological stress for given fish species or other aquatic organisms.

- *Duration* refers to how long a given thermal condition persists. For example, studies of cold-adapted stream fish (such as trout) shows that thermal tolerance is a function of temperature (magnitude) and its persistence (duration, expressed as the number of days that temperatures exceed a critical threshold; Wehrly and others, 2007).

- *Timing* of temperatures also is important because it may influence the onset of different portions of the life cycle of aquatic organisms (for example, spawning, hatching, migration) or seasonality of factors with major ecosystem consequences (such as onset of algal blooms). Biologists often apply the term *phenology* to the timing of biological events, such as hatching, flowering, or many other types of responses, and there are well established broad phenology networks to track these events in response to changes in weather and climate (USA National Phenology Network accessed at https://usanpn.org/).

Collectively, variation in temperature across seasons within a year, and among years, can be defined as a *thermal regime*, which can be defined in terms of magnitude, variability, frequency, duration, and timing of temperatures (Arismendi and others, 2013a; Maheu and others, 2015; table 1).

For practical purposes, the many ways in which status can be described indicate that it is critical to be clear on what aspects of thermal regimes are of most interest. Furthermore, by embracing a regime-based view of temperature, one can gain a tremendous range of useful insights (Arismendi and others, 2013a), just as can be done for air temperatures. For example, for the purpose of water-quality criteria, thermal regimes are often considered in the context of only a single weekly summary of maximum temperatures (McCullough, 2010). The other 358 days of a typical year also have value in describing stream temperature status; one should consider the costs and benefits of seasonal compared to year-round sampling in this context. Few terrestrial ecologists would consider data from a single week sufficient in describing a thermal regime.

Trends.—Changes in status over time are often referred to as trends. A common meaning of trend refers to a progressive change over time, such as a simple pattern of warming or cooling that may happen in a stream. Other more complex patterns of change are possible, such as temperature cycles linked to climate. Trends can be considered on any time scale. Variation among hours within a day may be of interest to understand short-term exposures of species to temperature (McCullough, 2010). Seasonal warming and cooling (variation among days within a season) is another common response of interest. Annual trends in temperature can provide important clues about responses to short-term events such as wildfires

Table 1. List of examples of how to describe elements of a thermal regime, including magnitude, variability, frequency, duration, and timing of temperatures.

[Modified from Benjamin and others (2016). **Descriptor:** The values in the table below (16, 18, and 20 °C) are common thresholds for mean or maximum temperatures associated with tolerances of coldwater species (cooler values are applied to some species or sensitive life stages [McCullough, 2010]). CTD, Cumulative Temperature Distribution is the date when each site reached the 50th or 75th percentile of total degree days. **Abbreviations:** n, number (quantity of); °C, degrees Celsius; >, greater than; %, percent]

Category	Descriptor	Definition
Magnitude (°C)	Maximum	Warmest temperature (typically of the year)
	MWMT	Maximum Weekly Maximum Temperature[1]
	MWAT	Maximum Weekly Average Temperature[2]
	Degree days	Accumulation of temperatures over time[3]
Variability (°C)	Mean range	Difference between the highest and lowest daily mean
	Max range	Difference between the highest and lowest maximum
	Mean variance	A statistical measure of deviations among daily means
	Max variance	A statistical measure of deviations among daily maximums
Frequency (n)	Days > 16 °C	Number of days in the record that exceeded 16 °C
	Days > 18 °C	Number of days in the record that exceeded 18 °C
	Days > 20 °C	Number of days in the record that exceeded 20 °C
Duration (n)	Consec. days > 16 °C	Consecutive number of days in the record that exceeded 16 °C
	Consec. days > 18 °C	Consecutive number of days in the record that exceeded 18 °C
	Consec. days > 20 °C	Consecutive number of days in the record that exceeded 20 °C
Timing	CTD 50%	Date of attaining 50% of the degree days in a given time frame[4]
	CTD 75%	Same as above, but for 75% of the distribution

[1]Highest 7-day average of maximum daily temperatures in any season or year.

[2]Highest 7-day average of average daily temperatures in any season or year.

[3]Can be calculated by adding up average temperature for each day greater than zero degrees.

[4]Summing degree days provides a tally of cumulative temperatures. Fifty percent is the point at which one-half of the total heat has accumulated within a time frame (for example, within a year).

(Dunham and others, 2007; Heck, 2007) or longer-term changes in climate (Isaak, Young, and others, 2016). As of this writing, however, there are surprisingly few streams that have been monitored for long-enough times (>10 years) to detect reliable trends in the face of regionally changing climates (Isaak and others, 2012; Arismendi and others, 2014; Luce and others, 2014).

Spatial variation.—In recent years, a host of new spatial statistical models have emerged that provide powerful new capabilities for modeling patterns of temperature in whole stream networks (Falke and others, 2013; Ver Hoef and others, 2014; Isaak and others, 2014; McNyset and others, 2015). In practical terms, this means that it is possible to efficiently make connections among locations sampled for stream temperatures to provide a robust and continuous model-based prediction of stream temperatures. The more points that are sampled and how they represent variation in a stream network result in more accurate and precise predictions at non-sampled locations (Som and others, 2014). For example, based on existing data, maps of stream temperatures derived from these new models have been produced for much of the Northeastern (DeWeber and Wagner, 2015) and Western United States (Isaak, Wenger, and others, 2016), and have been used to understand the distributions of temperature-sensitive species in streams.

Additionally, stream temperatures can vary at extremely fine spatial scales, sometimes with biologically significant influences at scales of 1 m or less in the case of coldwater thermal refuges (Torgersen and others, 2012). In short, one can think of spatial variation in terms of the *extent* of the system of interest and the *resolution,* or grain, at which information is sought (Peterson and Dunham, 2010). Examples of extent include questions about a watershed or stream network, or perhaps questions within the boundaries of a given jurisdiction (for example, a National Park or National Forest, State, or other category of land ownership), and not tied to a specific watershed. Within a given spatial extent, one can monitor temperature at a given resolution (for example, samples every 1 km, every 100 m, and so on) to produce a representation of how stream temperatures change through space (Fullerton and others, 2015). The same analogy regarding scale here also applies to time, which we discussed previously in section, "Trends" (Steel and Lange, 2007; Peterson and Dunham, 2010).

Factors influencing temperature.—In our coverage of questions related to status, trends, and spatial variation, we have already indicated some examples of questions tied to understanding factors that influence stream temperature. Ideally, one would quantify each component of the heat budget of a stream and be able to use the basic laws of physics to understand stream temperature. If there is an interest in factors that influence stream temperature, it is important to consider how streams heat in the context of a heat budget (Caissie, 2006), the linkages between these factors and natural or human influences on temperature (Poole and Berman, 2001), and what kinds of information are available that could serve as useful indicators of these influences (for example, geology, landform, climate, or vegetation; Wigington and others, 2012). Boyd and Kasper (2003) provide a useful, detailed review of specific factors that influence heating of streams, including factors influencing shade (for example, topographic and streamside vegetation), heat transfers from below-surface waters or mixing with tributaries, air temperatures, evaporation, and streamflows.

In practice, complete accounting for the heat budget of streams is seldom possible (Caissie, 2006). An alternative approach to understanding factors that influence stream temperature is through structured experimental manipulations (Johnson and Jones, 2000; Groom and others, 2011), but these can be expensive and difficult to implement, particularly in areas where strong land- and water-use restrictions are in effect. It is also difficult to conduct these experiments at scales that are relevant to management concerns about stream temperature (Fausch and others, 2002). Consequently, much of our understanding of factors that influence stream temperature relies on observational and correlational approaches (Caissie, 2006). For example, Isaak, Ver Hoef, and others (2016) and Falke and others (2015) used spatial statistical models to explore linkages between recent wildfires and spatial variability of temperatures in stream networks.

Examples of factors that are commonly studied in relation to changes in stream temperature include the following (see Caissie [2006] for further detail):

- Changes in stream-side vegetation or shading. Trees, shrubs, and other vegetation along the banks of streams, and in some cases (such as very tall trees) in upland areas, can intercept sunlight and prevent solar radiation from reaching water in the stream channel. Changes in vegetation occur seasonally (such as loss of leaves in fall or leaf-out in spring) and annually (such as forest growth, tree mortality, or changes in the types of vegetation) in response to many different natural and human influences. Shading is more likely to have an effect on smaller streams.
- Changes in snow and ice cover, rainfall, and streamflows. Melting snow and ice can lead to substantial cooling of streams, and in combination with rainfall contribute to greater streamflows. Larger streams take more energy to heat. Understanding sources of water, and how they are delivered over time (for example, seasonal patterns of rain, snow, or ice melt), in combination with how water moves through the landscape into streams (for example, storage in aquifers), can be important to understanding heating of streams.
- Changes in the shape of the stream channel. The complexity of stream channels, particularly in cases of complex floodplains or wetlands, can result in increased complexity of stream temperatures. This can provide species that can move an opportunity to take advantage of cold or warm spots in these places to better meet their thermal requirements to complete their life cycles. Localized inputs of groundwater or inputs of solar energy (for example, from lakes or ponds) are common examples of factors influencing temperatures in these settings.
- Changes in below-surface waters. Changes in availability or temperature of groundwater or how water moves between the surface and sub-surface within streams (through changes in shape of the stream channel) can affect stream temperatures (that is, relatively constant temperatures of spring-dominated streams compared to streams dominated by runoff and shallow groundwater storage).
- Influences of lakes or reservoirs. Water at the surface of lakes and reservoirs spends more time in the sun and can contribute heat to streams the surface water flows into. If water is released from the bottom of a deep reservoir into a stream, however, temperatures may be cooled in warmer seasons of the year. Many reservoirs are seasonally stratified into a warm top layer and cold bottom layer in summer.
- Climate change. All influences on stream temperature previously listed are directly or indirectly related to the known and potential influences of climate change. For example, a recent drought in the Western United States led to losses of vegetation (from wildfire), low streamflows, and increased water temperatures in a large stream network (Schultz and others, 2017).

In practice, at least some of the factors listed here are likely to play into questions about stream temperature to be addressed through monitoring.

Implications for biota.—Water temperature and streamflow are considered to be the two most influential variables that control stream biota and ecosystems (Magnuson and others, 1979; Poff, 1997). In practice, stream temperatures and flows often fluctuate together, with interactive effects on biota (Arismendi and others, 2013b; Kovach and others, 2015). Accordingly, many questions about stream temperature are focused on its effects on biota. To protect temperature-sensitive species, many states have identified biological temperature criteria for Clean Water Act regulation (see Todd and others [2008]) or developed methods to integrate spatial models of stream temperature with biological criteria to diagnose thermal impairment of streams (Falke and others, 2016). In short, when considering questions about biota, consider which species are in question (fish, amphibians, macroinvertebrates, and so on), and how they are hypothesized to respond to temperature (survival, growth, and phenology). There are an extensive amount of examples of studies relating individual species to different measures of stream temperature; we provide a few examples here to illustrate a range of possibilities (table 2).

It is not possible here to cover all considerations involved in addressing questions about biota (or ecosystem effects of stream temperature), except to emphasize that these questions are best served by engaging individuals with specialized expertise from the start of a monitoring effort.

Sampling Design

After monitoring questions are identified, the next step is to consider a sampling design. In short, a sampling design considers both the population of interest or sampling frame and how it is sampled. The population of interest consists of all of the possible observations within a defined frame of inference, for example, all of the possible locations that could be instrumented within a given water body. It is usually impossible or impractical to survey everything; a subset or sample of the population is often drawn to make an inference about the population as a whole. The manner in which a sample is drawn influences the bias and precision of the inferences about a population—how well a sample represents the population. Bias is the degree to which a sample truly represents the population, and precision refers to how strongly inferences about a population are resolved. A robust sampling design should consider the need to control both bias and precision.

A full treatment of sampling design is outside of the purview of this protocol, and decisions and intricacies of sample design should not sway or deter an individual from collecting temperature data. The background presented here is intended to provide a reference for those with an interest in the basics of sample design considerations. Given the scarcity of long-term, year-round temperature data, any information

Table 2. Categories of temperature descriptors and selected examples of associated biotic responses of stream biota to them.

[**Category**: n, number; °C, degrees Celsius]

Category	Descriptor	Examples of biotic responses
Magnitude (°C)	Maximum and minimum temperatures	Short-duration or acute physiological stress or death if temperatures are too warm (for example, trout and salmon; McCullough, 2010) or too cold (for example, smallmouth bass; Horning and Pearson, 1973).
	Degree days	Indicator of development time or growth potential in fish (Neuheimer and Taggart, 2007) and stream insects (Everall and others, 2015). Degree days includes both a description of magnitude and *duration* of exposure.
Variability (°C)	Temporal variance	Increased variability in temperatures may lead to greater likelihood of physiological stress in a location (Kammerer and Heppell, 2013).
	Spatial variation	Species need to invest more effort in finding suitable temperatures among locations within a network of streams when spatial variation in thermal suitability increases (Torgersen and others, 2012).
Frequency (n)	Days	Number of days in the record that exceed critical thresholds explained the distribution of different species of native and nonnative trout (Benjamin and others, 2016).
Timing	Date	Species may be adapted to the specific timing of temperatures in systems to successfully complete their life cycles (Vannote and Sweeney, 1980).

gained will be useful for many purposes. At a minimum, we recommend documenting the decision process for (1) where and when samples were collected, (2) the frequency of sampling, (3) total number of samples, and (4) method of sample allocation. We discuss each of these points briefly here to help the non-specialist enter into discussions with sampling experts.

Where and when to sample.—The answer to this question depends on the monitoring objectives. If the objective is to understand the seasonal fluctuations at a previously monitored site, then the answer is simple: deploy the data logger at the previously monitored site for a full-year deployment to represent all seasons. Multi-year deployments also may be of interest, particularly if climate-related associations are relevant (where 30 years or more of data are most desirable). If the monitoring objective is to quantify the distribution of thermal regimes in a given area, then the placement requires more thought. Examples include patterns of temperature among possible locations to sample within a given land ownership, range of a species of concern, water body (lake or stream network), water body type (perennial or intermittent), or any other possible frame of inference.

Frequency of sampling.—Frequency of sampling refers to how often temperatures are recorded. Given the high memory capacity of temperature data loggers, an interval of at least 1 hour or less is a good rule of thumb. Longer intervals between measurements run the risk of missing important high or low temperatures within a day (Dunham and others, 2005).

Sample size.—Desirable sample sizes, or number of locations sampled, depend on the size or extent of the sampling frame and specific objectives of the sampling effort, and the degree of variability in temperatures among sites. Temperatures can vary over very small (<1 m) extents in streams and lakes in association with variable groundwater inputs, lack of mixing between cold and warm layers, and other factors. Mobile animals are often highly capable of exploiting such fine-scale variation in temperature and this may be of interest (Beever and others, 2017). Alternatively, temperatures also vary over larger extents; a broader understanding of spatial and temporal variability in temperature may be of greater interest. Examples include associations between temperature and the topography of landscapes, vegetative cover, or availability of temperature in space or time for migrating species. In any case, the number of samples to represent this variability may be large (>30), even for smaller sampling frames. Note that *any* temperature data collection can be valuable, even if available resources limit sample sizes.

Sample allocation.—Sample allocation refers to how samples are distributed in space or time. The simplest approach is to distribute samples subjectively, based on ease of access, safety concerns, or other concerns not related to statistical representation. However, subjective samples cannot be thought to faithfully represent a larger population of possible samples within a population or sampling frame. The other end of the continuum is a purely random or equal probability sample. This means that each possible location in space or time has an equal chance of being sampled. Probabilistic samples such as this provide a much more reliable representation of the population or sampling frame. There are many other examples of probabilistic designs (Som and others, 2014).

A Few Preliminary Notes

Because this guide is written for non-specialists, we assume users are working with limited resources and hoping to accomplish useful temperature monitoring to address a limited scope of objectives or questions about stream temperature. Virtually any collection of high-quality stream temperature data can be tremendously useful. For example, crowdsourcing of temperature data from a variety of local monitoring efforts has long been the source of valuable temperature information on a national (Eaton and others, 1995) and regional basis (Dunham and others, 2003; DeWeber and others, 2015; Chandler and others, 2016). Thus, even collection of temperature data from a single location to address local objectives has potential to contribute significant information for regional to national applications.

Before getting into the details of how to monitor stream temperature, a few preliminary considerations should be taken into account: (1) the identification of relevant safety protocols, (2) the selection of temperature data loggers and data storage systems, and (3) the planning for the timing of field operations. These three primary considerations should be addressed before moving forward with the Standard Operating Procedures (SOP).

A variety of safety considerations are relevant to working in and around streams, including driving motor vehicles on backcountry roads, hiking to remote field sites, wading on slippery streambeds and in swift water currents, and using hand tools to install temperature data loggers. Even seemingly safe situations can become life-threatening if proper precautions are not taken. Wearing a U.S. Coast Guard approved personal flotation device is recommended when working in and around bodies of water. Beyond that, we encourage all users to consult safety officers within their local units or other experienced personnel for specific guidance on this topic.

In regard to selection of temperature data loggers a variety of options are available (Dunham and others, 2005; U.S. Environmental Protection Agency, 2014). For consistency, we focus on a single brand of instruments (table 3) and their associated hardware and software (table 4). Further, we focus on a single data storage software package (see SOP 6—Importing and Managing Data) so we can be specific on protocols to use. That said, the protocols described here can be adapted to a wide variety of temperature data loggers and software packages. The basic concepts of launching, checking the calibration, installing in a stream, downloading, and exporting of data are all necessary components of any monitoring project.

The timing of field operations will have a profound influence on data quality as well as the safety of the field personnel. Becoming familiar with a hydrologic regime prior to stepping foot in a stream is paramount to a safe and successful monitoring project. Installations should take place at base flow to ensure loggers can be placed safely in the thalweg. The thalweg is defined as the deepest part of the channel at any given cross section. Installing a data logger during high flows is not only dangerous to field personnel but can lead to failure to place the data logger in a deep enough location to stay wet as streamflows recede (unless the entire channel dries). Additionally, if interested in year-round monitoring, additional considerations as to placement location would be required given the higher probability of loss or damage to equipment and thereby data. A review of historical data from U.S. Geological Survey streamgages (https://waterdata.usgs.gov/usa/nwis/rt) can be useful for anticipating when suitable low flows are likely to occur on a particular stream or within a given watershed.

Table 3. Onset data loggers commonly used in stream temperature monitoring programs.

[**Accuracy**: Accuracy for commonly observed stream temperatures (0–35 °C). **Unit cost:** $, U.S. dollars. **Abbreviations:** cm, centimeter; m, meter ; °C, degrees Celsius]

Data logger	Accuracy (°C)	Resolution (at 25 °C)	Battery life (years)	Replaceable battery?	Memory (measurements)	Waterproof (m)	Dimensions (cm)	Unit cost
Onset HOBO® Water Temperature Pro v2 U22-001	±0.21	0.02 °C	6	No	42,000	to 120 m	3.0 × 11.4	$129
Onset HOBO® 64K Pendant® Temperature UA-001-64	±0.53	0.14 °C	1	Yes	52,000	to 30 m	5.8 × 3.3 × 2.3	$59
Onset HOBO® TidbiT® v2 UTBI-001	±0.21	0.02 °C	5	No	42,000	to 305 m	3.0 × 4.1 × 1.7	$133

Table 4. Software and hardware components necessary to use Onset® data loggers.

[**Unit cost:** $, U.S. dollars]

Product	Purpose	Unit cost
Onset HOBOware® Pro Software BHW-PRO-DLD	Software used for all HOBO® data loggers. Use software to launch and read out data loggers, plot data, and export for further analysis.	$99
Onset Optic USB Base Station BASE-U-4	Hardware interface between Onset® data loggers and HOBOware® Pro. Use the base station to launch the loggers on a PC/Mac. Couplers are included for compatibility with Onset U22, Pendant®, and TidbiT® data loggers.	$124
Onset HOBO® Waterproof Shuttle U-DTW-1	Use the waterproof shuttle to download and re-launch the loggers in the field. Connect the waterproof shuttle to a PC/Mac to offload that data into HOBOware® Pro. Waterproof to 20 meters. Couplers are included for compatibility with Onset U22, Pendant®, and TidbiT® loggers.	$249

Section 2. Standard Operating Procedures

Introduction

Figure 1 shows the workflow of the standard operating procedures. Please note that these procedures refer primarily to Onset data loggers. These are commonly used products with which we are most familiar, but procedures for other products would be similar.

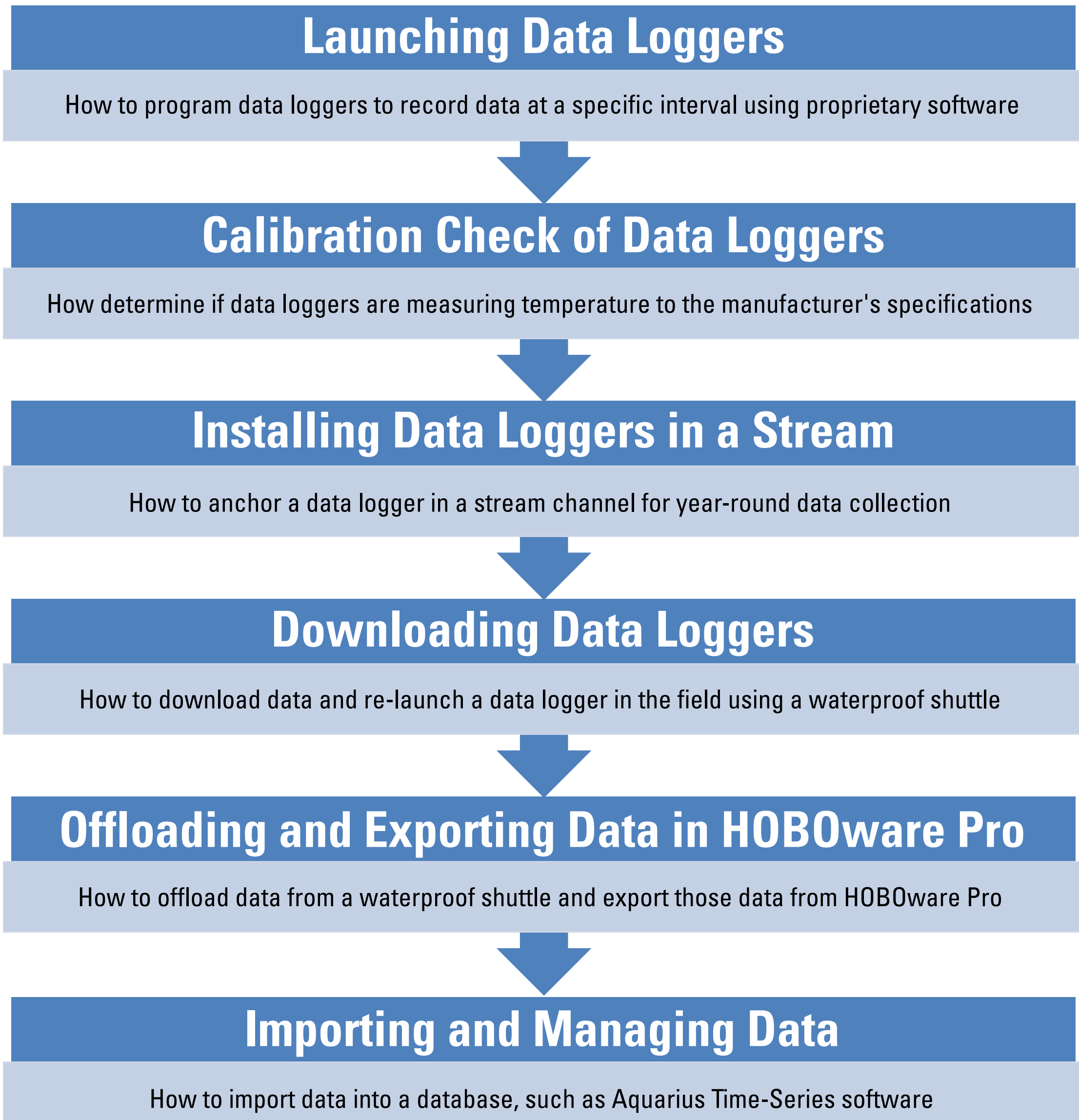

Figure 1. Diagram showing standard operating procedure workflow.

Standard Operating Procedure (SOP) 1—Launching Data Loggers

Overview

This SOP describes how to program temperature data loggers prior to a calibration check or installation in the field. This SOP covers setting a logging interval, programming a delayed launch, and which metrics to record.

Supplies

- Computer with HOBOware Pro software installed
- Onset Optic USB Base Station
- Onset data loggers (U22, Pendant, or TidbiT)
- COUPLER2-A (for Pendant), COUPLER2-C (for U22), or COUPLER2-D (for TidbiT)

Procedure—Set Up HOBOware Pro Software

1. Install HOBOware Pro.
2. Open HOBOware Pro and continue through the HOBOware Setup Assistant.
    a. Click **Start** (fig. 1.1)
    b. Click **USB devices only** > **Next** (fig. 1.2)
    c. Select **SI** from **Unit System** drop-down, then click **Next** (fig. 1.3)
    d. Leave all **Data Assistants** boxes checked, then click **Next** (fig. 1.4)

Figure 1.1. Screen capture showing HOBOware Pro initial **Setup Assistant** dialog box.

Figure 1.2. Screen capture showing HOBOware Setup Assistant **Device Types** selection dialog box.

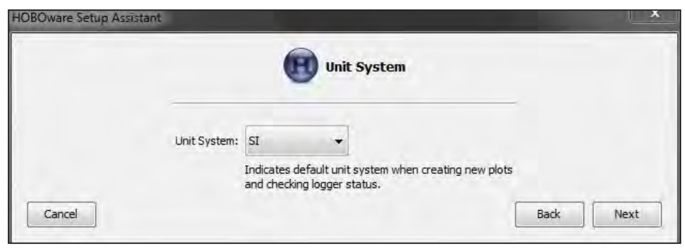

Figure 1.3. Screen capture showing HOBOware Setup Assistant **Unit System** dialog box.

Figure 1.4. Screen capture showing HOBOware Setup Assistant **Data Assistants** selection dialog box.

e. Select whether or not to send metrics to Onset Computer Corporation, then click **Next** (fig. 1.5).

f. Click **Done** (fig. 1.6)

3. Select the option to log battery voltage.

a. On main screen, click **File** > **Preferences** (fig. 1.7).

b. In the navigation pane, click **Display,** then click **Series** to access options (fig. 1.8).

c. Check the box next to **Show the option to log battery,** then click **OK**.

4. Complete steps 1–3 only once as these settings will remain until an update is installed. After updates are installed, repeat steps 1–3.

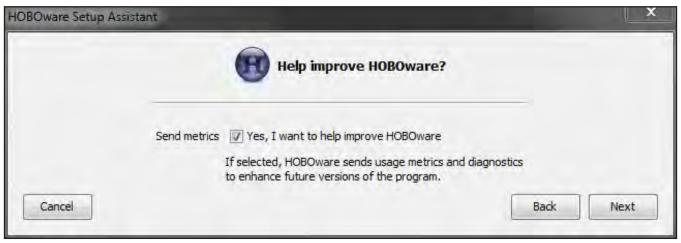

Figure 1.5. Screen capture showing HOBOware Setup Assistant **Help improve HOBOware?** dialog box.

Figure 1.6. Screen capture showing HOBOware Setup Assistant **Congratulations**… dialog box.

Figure 1.7. Screen capture showing HOBOware Pro **Preferences**… option under the **File** menu.

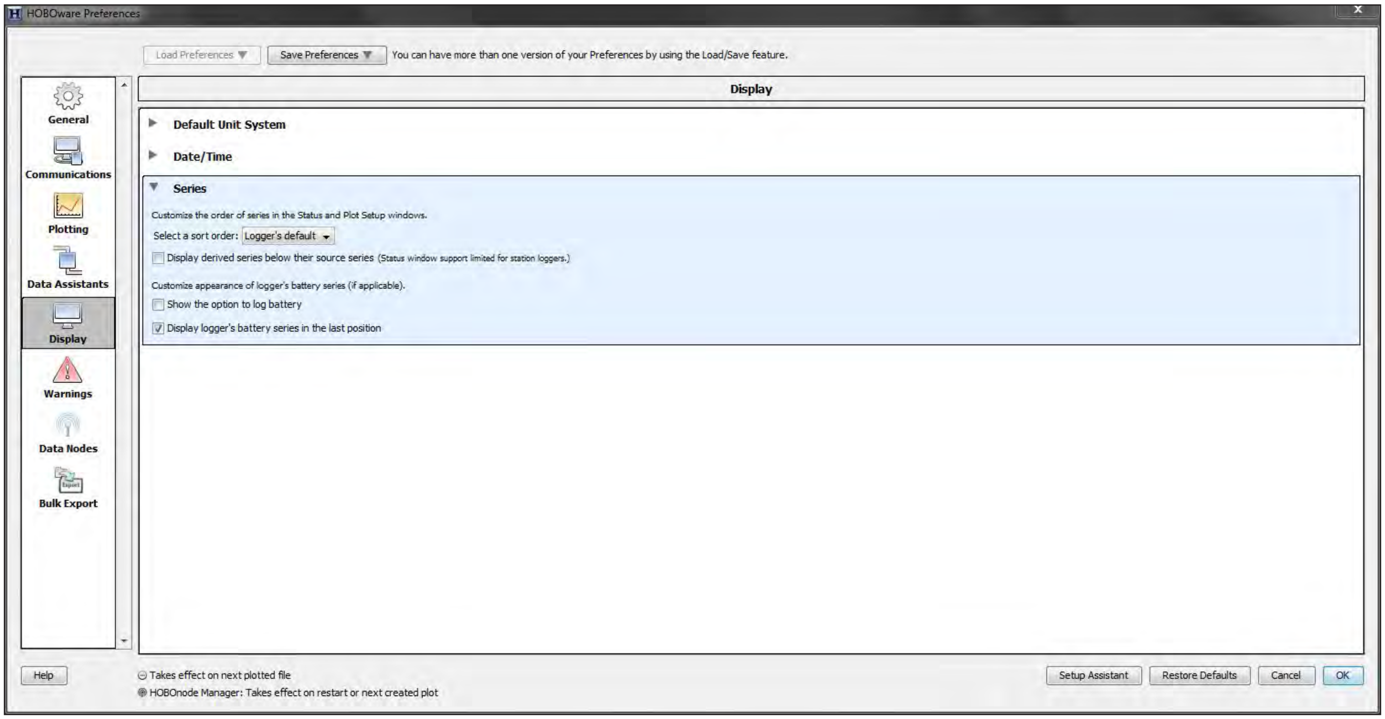

Figure 1.8. Screen capture showing HOBOware Pro Preferences dialog box, **Display** tab and **Series** preferences.

Procedure—Launch a Data Logger

1. Connect the Onset Optic USB Base Station to the computer using the USB cable and the temperature data logger to the base station using the appropriate coupler (fig. 1.9).

    a. Data loggers can occasionally have a tight fit with the coupler. A data logger is fully inserted when you hear an audible "click."

    b. Wait a few seconds for the data logger to be detected by the computer. If no data logger is detected, check all connections, especially the data logger/coupler connection, and make sure the data logger is fully inserted.

    c. For older versions of U22 data loggers, make sure the arrow printed on the outside of the data logger is lined up with the arrow on the coupler.

    d. For newer versions of U22 data loggers, a ridge on the optic end should match the groove in the coupler, ensuring good alignment.

Figure 1.9. Photograph showing Onset couplers for Onset data loggers. From left to right: Coupler2-A for Pendant data loggers, Coupler2-C for U22 data loggers, and Coupler2-D for TidbiT data loggers.

2. On the main screen, click **Device** > **Launch**… to open the **Launch Logger** dialog box (fig. 1.10).

3. Create a Launch Worksheet to record basic metrics from the launch process (fig. 1.11). Only use the Launch Worksheet for field installations (SOP 3—Installing Data Loggers in a Stream). There is no need to record basic metrics from a calibration check (SOP 2—Calibration Check of Data Loggers).

4. Record the unique data logger serial number from the **Launch Logger** dialog box (fig. 1.12).

5. In the **Sensors** group box, make sure both **Temperature** and **Logger's Battery Voltage** boxes are checked (fig. 1.13).

Figure 1.10. Screen capture showing HOBOware Pro **Launch**… option under the **Device** menu.

Serial#	LaunchDate	LaunchTime	LaunchVoltage	Interval
10950791	6/13/2016	8:00am	3.48	1 hour

Figure 1.11. Example of a Launch Worksheet.

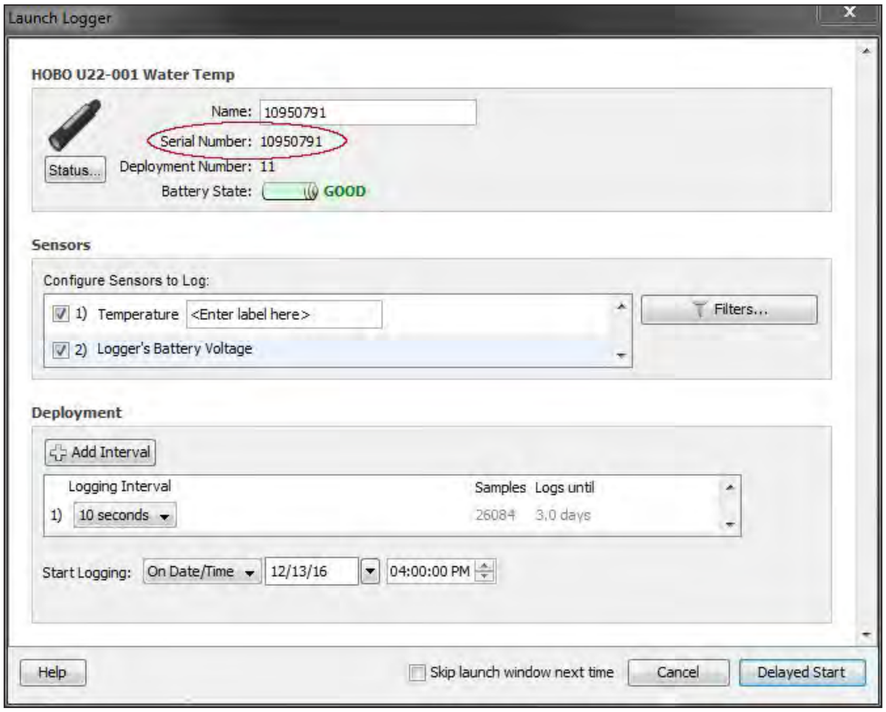

Figure 1.12. Screen capture showing HOBOware Pro **Launch Logger** dialog box. The red oval highlights the unique data logger serial number.

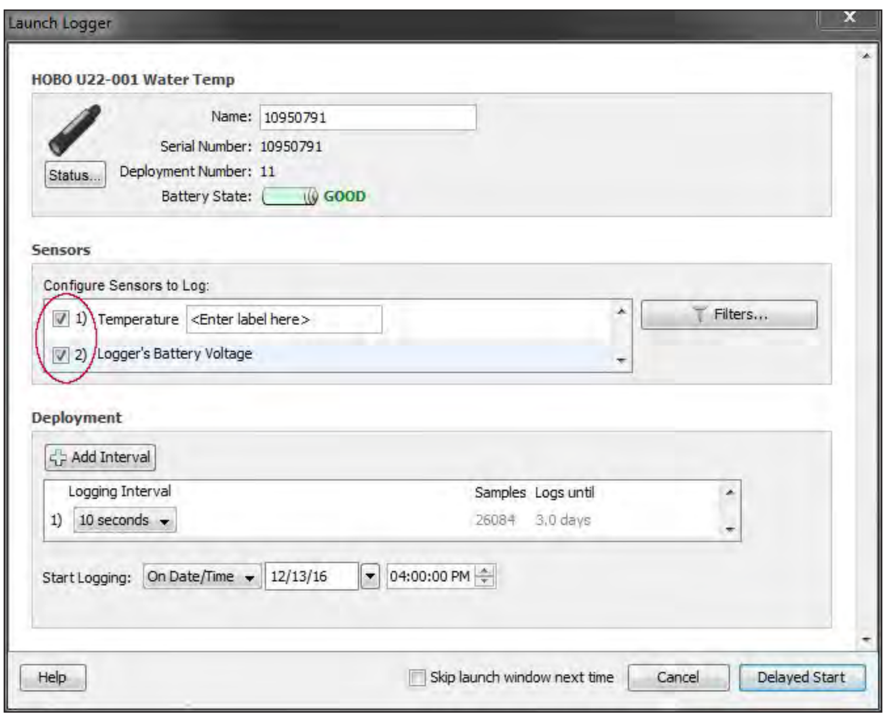

Figure 1.13. Screen capture showing HOBOware Pro **Launch Logger** dialog box. The red oval highlights **Temperature** and **Logger's Battery Voltage** check boxes.

6. In the **Deployment** group box, select desired logging interval from the **Logging Interval** drop-down list (fig. 1.14).
    a. Logging interval recommendations are: 10 seconds for calibration checks (SOP 2—Calibration Check of Data Loggers) and 1 hour for field installations (SOP 3—Installing Data Loggers in a Stream). A 1-hour logging interval has been shown to have a low probability of missing the daily maximum temperature by more than 1°C (Dunham and others, 2005, fig. 5).
7. In the **Deployment** group box, select a delayed start in **Start Logging: On Date/Time** and set to mm/dd/yy at hh:mm:ss. This is the time when the data loggers will activate and begin recording temperatures.
    a. A delayed start will reduce, but not eliminate, the amount of measurements collected before the data logger is installed in a stream. It is acceptable for data loggers to begin recording several days or weeks before their field installation as long as data recorded prior to installation is flagged as “pre-install” at the conclusion of monitoring.
    b. Record the date/time of the delayed start on the Launch Worksheet (fig. 1.11).
8. Click **Delayed Start** to launch the data logger.
9. Record the battery voltage at the time of launch on the Launch Worksheet. Voltage is important to note because installing a data logger with a low battery could result in data loss.
    a. On main screen, click **Device** > **Status** (fig. 1.15).
    b. The battery voltage is shown in the **Current Readings** group box of the Status dialog box (fig. 1.16).
    c. Onset U22 data logger battery voltage should be greater than 3.3 volts (V); and Onset TidbiT and Onset Pendant data loggers battery voltage should be greater than 2.7 V. Send data loggers with voltages below these levels back to the manufacturer.
10. Disconnect the data logger from the base station. It is now ready for its calibration check (SOP 2—Calibration Check of Data Loggers) or installation in the field (SOP 3—Installing Data Loggers in a Stream).

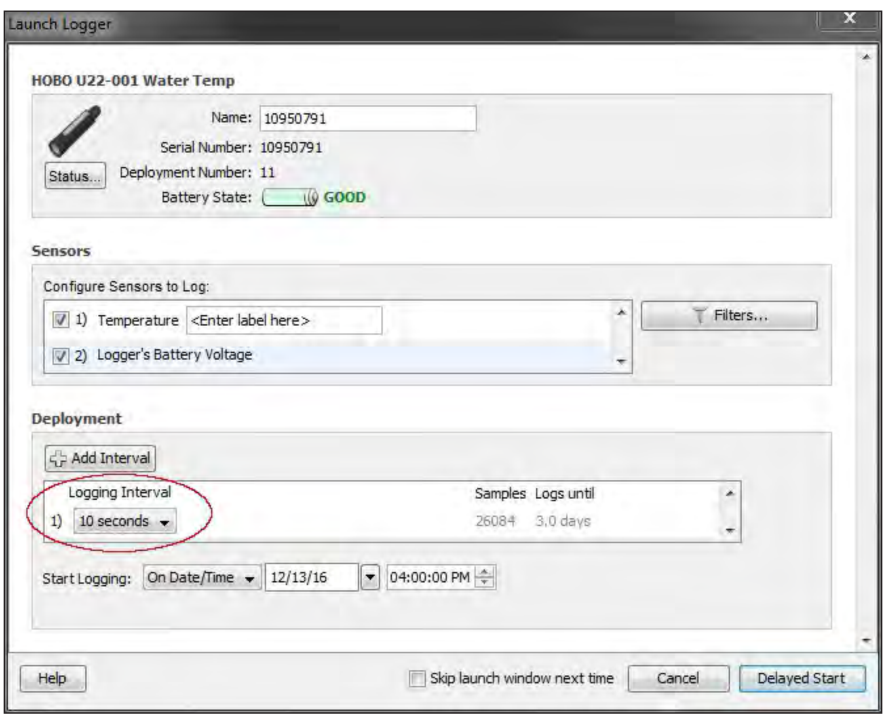

Figure 1.14. Screen capture showing HOBOware Pro **Launch Logger** dialog box. The red oval highlights the **Logging Interval** drop-down list.

Figure 1.15. Screen capture showing HOBOware Pro **Status…** option under the **Device** menu.

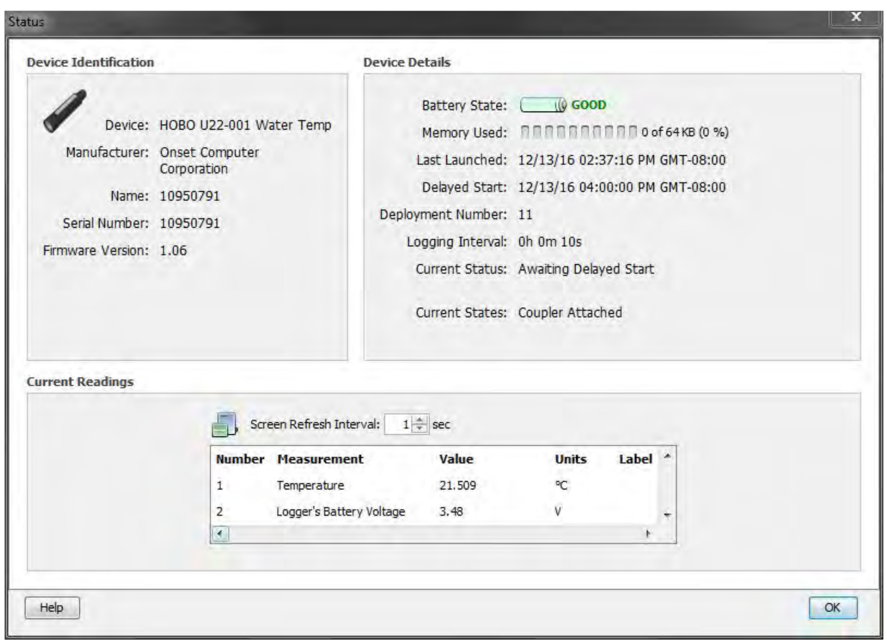

Figure 1.16. Screen capture showing HOBOware Pro **Status** dialog box.

Standard Operating Procedure (SOP) 2—Calibration Check of Data Loggers

Overview

This SOP describes how to determine if data loggers are measuring temperature to the manufacturer's specifications. Thermometers and data loggers calibrated to National Institute of Standards and Technology (NIST) standards are available as a reference during calibration checks. A calibration check should be performed before and after each field installation. A calibration check consists of data loggers recording for 30 minutes in a warm bath, 30 minutes in a cool-down bath, and 30 minutes in a cold bath. This process takes approximately 2 days to complete.

Supplies

- Three coolers (large enough to submerge all data loggers with lots of extra room)
- Crushed ice
- Onset data loggers (U22, Pendant, or TidbiT)
- One NIST-calibrated Onset data logger (use same model as data logger being calibrated: U22, Pendant, or TidbiT)
- 8-in. cable/zip ties (0.095 in. width)
- 10-oz lead fishing weights (one weight per five data loggers)
- Onset Optic USB Base Station
- COUPLER2-A (for Pendant), COUPLER2-C (for U22), or COUPLER2-D (for TidbiT)
- Computer with HOBOware Pro software installed

Procedure—Day 1

1. Fill a cooler about 3/4 full with room temperature water and place in a climate controlled room (stable air temperature). This will be the warm bath.
2. Launch data loggers, including the NIST-calibrated data logger following procedures in SOP 1.
    a. Select a 10 second logging interval.
    b. Set a delayed start to a time the following day to initiate the calibration check. Make sure there is adequate time to set up the cold bath (see step 4).
    c. Create a Calibration Check Worksheet to record basic metrics from the calibration process (fig. 2.1).
    d. Record the serial number and battery voltage at the time of launch on Calibration Check Worksheet.

Serial#	CalibVoltage	CalibDate	CalibMeanWarmDiff	CalibMeanCoolDiff
10768077	3.57	7/26/2016	0.068	0.011
10768078	3.54	7/26/2016	0.057	0.084
10768079	3.57	7/26/2016	0.019	0.000
10768080	3.57	7/26/2016	0.043	0.055

Figure 2.1. Example of a Calibration Check Worksheet.

3. Bundle five data loggers and one 10-oz lead fishing weight together with an 8-in. cable/zip tie (fig. 2.2).

4. Immerse launched and bundled data loggers in the warm bath and let soak overnight with the cooler lid open (fig. 2.3).

Figure 2.2. Photograph showing five Onset U22 data loggers attached to a 10-ounce lead weight with an 8-inch cable/zip tie.

Figure 2.3. Photograph showing four clusters of five Onset U22 data loggers soaking in a warm bath used for a calibration check.

Procedure—Day 2

1. Approximately 3 hours before the data loggers are programmed to start recording, fill two coolers about 3/4 full with crushed ice and add cold water until ice is fully immersed in water.
    a. Close lids and place coolers in the same climate controlled room (stable air temperature). These will be the cool-down and cold baths.
2. Following the delayed start time, begin mixing the water in the warm bath by gently lifting one end of the cooler about 4 in. off the ground.
    a. Repeat this mixing/lifting about every 20 seconds for 30 minutes. The warm calibration check is complete.
3. Remove the bundled data loggers from the warm bath and immerse them in the cool-down bath (one of the two coolers with ice/water mixture) and close the lid.
    a. The cool-down bath is used to decrease the temperature of the data loggers from room temperature to about 0 °C.
    b. Leave the data loggers in the cool-down bath for 30 minutes.
4. Remove the bundled data loggers from the cool-down bath and immerse them in the cold bath.
5. Mix the water in the cold bath by gently lifting one end of the cooler about 4 in. off the ground.
    a. Repeat this mixing/lifting about every 20 seconds for 30 minutes. The cold calibration check is complete.
6. Open HOBOware Pro software and download all the available updates, if prompted (fig. 2.4)
7. Connect the Onset Optic USB base station to the computer using the USB cable and connect a temperature data logger to the base station using the appropriate coupler (see SOP 1—Launching Data Loggers).

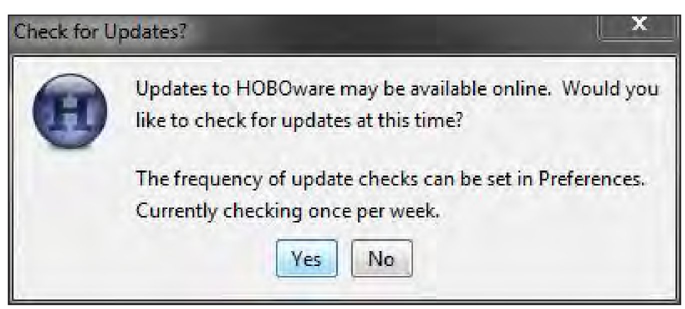

Figure 2.4. Screen capture showing HOBOware Pro **Check for Updates?** dialog box.

8. Readout data from the data logger.

   a. On the HOBOware Pro main screen, click **Device** > **Readout**… (fig. 2.5).

   b. When prompted to stop the data logger, click **Stop** (fig. 2.6).

   c. Create or select a folder in which to store .hobo file, then save the file (fig. 2.7).

   d. The **Plot Setup** dialog box will open (fig. 2.8). To see a graph of the data, click **Plot**, otherwise click **Cancel**.

Figure 2.5. Screen capture showing HOBOware Pro screen capture showing the **Readout**… option under the Device menu.

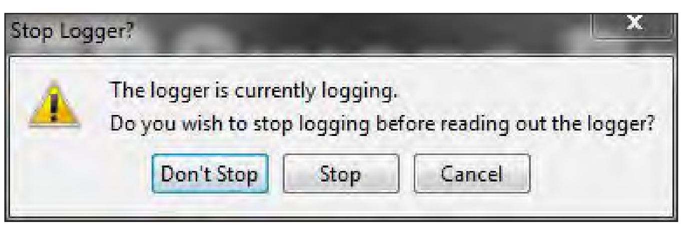

Figure 2.6. Screen capture showing HOBOware Pro **Stop Logger?** dialog.

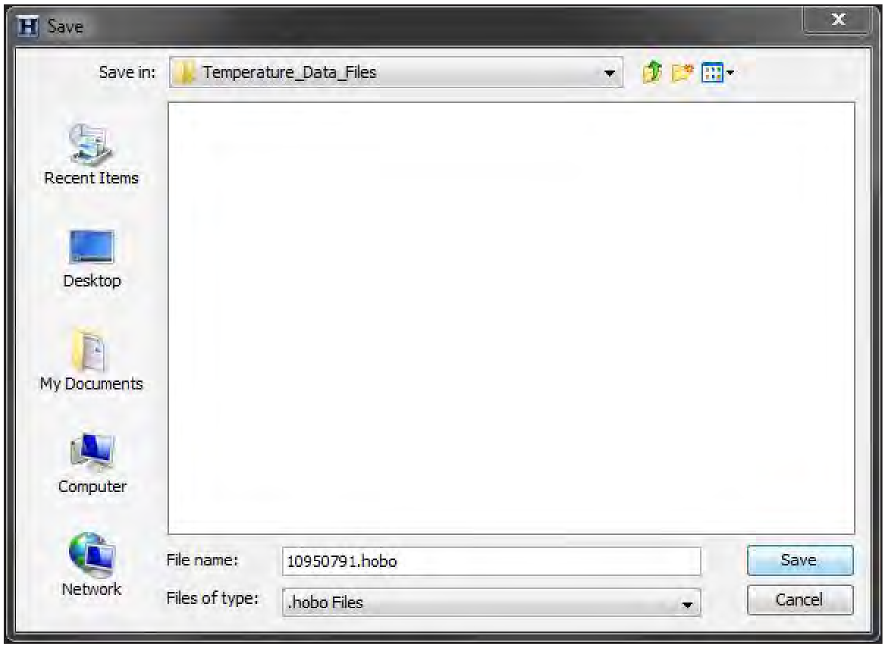

Figure 2.7. Screen capture showing HOBOware Pro **Save** dialog box to determine the location to save a .hobo file.

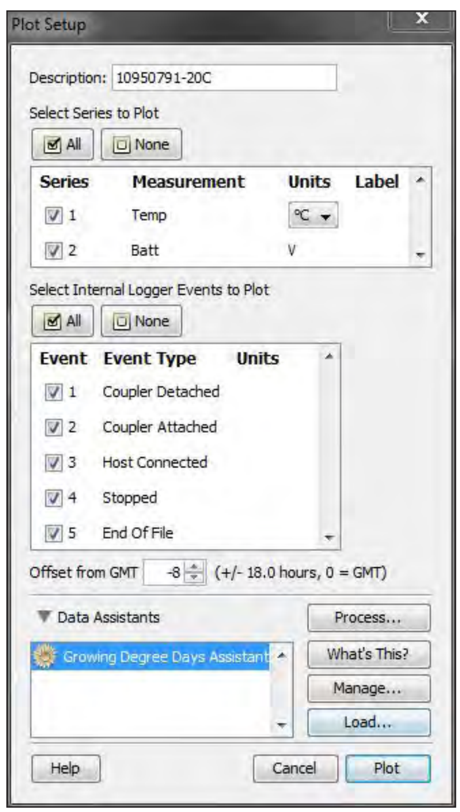

Figure 2.8. Screen capture showing HOBOware Pro **Plot Setup** dialog box.

9. Disconnect the temperature data logger from the base station. After readout, the data logger will be stopped and will remain in that state until it is launched again.

10. Continue to readout data from all data loggers (repeat step 7).

11. After reading out data from all data loggers, export the .hobo files as .csv files.

    a. On the HOBOware Pro main screen, click **Tools** > **Bulk File Export** > **Select Files to Export**… (fig. 2.9).

    b. Browse to the folder where the .hobo files were saved and select all the files, then click **Continue** (fig. 2.10).

    c. In the **Choose Export Folder** dialog box, choose folder where to save the .csv files, then click **Export** (fig. 2.11).

    d. When the bulk file export is complete, click **OK**.

12. Close HOBOware Pro.

13. Open Microsoft Excel or other spreadsheet application and create a blank worksheet.

Figure 2.9. Screen capture showing HOBOware Pro **Select Files to Export**… option under the **Bulk File Export** option, under the **Tools** menu.

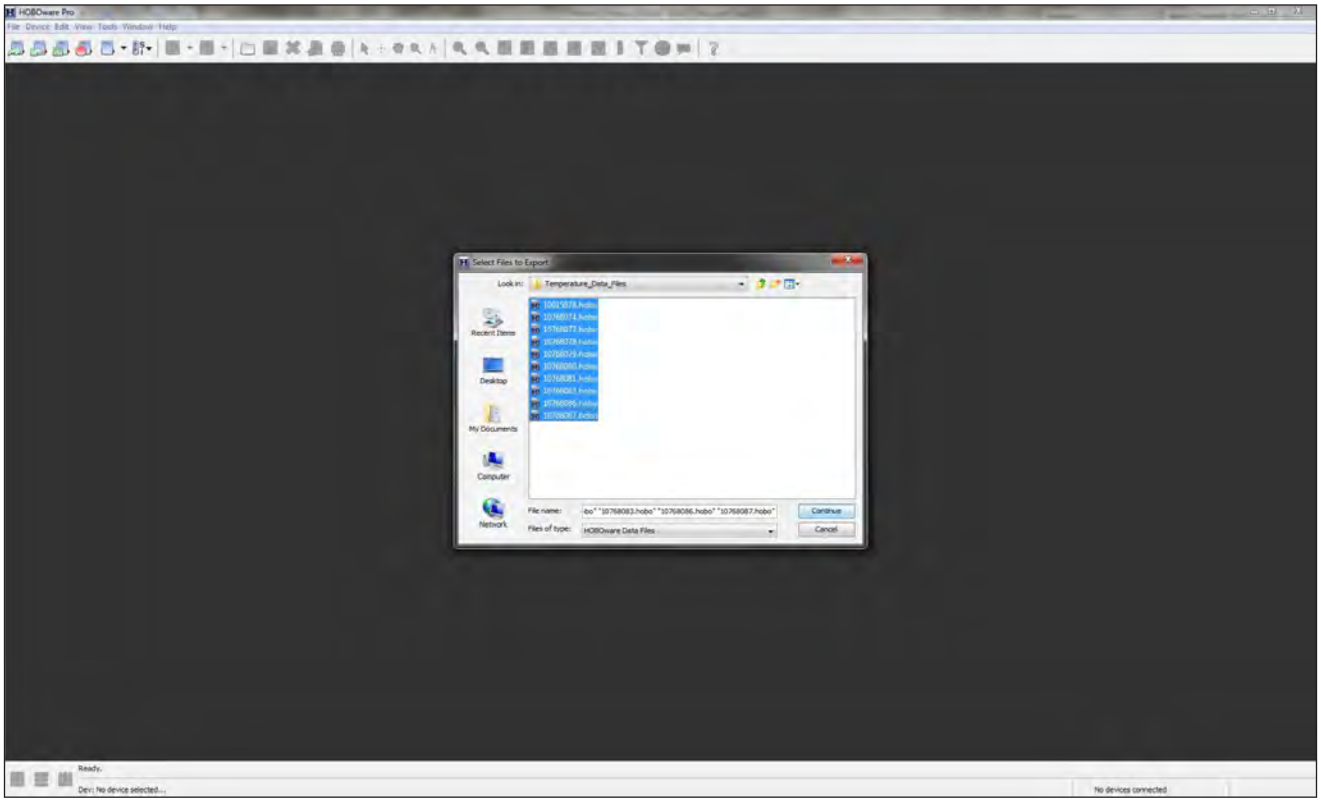

Figure 2.10. Screen capture showing HOBOware Pro **Select Files to Export** dialog box to select .hobo files to export as .csv files.

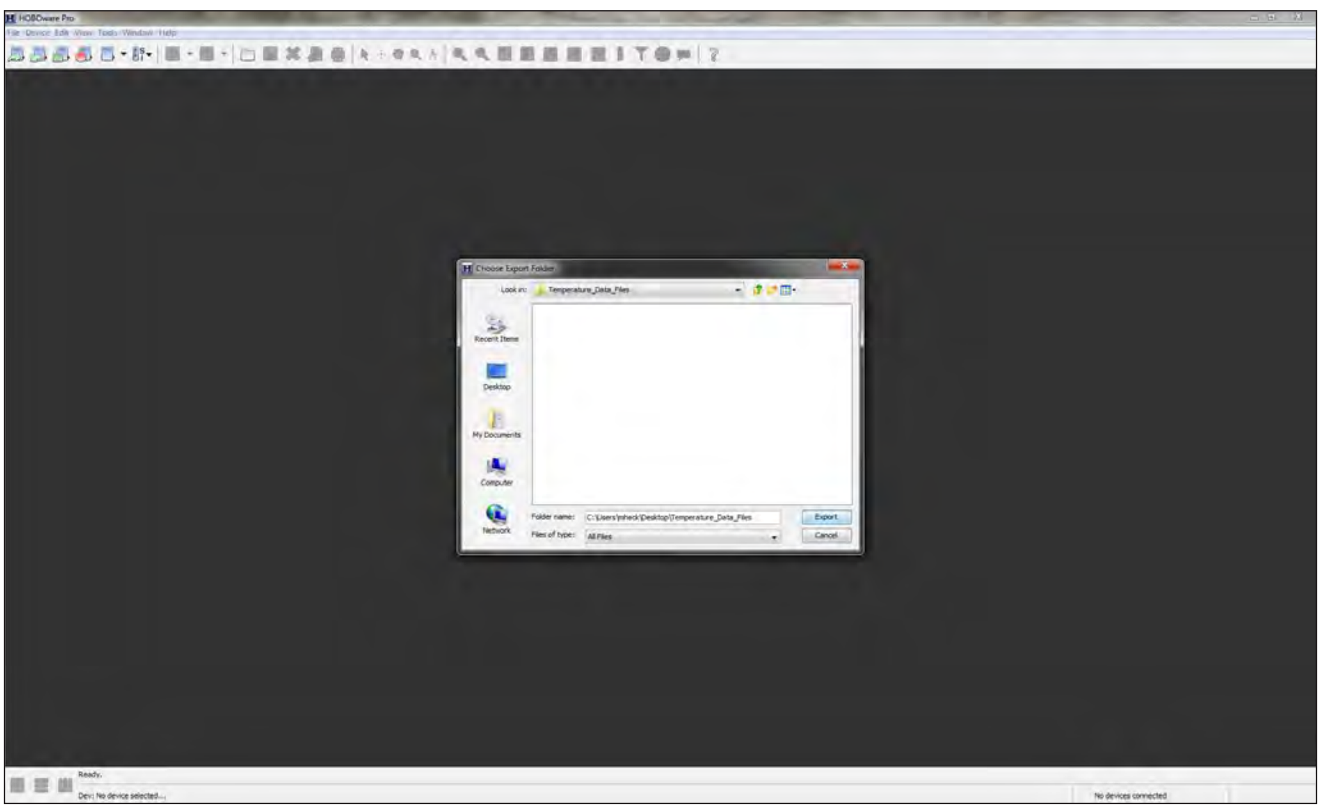

Figure 2.11. Screen capture showing HOBOware Pro **Choose Export Folder** dialog box to determine the location to export .csv files.

14. Open an exported .csv file, select the Date Time and Temp columns (fig. 2.12), then copy and paste them into columns A-B of the blank worksheet.

15. Continue opening .csv files and copying and pasting the Date Time and Temp columns into C-D, E-F, G-H, and so on (fig. 2.13). The header of the Temp column can be shortened to the data logger serial number (S/N).

16. Create a graph of data logger temperatures over time. Make sure to include the NIST-calibrated data logger temperatures (fig. 2.14).

    a. Identify a period during the warm bath of greater than or equal to 15 minutes (90 consecutive records) when data loggers are recording highly consistent temperatures. It is not possible to quantify what “highly consistent” temperatures are because the purpose of the calibration check is to look for data loggers that are dissimilar from one another and the NIST data logger. That comparison needs to be made when all data loggers are recording temperatures in a highly consistent or similar way.

    b. Identify a period during the cold bath of greater than or equal to 15 minutes (90 consecutive records) when data loggers are recording highly consistent temperatures.

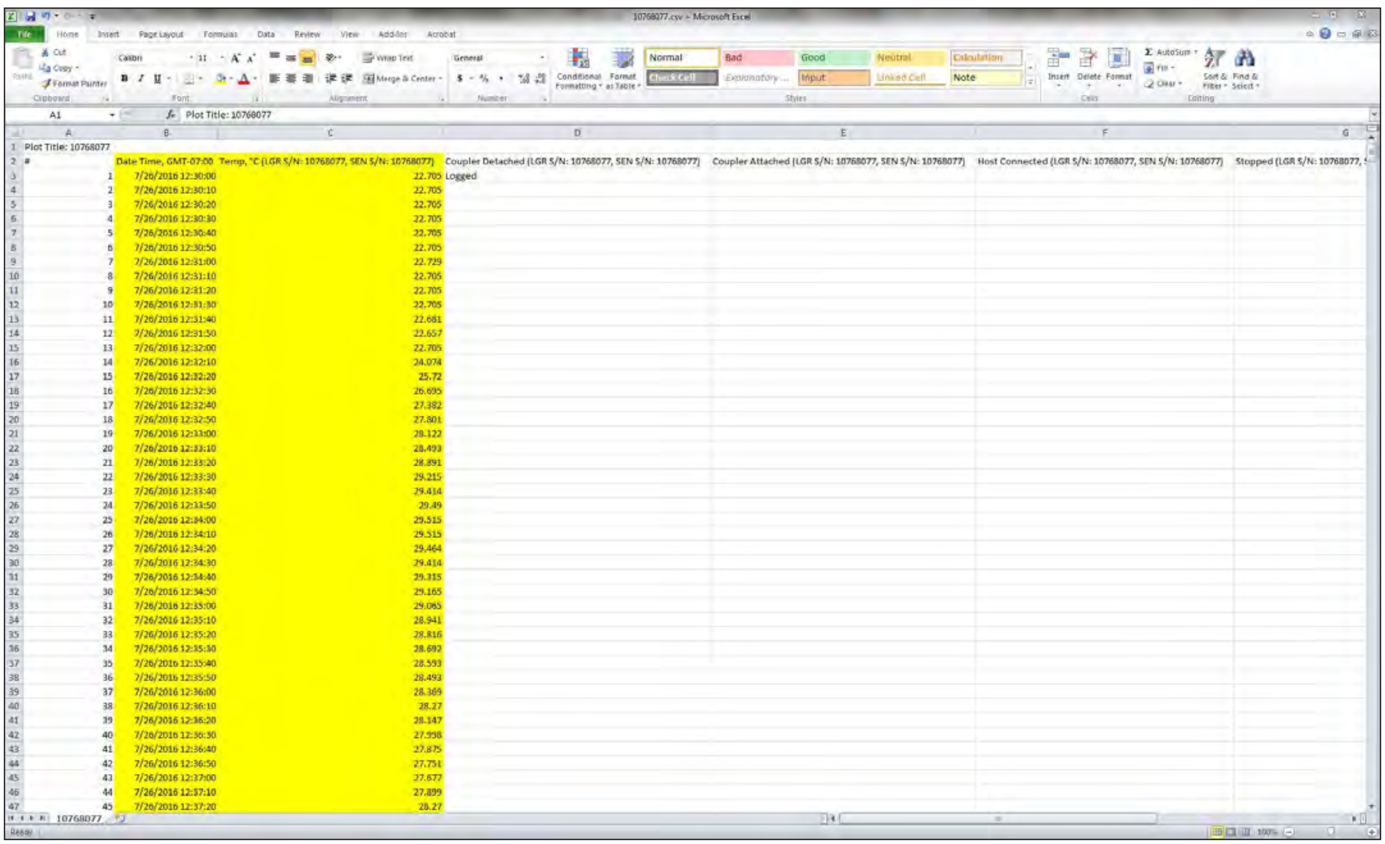

Figure 2.12. Screen capture showing exported .csv file opened in Microsoft® Excel with the **Date Time** and **Temp** columns highlighted.

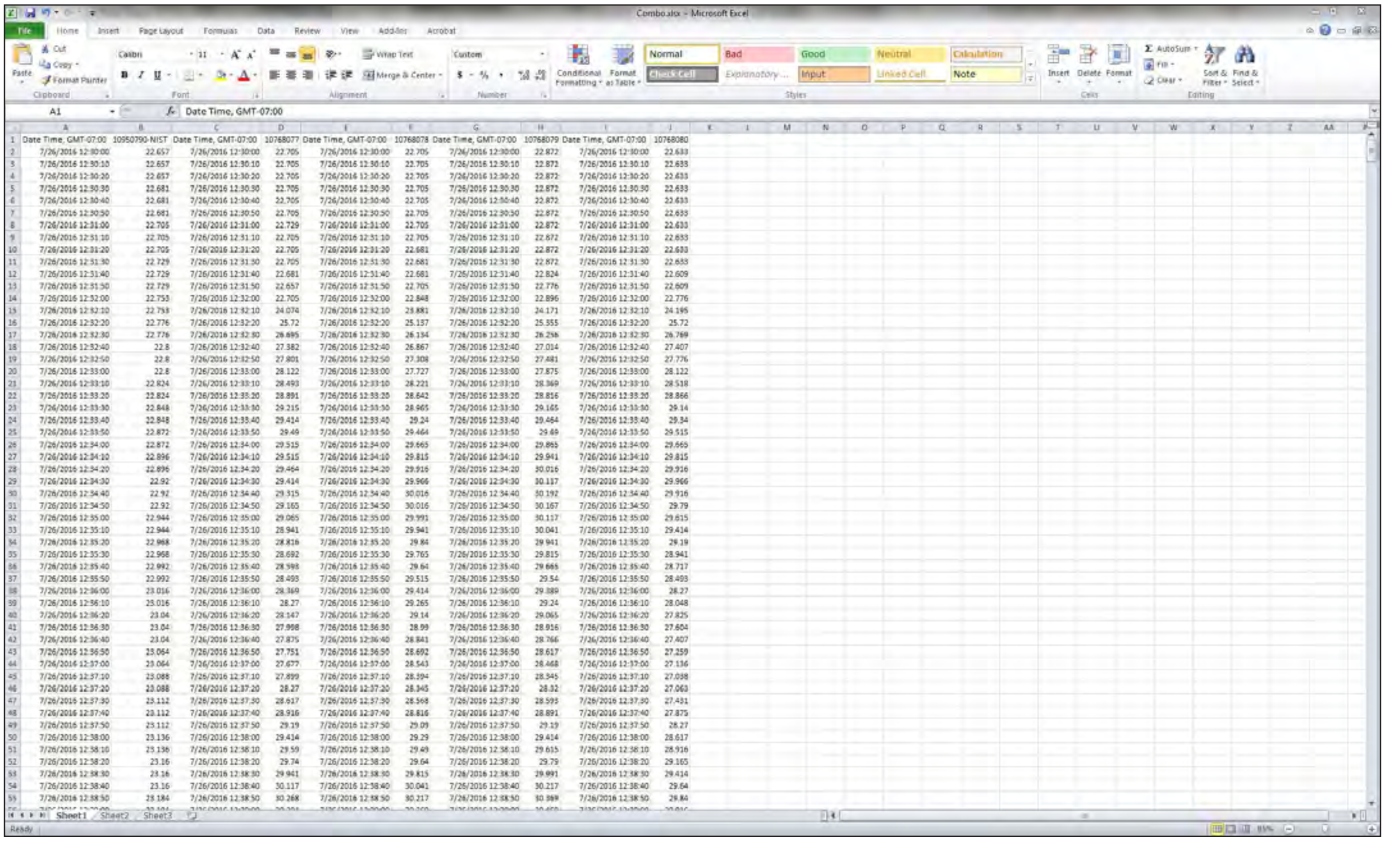

Figure 2.13. Screen capture showing Microsoft® Excel with **Date Time** and **Temp** columns copied from five .csv files and pasted into one worksheet. The **Temp** column headers were shortened to the data logger serial number (S/N).

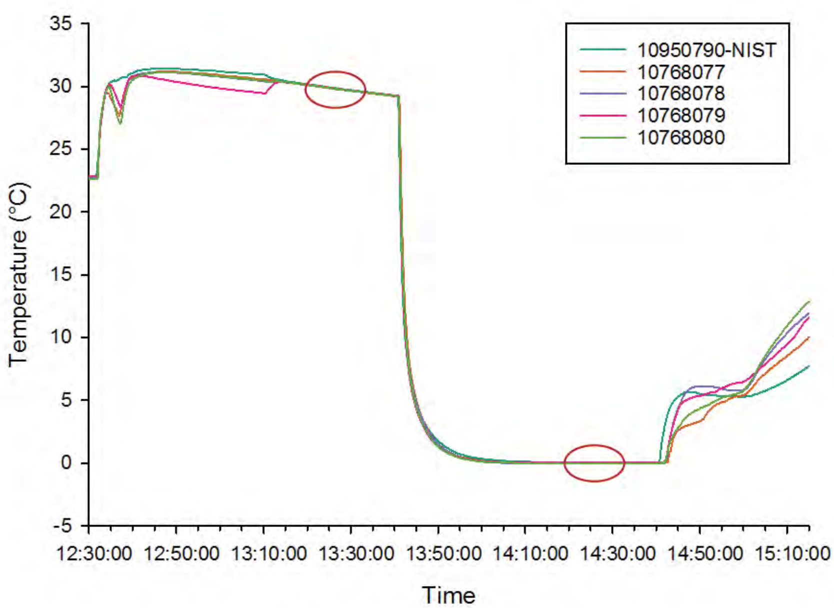

Figure 2.14. Graph showing temperature over time for five Onset U22 data loggers. During this calibration check, data loggers were placed in a warm bath before moving to a cool-down and then a cold bath. Periods of 15 minutes (90 consecutive records) with highly consistent temperatures are highlighted by red ovals.

17. Calculate the mean temperature for each data logger during that period of 90 consecutive records during the warm calibration.
18. Calculate the difference between the mean temperature of the NIST calibrated data logger and mean temperature of each individual data logger.
    a. Record that value under CalibMeanWarmDiff in the Calibration Check Worksheet (fig. 2.1).
19. Calculate the mean temperature for each data logger during that period of 90 consecutive records during the cold calibration.
20. Calculate the difference between the mean temperature of the NIST calibrated data logger and mean temperature of each individual data logger.
    a. Record that value under CalibMeanCoolDiff in the Calibration Check Worksheet (fig. 2.1).
21. Diagnose data loggers with inaccurate measurements by identifying data loggers with a CalibMeanWarmDiff or a CalibMeanCoolDiff that is outside the manufacturer specified tolerance.
    a. Accuracy for Onset U22 and TidbiT data loggers is ±0.21 °C.
    b. Accuracy for Onset Pendant data loggers is ±0.53 °C.
    c. Send inaccurate data loggers back to the manufacturer.

Procedure—Post-Field Installation Calibration Check

1. Perform a calibration check after a data logger has been collected following field installation to check for drift in temperature measurements.
    a. Drift of temperature measurements is when pre- and post-field calibration checks are not equal.
2. Test the accuracy of a data logger following its field installation by performing the same 2-day calibration check as outlined here.

Standard Operating Procedure (SOP) 3—Installing Data Loggers in a Stream

Overview

This SOP describes how to anchor a data logger in a stream channel for year-round data collection. This SOP also covers which site characteristics to record to make retrieving the data logger easier.

Supplies

- Global Positioning System (GPS; pre-loaded with site coordinates in decimal degrees latitude/longitude or Universal Transverse Mercator [UTM])
- Maps
- Stream Temperature Data Logger Installation Form (see example in appendix 1)
- Pencil
- Digital camera
- Digital thermometer
- Onset data loggers (U22, Pendant, or TidbiT)
- PVC solar shields (1 per data logger)
- 8-in. cable/zip ties (0.095 in. width; minimum two per Pendant)
- 11-in. cable/zip ties (0.18 in. width; minimum two per U22 or TidbiT)
- 36-in. cable/zip ties (0.35 in. width; three per site)
- UV resistant sand bags (two per site)
- 36-in. rebar (0.5 in. diameter; one per site)
- Rebar caps (one per piece of rebar)
- DUCKBILL Earth Anchors Model 40 (one per site)
- Driving rod for DUCKBILL Earth Anchors Model 40 (one per site)
- DUCKBILL Earth Anchors Model 68 (one per site)
- Driving rod for DUCKBILL Earth Anchors Model 68 (one per site)
- 5 lb sledge hammer
- Flagging (optional)
- Wire cutters
- Waders/wading boots or wet wading gear

Procedure—Data Logger Installation

1. Navigate to the site using a GPS unit and maps.

   a. Get as close as possible to the pre-loaded UTM or latitude/longitude coordinates; it is rarely possible to reach the exact location because of the inherent accuracy of commercial GPS units.

   b. If coordinates are not within the stream channel (for example, they are on the adjacent hillslope), take the shortest distance to the stream.

   c. The coordinates are only a starting point. The actual location for data logger placement will depend on where adequate security, depth, and mixing are found.

2. Choose an actual location for the anchor based on adequate security, depth, and mixing (fig. 3.1).

   a. Security. Enables data logger to survive high flows where debris and hydraulics can dislodge and displace the data logger. A secure anchor location might be behind a large object, such as a boulder or large wood.

   b. Depth. Enables data logger to remain underwater at base flows, when shallow habitats desiccate but some water is still present in the channel. Anchoring the data logger in or near the thalweg will ensure the data logger remains wet until the stream no longer holds water.

   c. Mixing. Enables data logger to collect accurate data. Stagnant water is more susceptible to warming/cooling, which may not be representative of conditions in the stream. If possible, anchor the data logger in a location with moving water. Avoid selecting a location too close to a tributary junction or seep as these locations may not be representative either.

3. Choose an anchor method based on stream characteristics. See table 3.1 for a comparison of anchor methods.

   a. Cable/zip ties are the preferred method in streams with abundant wood/roots adjacent to deep, mixed water. For very large pieces of wood, it may be necessary to join two or more 36-in. cable/zip ties together end-to-end, as a daisy-chain (fig. 3.2).

   b. DUCKBILL Earth Anchor (fig. 3.3) is the preferred method in streams without suitable wood and with substrates ranging from silt to cobble, and good for large, high-discharge streams. In general, use the largest size DUCKBILL that can be driven into the substrate. Using the sledge hammer and the appropriate driving rod, drive the DUCKBILL as deep as possible straight down into the substrate, but leave at least 6 in. of cable protruding. After reaching the desired depth, remove the driving rod and pull on the cable with considerable pressure to rotate and anchor the DUCKBILL (fig. 3.4).

Figure 3.1. Photographs showing temperature monitoring site looking downstream during low flow (*A*) and high flow (*B*), and looking upstream during low flow (*C*) and high flow (*D*). Note the data loggers are attached to a sandbag anchor at the base of the boulder. Photographs by Todd Allai, Bureau of Land Management.

Table 3.1. Comparison of four anchor methods commonly used to install data loggers in wadeable streams.

[Tradeoffs between the probability of an anchor surviving high flows (Stability), the ease of finding the anchor at a later date (Retrieval), the amount of in-channel disturbance necessary to remove the anchor following monitoring (Footprint), and the amount of time and cost of equipment (Cost) are compared. The more stars in a rating, the better the rating]

Anchor method	Security	Footprint	Retrieval	Cost
Cable ties	**	****	**	****
Sandbag	*	***	****	***
Rebar	***	**	***	**
Duckbill Earth Anchor	****	*	*	*

Figure 3.2. Photograph showing data logger anchored to large wood in stream with a 36-inch cable/zip tie.

Figure 3.3. Photograph showing DUCKBILL Earth Anchors Model 88 (outer), Model 68 (middle), and Model 40 (inner).

Figure 3.4. Photograph showing data logger attached to a DUCKBILL anchor. Note the thin grey cable to the left of the white PVC solar shield. The actual DUCKBILL is buried in the sediment where the cable disappears and is highlighted by a red oval. Photograph by Brianna Sempert, U.S. Geological Survey.

c. Rebar is the preferred method in streams without suitable wood and with silt or sand substrates, and good in streams with poor visibility, as rebar sticking out of the water is easy to locate. Using the sledge hammer, drive the rebar vertically into the substrate, leaving a portion protruding from the water surface. Use a rebar cap for safety and visibility (fig. 3.5).

d. Sandbags are the preferred method in streams without suitable wood, with bedrock or boulder substrates, or when impact or footprint of the anchor is a concern. Sandbags work best in smaller streams where high flows do not occur. Double-up sandbags and fill 3/4 full with gravel/cobble. Filling with smaller substrate will result in a heavier bag (fig. 3.6).

4. Insert the previously-launched data logger into the PVC solar shield and thread two 8-in. or 11-in. cable/zip ties through the solar shield and data logger. Secure solar shield and data logger to anchor (fig. 3.7).
   a. If using a 36-in. cable/zip tie around wood, loop the smaller cable/zip ties around the 36-in. cable/zip tie.
   b. If using a DUCKBILL anchor, attach the data logger to the provided loop in the anchor cable.
   c. If using rebar, attach the data logger where the rebar protrudes from the substrate. If there is concern that the cable/zip tie will slip on the rebar, consider attaching a wire clamp above the cable/zip ties to prevent them from moving.
   d. If using sandbags, attach the data logger to the hole in the sandbag where the ties are attached.
5. Hang flagging on vegetation near the data logger. If regulations discourage the use of flagging or theft is a concern, do not hang flagging.
6. Measure water temperature at the data logger location using the digital thermometer.
7. Take multiple photos of the data logger location. If possible, a crew member should stand next to data logger and point at it for scale/reference. Capture unique features near data logger (such as large boulders or snags).

Procedure—Record Data on Stream Temperature Data Logger Installation Form

1. Site #: Enter unique site identifier.
2. Crew: Enter names of personnel involved with installation.
3. Date: Enter date of installation.
4. Time: Enter time of installation.
5. Data Logger Serial #: Enter serial number; see the seven- or eight-digit number printed on the outside of the data logger (figs. 3.8 and 3.9).
6. Latitude/Longitude or UTM coordinates: Enter coordinates of the actual location (obtained from GPS) where the data logger is installed, not the pre-loaded coordinates used to generally locate the installation site.
7. Site Condition: Circle Wet or Dry depending on whether there is water present at the site.
8. Water Temperature: Enter temperature, measured with digital thermometer, at time of installation.

Figure 3.5. Photograph showing data logger anchored to a 36-inch piece of rebar protruding vertically from the substrate, highlighted by a red oval. Note the yellow rebar cap for safety and visibility.

Figure 3.6. Photograph showing data logger anchored to a sandbag at the base of a large boulder, highlighted by a red oval. Photograph by Todd Allai, Bureau of Land Management.

Figure 3.7. Photograph showing Onset U22 data logger inside a PVC solar shield and attached to a DUCKBILL anchor cable with two 11-inch cable/zip ties.

Figure 3.8. Photograph showing serial number placement on an Onset U22 data logger.

Figure 3.9. Photograph showing serial number placement on an Onset Pendant data logger.

9. Logger Condition: Circle the description that best matches the data logger condition at time of installation. Take note of where the sensor is located (fig. 3.10) on the data logger and record whether the sensor is completely submerged, submerged but close to the water's surface, exposed to air but close to the water's surface, or completely dry. Depending on the objective of the study, it may be appropriate to install a data logger close to the water's surface or in a dry stream channel.

    a. The sensor on U22 data loggers is located at the mounting hole end of the device (fig. 3.10).

    b. The sensor on Onset Pendant and TidbiT data loggers is located in the center of the device. Because these data loggers are so small and it is difficult to determine where the sensor is relative to the water surface, consider the entire data logger when recording its condition.

10. Bank: Looking downstream, circle the closest bank (Right or Left) to the anchored data logger. If the data logger is closest to the center of the stream channel, circle "Middle."

11. Anchor: Circle the anchor method used: Sandbags, Rebar, Cable/zip ties, or DUCKBILL.

12. Flagging: Circle Yes or No, for whether or not flagging was hung adjacent to data logger. Note flagging color in margin.

13. Quality: Circle Great, OK, or Poor, to subjectively evaluate the overall quality of the data logger location and anchor method in terms of survivability. This is in reference to the probability the data logger remains in the same location where initially installed and can be located by personnel unfamiliar with the site.

14. Camera ID: Enter a unique identifier of the camera used to take the site photos, if more than one camera is being used to photograph data logger installations.

15. Photo #'s: Enter camera photograph file numbers of every photograph taken at the site.

16. Notes: Enter a description or sketch of the site so it can be easily accessed and located by personnel unfamiliar with the site. Take ample notes to describe exact location of the data logger (for example, sandbag placed about 0.5 m off the right bank and about 1 m downstream of overhanging mountain mahogany).

Figure 3.10. Photograph showing Onset U22 data logger with the sensor end highlighted by a red circle.

Standard Operating Procedure (SOP) 4—Downloading Data Loggers

Overview

This SOP describes how to download a data logger in the field using a waterproof shuttle. This SOP also covers replacing a missing data logger and removing a data logger at the conclusion of monitoring.

Supplies for Download of Data Logger

- Computer with HOBOware Pro software installed
- Onset HOBO Waterproof Shuttle
- USB interface cable
- Onset Optic USB Base Station (for stopping the data logger in the office after removal)
- COUPLER2-A (for Pendant), COUPLER2-C (for U22), or COUPLER2-D (for TidbiT)
- GPS (pre-loaded with site Latitude/Longitude or UTM coordinates)
- Maps
- Stream Temperature Data Logger Download Form (see example in appendix 1)
- Pencil
- Digital camera
- Digital thermometer
- Wire cutters
- 8-in. cable/zip ties (0.095 in. width; minimum two per Pendant)
- 11-in. cable/zip ties (0.18 in. width; minimum two per U22 or TidbiT)
- Flagging (optional)
- Waders/wading boots or wet wading gear

Supplies if Data Logger is Missing

- All of the supplies listed in supplies for download of data logger
- Stream Temperature Data Logger Installation Form (see example in appendix 1)
- Onset data loggers (U22, Pendant, or TidbiT)
- PVC solar shields (one per data logger)
- 36-in. cable/zip ties (0.35 in. width; three per site)
- UV resistant sandbags (two per site)
- 36-in. rebar (0.5 in. diameter; one per site)
- Rebar caps (one per piece of rebar)
- DUCKBILL Earth Anchors Model 40 (one per site)
- DUCKBILL driving rod for Model 40 (one per site)
- DUCKBILL Earth Anchors Model 68 (one per site)
- DUCKBILL driving rod for Model 68 (one per site)
- 5-lb sledge hammer

Procedure—Prepare the Onset HOBO Waterproof Shuttle (completed in office)

1. Loosen the center cap to open Onset HOBO Waterproof Shuttle (fig. 4.1).
    a. If necessary, use pliers to gently loosen the center cap.
2. Open HOBOware Pro software and download all the available updates, if prompted.
3. Connect the Onset HOBO Waterproof Shuttle to the computer using the USB interface cable.
    a. Wait for the shuttle to be detected by the computer.
4. On the HOBOware Pro main screen, click **Device** > **Manage Shuttle**… (fig. 4.2), to open the **Waterproof Shuttle Management** dialog box.

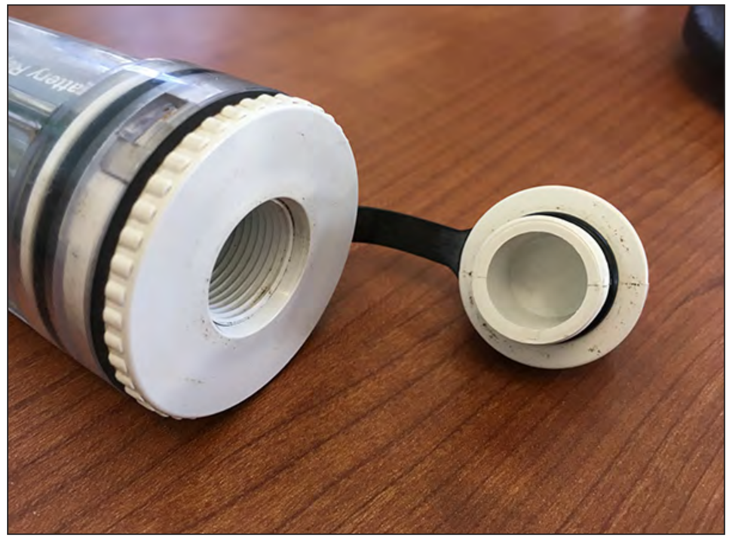

Figure 4.1. Photograph showing Onset HOBO Waterproof Shuttle with center cap open.

Figure 4.2. Screen capture showing HOBOware Pro **Manage Shuttle**… option under the **Device** menu.

5. Check battery level in **Waterproof Shuttle Management**… dialog box (fig. 4.3). If the battery voltage level is low (≤2.2 V), replace the shuttle batteries, otherwise continue with step 6.

    a. Disconnect the shuttle from computer (the center cap should already be open).

    b. Pull the rubber loop free of the large cap. The large cap cannot be unscrewed with the rubber loop in place (fig. 4.4).

    c. Push down on the large cap and turn counter-clockwise to remove (fig. 4.5).

    d. Gently remove the circuit board from the plastic shuttle housing (fig. 4.6).

    e. Remove the two AA batteries and replace with new batteries in the correct orientation (that is, positive end facing the USB port on the circuit board).

    f. Slide the circuit board back into the shuttle housing, carefully aligning it with the slots in the housing (fig. 4.7).

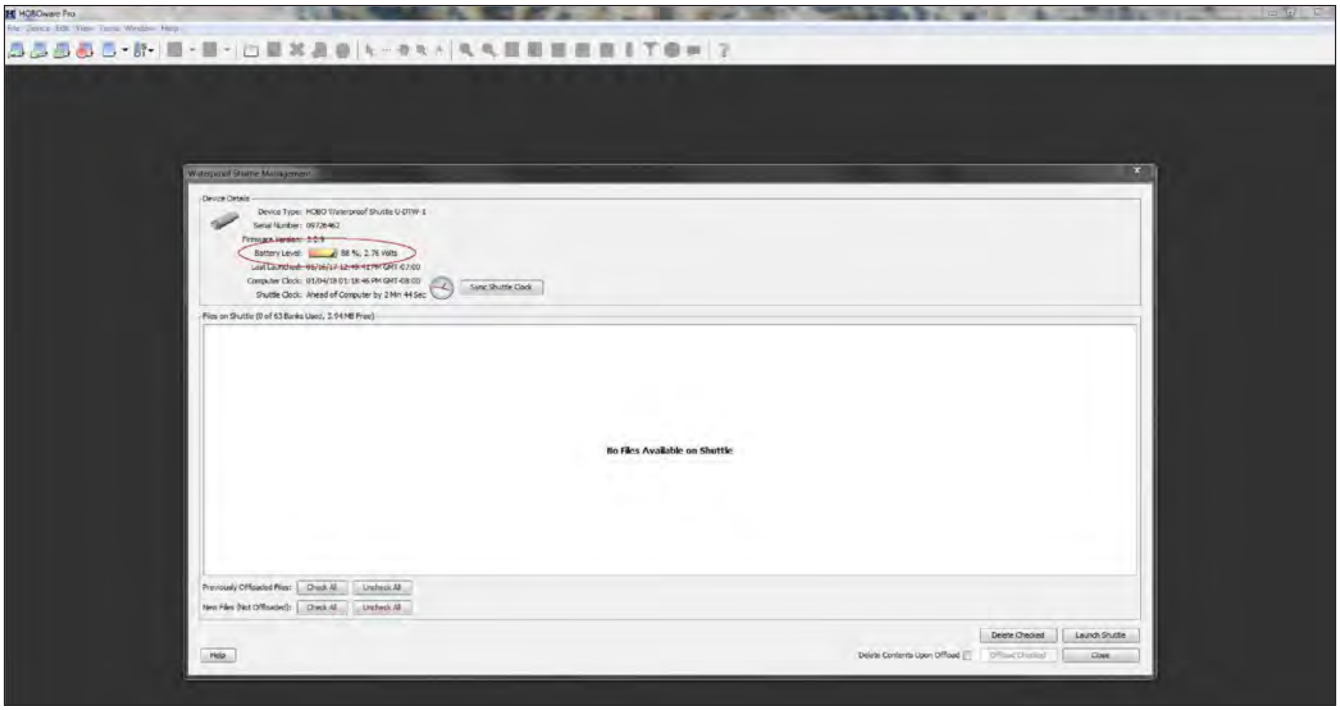

Figure 4.3. Screen capture showing HOBOware Pro **Waterproof Shuttle Management** dialog box. The red oval highlights the battery voltage.

Figure 4.4. Photograph showing Onset HOBO Waterproof Shuttle with center cap and rubber loop removed.

Figure 4.5. Photograph showing Onset HOBO Waterproof Shuttle with large cap removed.


Figure 4.6. Photograph showing Onset HOBO Waterproof Shuttle with circuit board removed.

g. When the circuit board is reinstalled correctly, the USB port should face the open end and the LEDs should be visible through the opening on the label (fig. 4.8).

h. Line up the tabs on the large cap with the slots on the shuttle housing, press down gently, and turn clockwise until the large cap is completely closed.

i. Replace the rubber loop between the shuttle housing and the large cap.

j. Re-connect the Onset HOBO Waterproof Shuttle to the computer using the USB interface cable and confirm the battery voltage is ≥2.2 V (see steps 4-5).

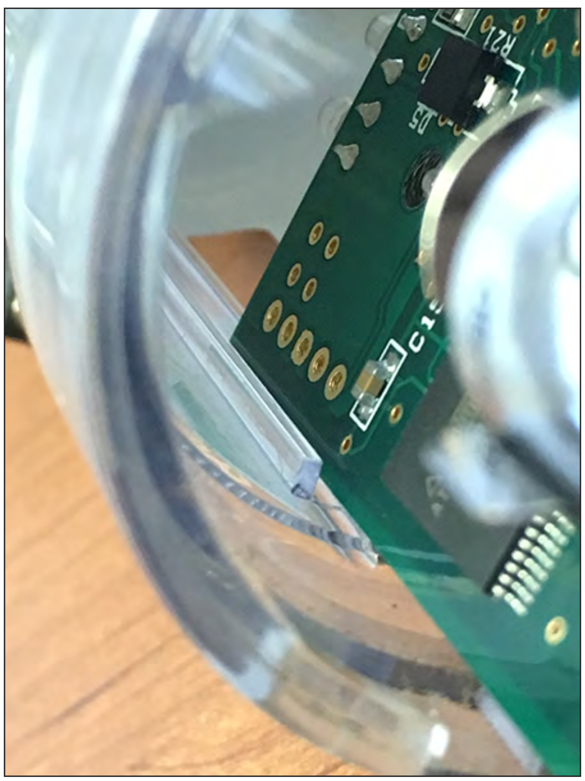
Figure 4.7. Photograph showing close-up of Onset HOBO Waterproof Shuttle with circuit board aligned with shuttle housing slots.

Figure 4.8. Photograph showing Onset HOBO Waterproof Shuttle with circuit board reinstalled correctly. Note the USB port facing the open end and the LEDs are visible through the opening on the label.

6. Launch the shuttle to synchronize its clock with the computer's clock and prepare to download data loggers.

    a. Click the **Launch Shuttle** button in lower right corner of the **Waterproof Shuttle Management** dialog box.

    b. Click **Yes** when prompted to launch the shuttle. The text "Shuttle Launched Successfully" will display in **Files on Shuttle** field (fig. 4.9).

7. Disconnect the Onset HOBO Waterproof Shuttle from the computer and replace the center cap (hand tighten; do not use pliers or other tools).

Procedure—Locate Site

1. Create the Download Form prior to entering the field using pictures/descriptions taken during data logger installation (see SOP 3–Installing Data Loggers in a Stream).

2. Navigate to the site using a GPS unit, maps, and the Stream Temperature Data Logger Download Form (see example in appendix 1).

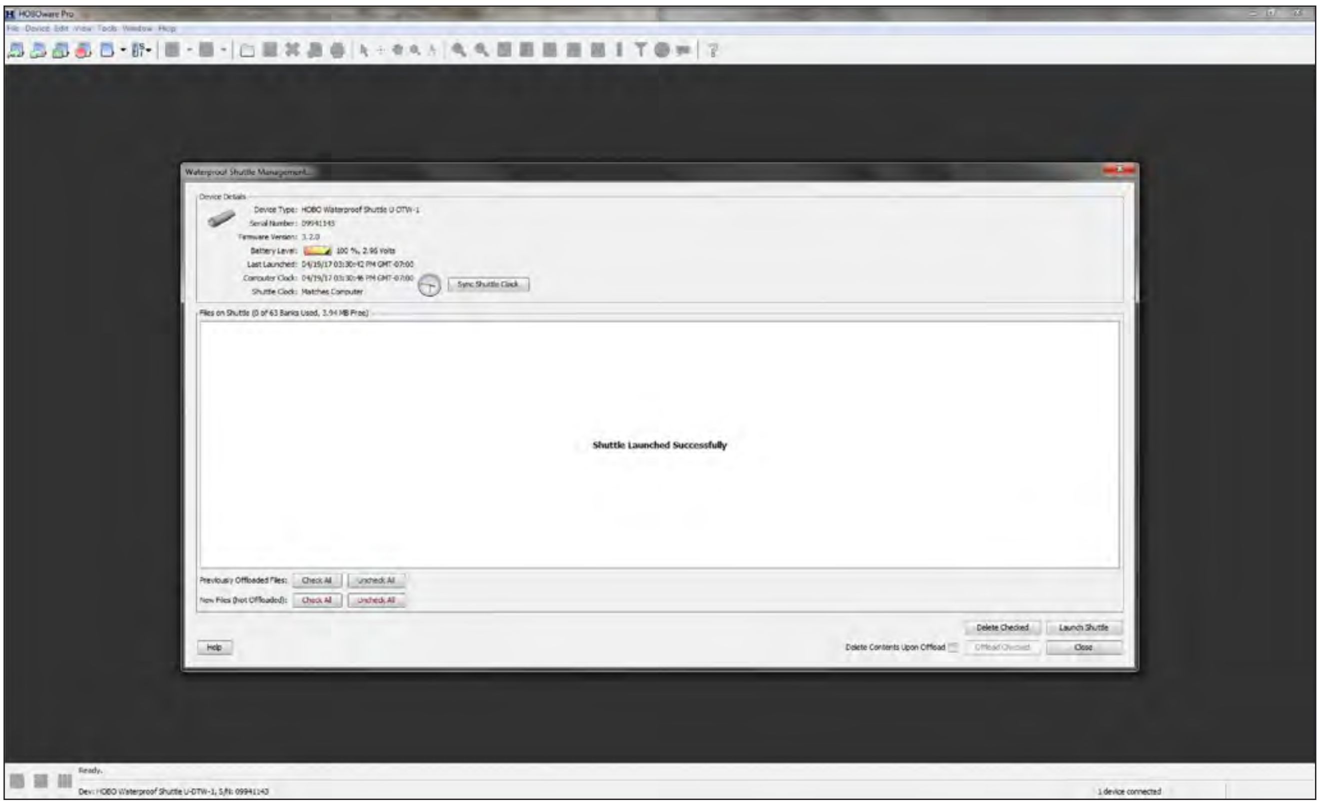

Figure 4.9. Screen capture showing HOBOware Pro **Waterproof Shuttle Management** dialog box. Note that the shuttle has been launched successfully.

Procedure—Download Data Logger

1. Remove the temperature data logger from anchor by cutting the cable/zip ties with wire cutters.
2. Slide the data logger out of the PVC solar shield and discard the cable/zip ties.
3. Remove any sediment or algae from the optic communications window on the data logger (fig. 4.10).
4. Connect the data logger to the Onset HOBO Waterproof Shuttle by using the appropriate coupler.
5. Press the coupler lever. The yellow Transfer light will flash (fig. 4.11).
    a. Do not remove the data logger when the yellow Transfer light is flashing.
    b. When the data is finished downloading the green OK light will flash (fig. 4.12).
6. If the red Fail light flashes during the download (fig. 4.13), remove the data logger from the coupler and make sure the communications window is clean, then re-insert the data logger and press the coupler lever.
    a. If the red Fail light continues to flash, remove the malfunctioning data logger from the site and replace with a new data logger. Contact the manufacturer to arrange data extraction and servicing of the malfunctioning data logger. Use methods outlined in SOP 3—Installing Data Loggers in a Stream to install the new data logger. Use a Stream Temperature Data Logger Installation Form to record data on the new installation.

Figure 4.10. Photographs showing Onset U22 data logger with (*A*) a dirty and (*B*) a clean optic communications window.

Figure 4.11. Photograph showing Onset HOBO Waterproof Shuttle with coupler pressed and a lit yellow Transfer light. A flashing Transfer light indicates that data is in the process of being transferred from a data logger to the shuttle.

Figure 4.12. Photograph showing Onset HOBO Waterproof Shuttle with a lit green OK light. A flashing OK light indicates that data transfer process from data logger to shuttle is complete.

Figure 4.13. Photograph showing Onset HOBO Waterproof Shuttle with a lit red Fail light. A flashing Fail light indicates that data transfer process from data logger to shuttle has failed.

7. When the green OK light flashes, remove the data logger from the coupler. The shuttle will automatically relaunch the logger with its previous launch settings.
8. After the data logger is removed from the coupler and shuttle, press the coupler lever to stop the flashing green OK light, or wait several minutes for OK light to stop flashing on its own.
9. Reattach the data logger to anchor using two new cable/zip ties.
    a. If the original anchor is failing to provide adequate security, depth, or mixing, move the data logger to a new location. Use methods outlined in SOP 3—Installing Data Loggers in a Stream to install the data logger in new location. Use a Stream Temperature Data Logger Installation Form to record data on the new installation.
10. An Onset HOBO Waterproof Shuttle can store 63 data files. It is recommended that all files be offloaded and the shuttle launched once per day (see SOP 5—Offloading and Exporting in HOBOware Pro).

Procedure—Record Data on Stream Temperature Data Logger Download Form

1. Crew: Enter names of personnel involved with download.
2. Date: Enter date of download
3. Time: Enter time of download.
4. Site Condition: Circle Wet or Dry, depending on whether there is water present at the site.
5. Water Temperature: Enter temperature, measured with digital thermometer, at time of installation.
6. Found Data Logger?: Circle Yes or No, for whether or not the data logger was located.
    a. If Yes, continue working down the Download Form.
    b. If No, make notes about what was found (for example, anchor but no logger) and install a new data logger using a Stream Temperature Data Logger Installation Form. The Site # will remain the same. Consider using a different anchor method if it was the anchor that failed.
7. Logger Condition at Arrival: Circle the description that best matches the data logger's condition at time of download. Take care to observe the data logger condition *before* removing it from the anchor.
8. Successful Download?: Circle Yes or No, whether the data logger was successfully downloaded.
    a. A successful download is indicated by a flashing green OK light on the Onset HOBO Waterproof Shuttle.
    b. An unsuccessful download is indicated by a flashing red Fail light on the Onset HOBO Waterproof Shuttle.
9. Action Following Download: Circle Reinstall or Remove, for whether the data logger was reinstalled or removed following its download.
    a. A data logger should be removed if it failed to download properly or because the monitoring is finished.
10. Logger Condition at Departure: Circle the description that best matches the data logger condition at time of departure.
11. Camera ID: Enter the unique identifier of the camera used to take the site photographs, if more than one camera is being used to photograph data logger downloads.

12. Photo #'s: Enter the camera photograph file numbers of every photograph taken at the site.

13. Notes: Enter an update on the site and data logger location.

Procedure—Stop a Data Logger Following Monitoring

If the data logger is removed because monitoring is finished (step 9a, Procedure—Record Data on Stream Temperature Data Logger Download Form), recording must be stopped using a computer.

1. Connect the Onset Optic USB Base Station to the computer using the USB cable and connect the temperature data logger to the base station using the appropriate coupler.

2. Stop the logger from recording data.

    a. On the HOBOware Pro main screen, click **Device** > **Stop** (fig. 4.14)

    b. Click **Yes** to stop the data logger recording (fig. 4.15)

    c. Click **Ok** to exit the dialog box indicating the data logger has been stopped.

3. Verify that the logger has been stopped.

    a. On the HOBOware Pro main screen, click **Device** > **Status** (fig. 4.16)

    b. On the **Status** dialog box in the **Device Details** group box, the **Current Status** field should read: "Logger is stopped" (fig. 4.17).

4. Disconnect the data logger from the base station. The data logger is now stopped and will remain in that state until launched again (SOP 1—Launching Data Loggers).

Figure 4.14. Screen capture showing HOBOware Pro **Stop**… option under the **Device** menu.

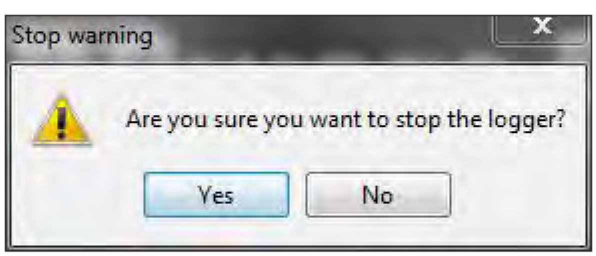

Figure 4.15. Screen capture showing HOBOware Pro **Stop Warning** dialog box.

Figure 4.16. Screen capture showing HOBOware Pro **Status**… option under the **Device** menu.

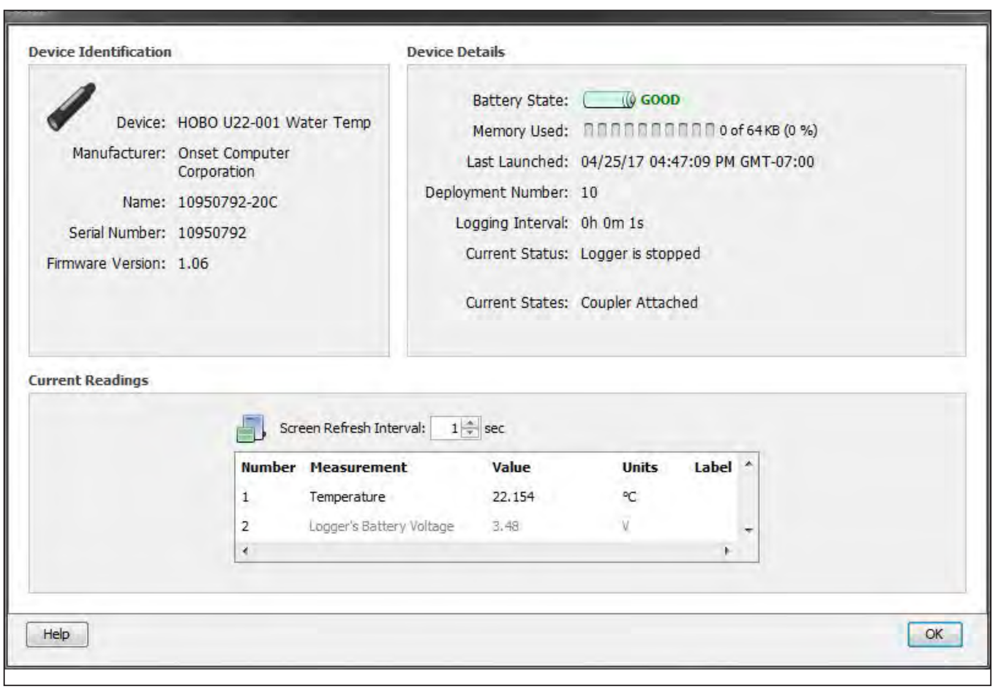

Figure 4.17. Screen capture showing HOBOware Pro **Status** dialog box. In the **Device Details** group box, note that the **Current Status** field shows: "Logger is stopped."

Standard Operating Procedure (SOP) 5—Offloading and Exporting Data in Hoboware Pro

Overview

This SOP describes how to offload data from a waterproof shuttle and export those data from HOBOware Pro software.

Supplies

- Computer with HOBOware Pro software installed
- Onset HOBO Waterproof Shuttle
- USB interface cable

Procedure—Offload Data from Waterproof Shuttle

1. Remove the center cap on the Onset HOBO Waterproof Shuttle (fig. 5.1).
   a. If necessary, use pliers to gently loosen the center cap.

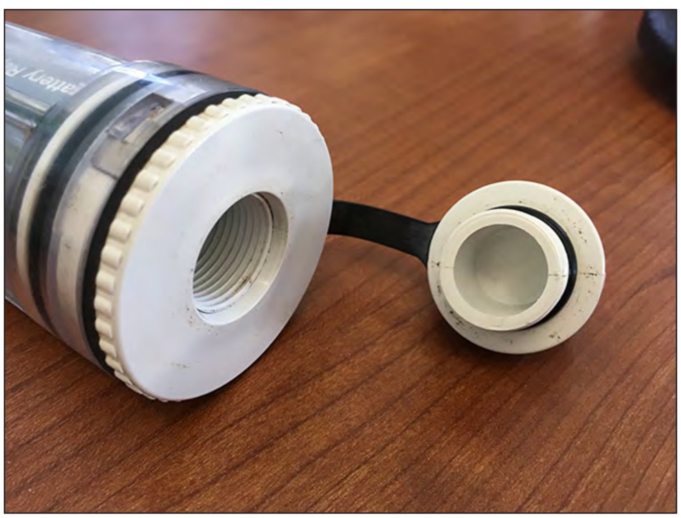

Figure 5.1. Photograph showing Onset HOBO Waterproof Shuttle with center cap open.

2. Open HOBOware Pro software and download all the available updates, if prompted.
3. Connect the Onset HOBO Waterproof Shuttle to the computer using the USB interface cable.
   a. Wait a few seconds for the shuttle to be detected by the computer.
4. On the HOBOware Pro main screen, click **Device** > **Manage Shuttle**… (fig. 5.2), to open the **Waterproof Shuttle Management** dialog box.
   a. All the files from the data loggers that were downloaded will display with “NOT OFFLOADED” status.
5. Offload all files.
   a. Make sure boxes for all files are checked.
   b. Click the **Offload Checked** button in lower right corner of the dialog box (fig. 5.3).
6. Choose a folder to save the files (figs. 5.4 and 5.5).
   a. Click **Choose**… to open dialog box for selecting a folder where the files will be saved.
   b. Do not change the Datafile Name. The name should be the data logger’s serial number with a “.hobo” extension.

Figure 5.2. Screen capture showing HOBOware Pro **Manage Shuttle**… option under the **Device** menu.

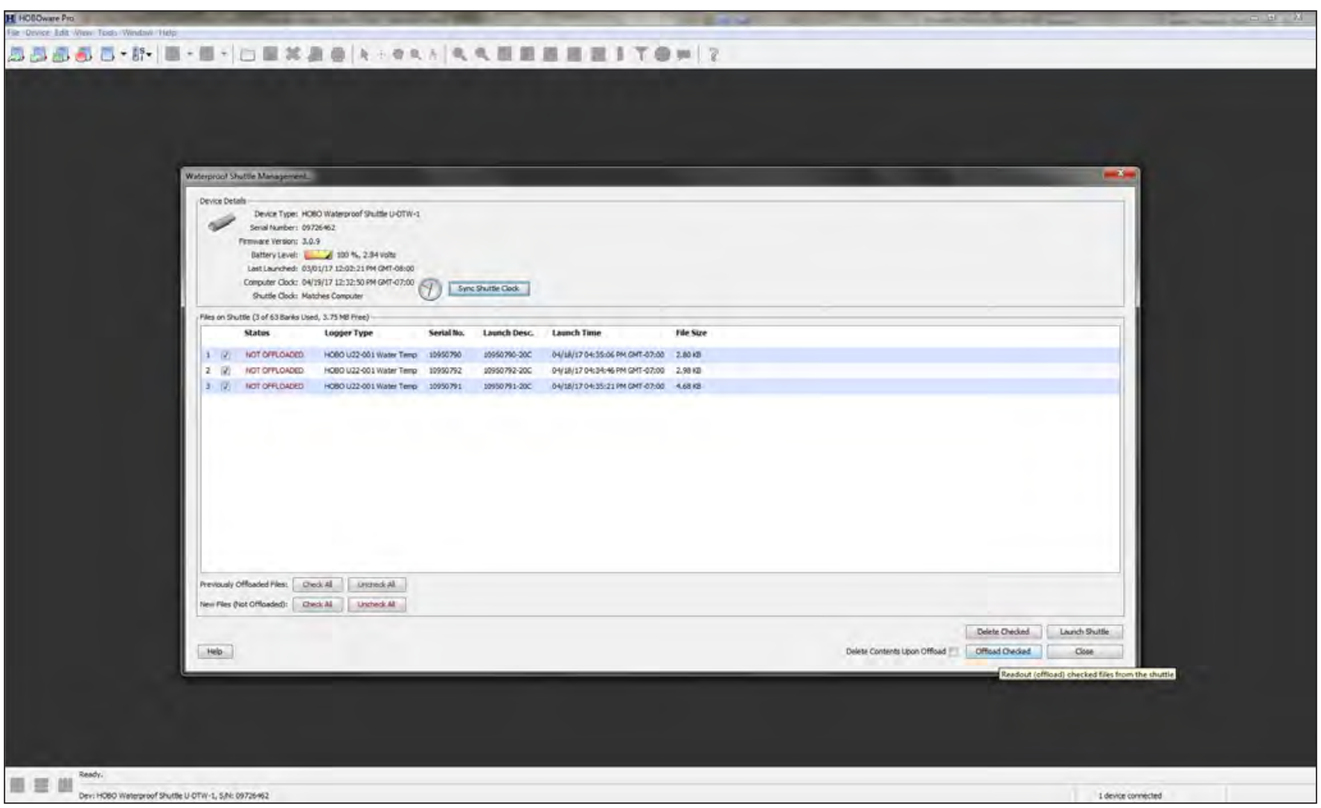

Figure 5.3. Screen capture showing HOBOware Pro **Waterproof Shuttle Management** dialog box with three files that have not been offloaded.

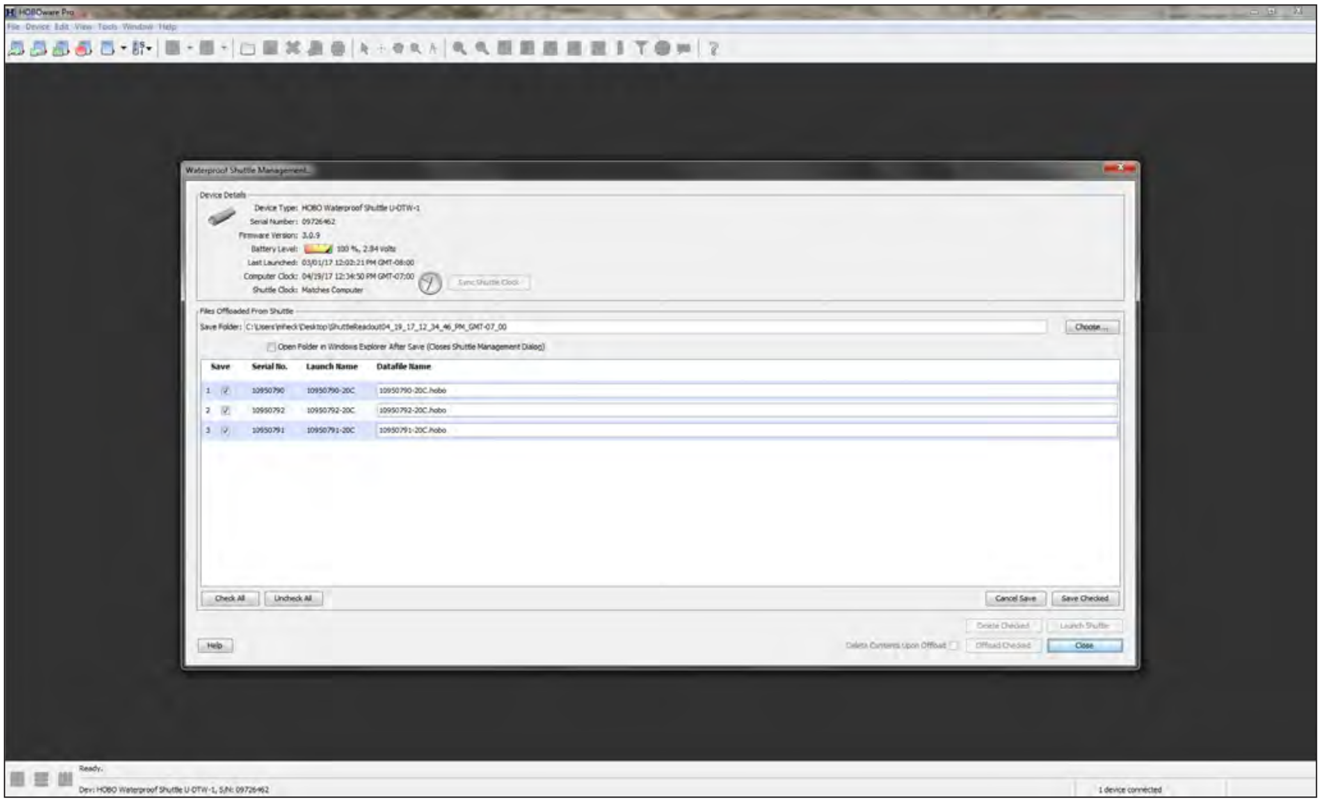

Figure 5.4. Screen capture showing HOBOware Pro **Waterproof Shuttle Management** dialog box showing that three files have been offloaded but still need to be saved to a folder on a computer.

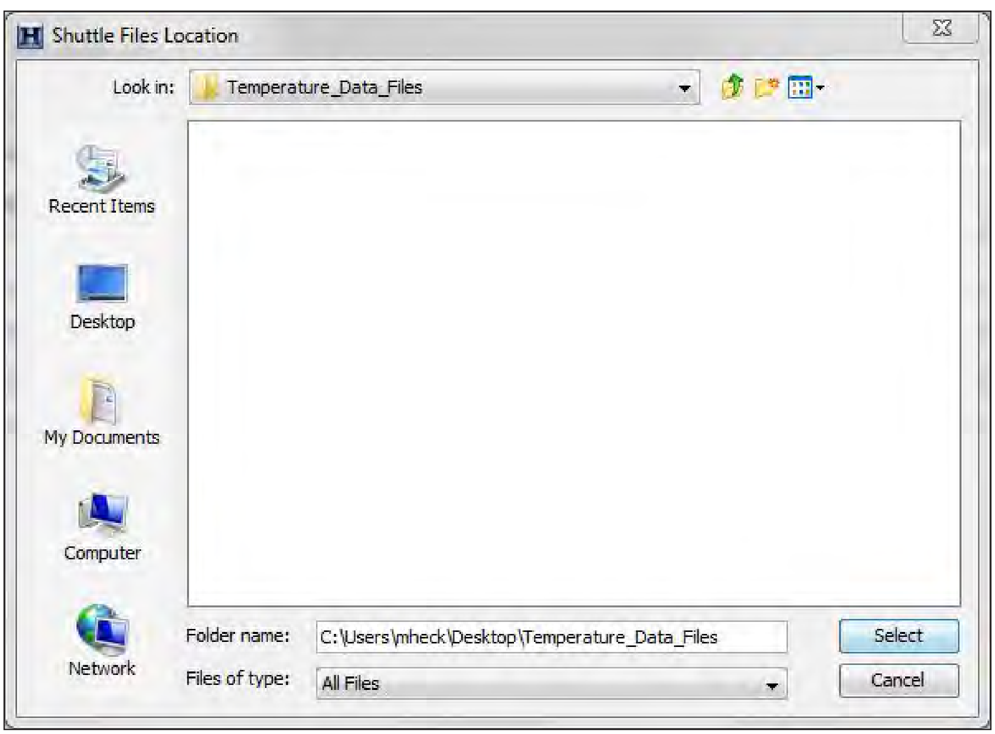

Figure 5.5. Screen capture showing HOBOware Pro **Shuttle Files Location** dialog box for selecting the folder where to save files.

7. Save all files.

   a. Click the **Save Checked** button in lower right corner of the **Waterproof Shuttle Management** dialog box (fig. 5.6).

   b. After all files have been offloaded and saved, their Status will be "OFFLOADED" in the **Waterproof Shuttle Management** dialog box (fig. 5.7).

   c. Open Windows Explorer to double-check that all the .hobo files have been saved to the folder (fig. 5.8).

8. Launch the shuttle to prepare for another round of data logger downloads.

   a. Click the **Launch Shuttle** button in lower right corner of the **Waterproof Shuttle Management** dialog box.

   b. Click **Yes** to launch the shuttle.

   c. The text "Shuttle Launched Successfully" will display in **Files on Shuttle** group box (fig. 5.9).

9. Disconnect the Onset HOBO Waterproof Shuttle from the computer and replace the center cap (hand tighten, do not use pliers or others tools to tighten center cap).

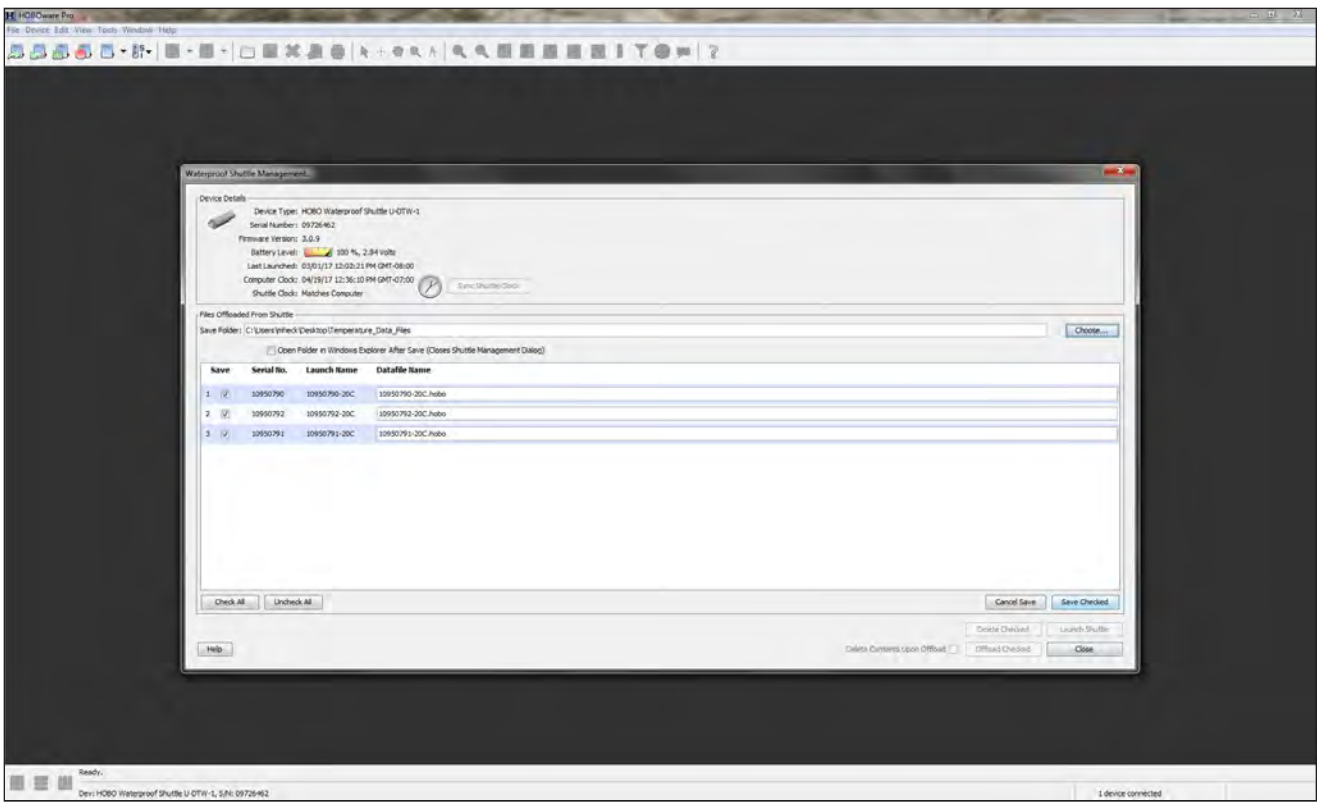

Figure 5.6. Screen capture showing HOBOware Pro **Waterproof Shuttle Management** dialog box after the folder where to save the files was changed.

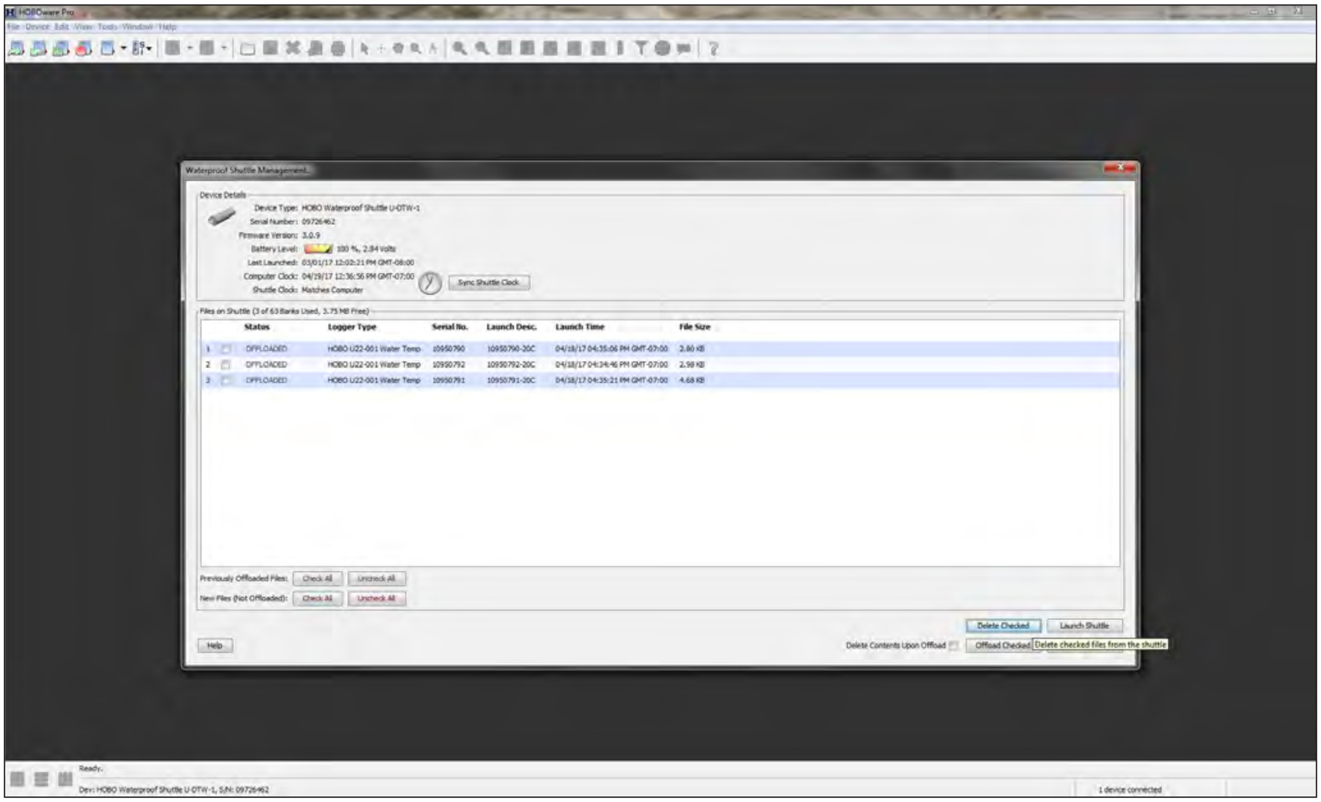

Figure 5.7. Screen capture showing HOBOware Pro **Waterproof Shuttle Management** dialog box after all files were properly offloaded and saved. Note their status has changed from "NOT OFFLOADED" to "OFFLOADED".

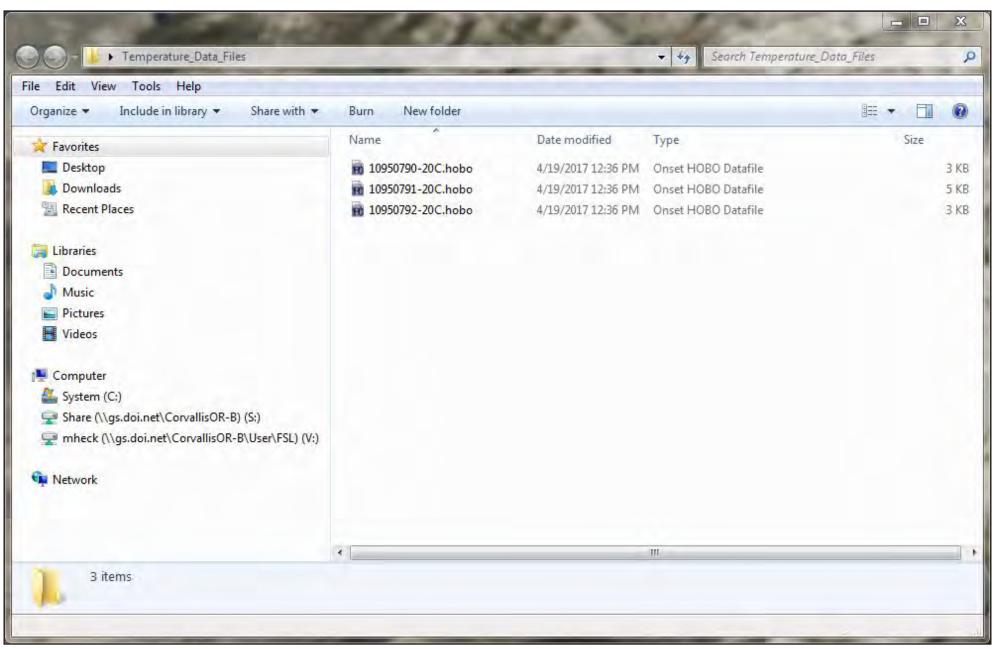

Figure 5.8. Screen capture showing folder where offloaded .hobo shuttle files are saved.

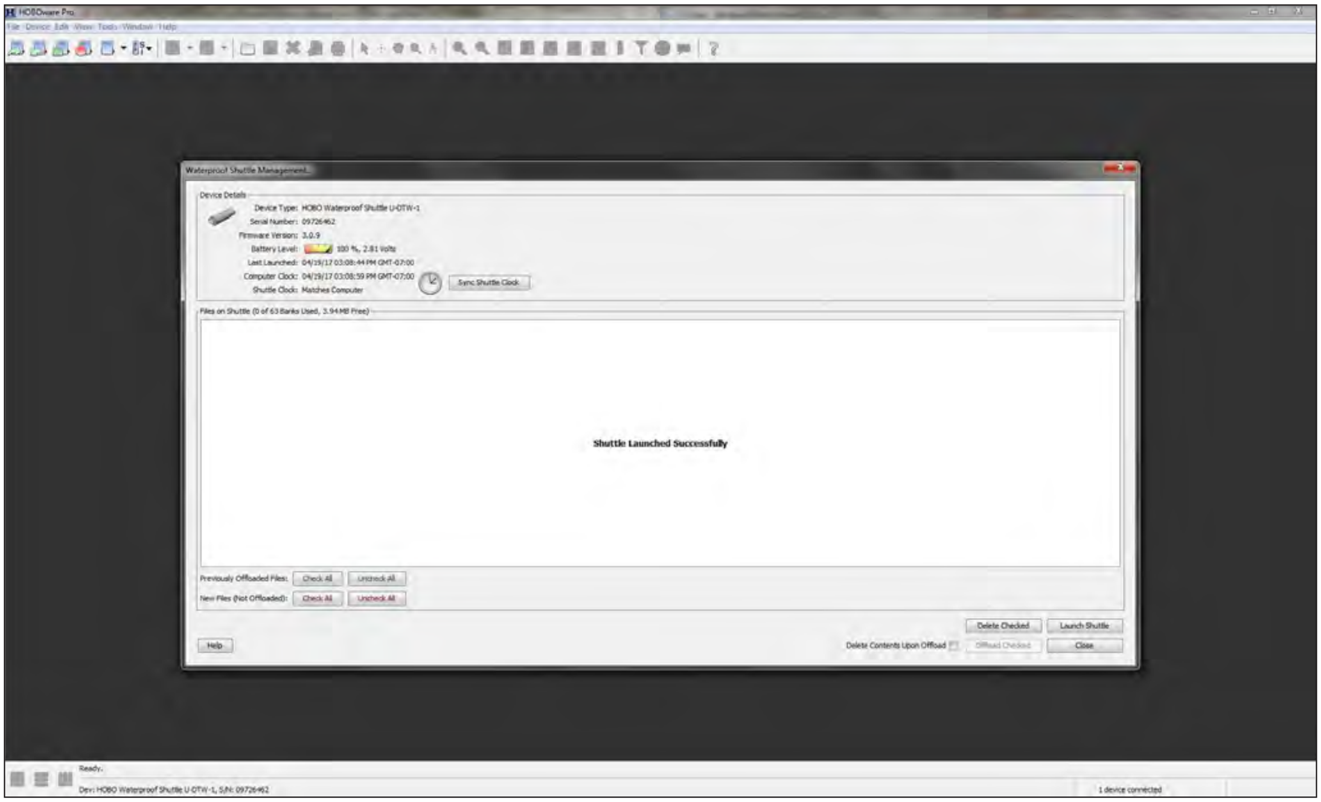

Figure 5.9. Screen capture showing HOBOware Pro screen **Waterproof Shuttle Management** dialog box after launching a shuttle. Launching a shuttle erases all shuttle files and synchronizes the shuttle clock with the computer clock.

Procedure – Export Data from HOBOware Pro

1. Open HOBOware Pro software and download all the available updates, if prompted.
2. Export .hobo files as .csv files
    a. Click **Tools** > **Bulk File Export** > **Select Files to Export**… (fig. 5.10)
3. Browse to the folder where the .hobo files were saved and select all the files. Click **Continue** (fig. 5.11).
4. In the **Choose Export Folder** dialog box, choose folder where to save the .csv files. Browse back to the folder with the .hobo files and click **Export** (fig. 5.12).
5. When the Bulk File Export is complete, click **OK** (fig. 5.13).

Figure 5.10. Screen capture showing **HOBOware Pro Select Files to Export**… option under the **Bulk File Export** option, under the **Tools** menu.

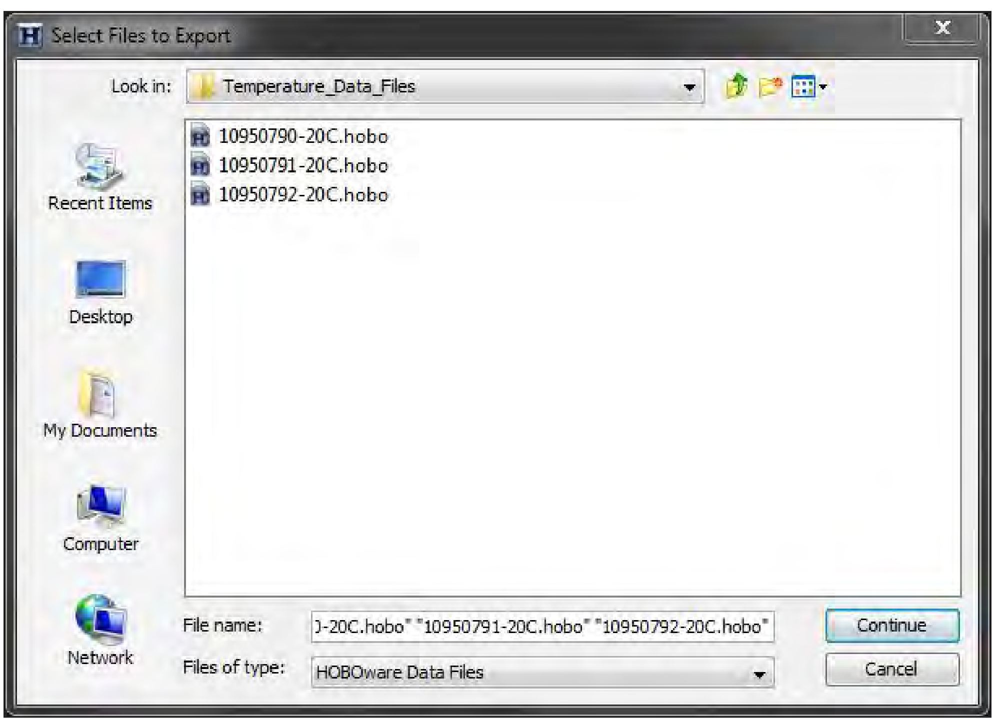

Figure 5.11. Screen capture showing HOBOware Pro **Select Files to Export** dialog box to select .hobo files to export as .csv files.

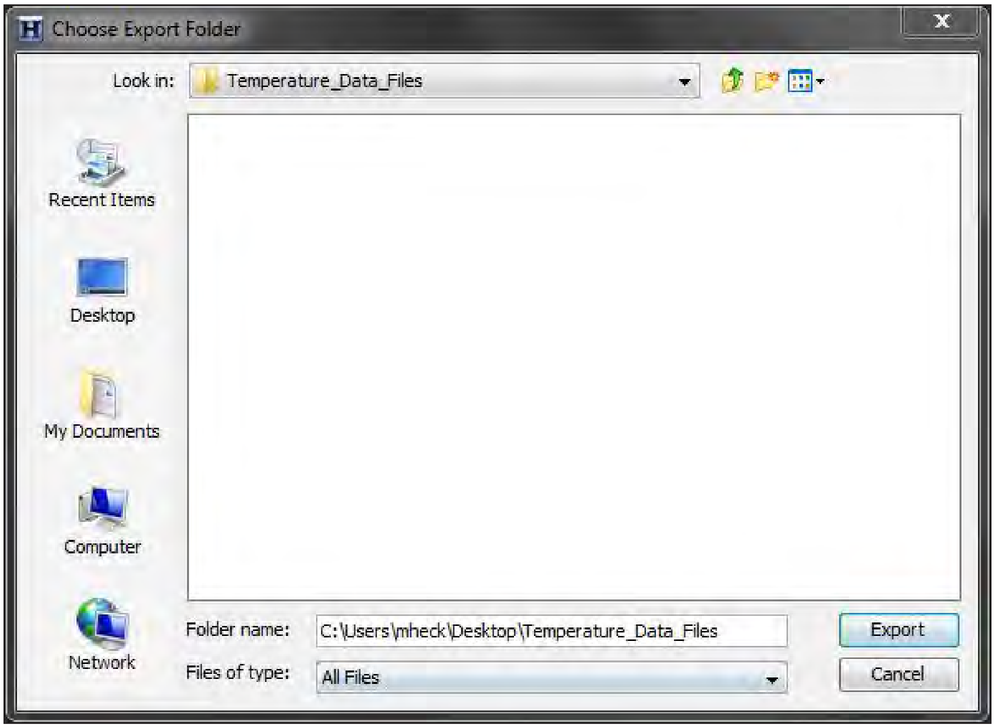

Figure 5.12. Screen capture showing HOBOware Pro **Choose Export Folder** dialog box to choose the folder where .csv files will be exported.

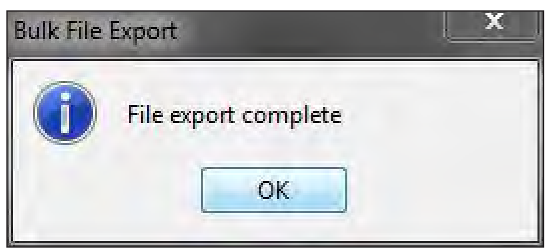

Figure 5.13. Screen capture showing HOBOware Pro **Bulk File Export** dialog box.

Standard Operating Procedure (SOP) 6—Importing and Managing Data

Overview

This SOP describes a procedure to enter data logger data into a database. Temperature data loggers generate a large amount of data that need to be stored and managed. The data will be more easily accessed and analyzed if the data management system is planned and implemented with care. We recommend either using an off-the-shelf water data software application to manage the data or developing a custom relational database in, for example, Microsoft Access, Oracle, Microsoft SQL Server, or another application. Storing .csv files in folders and working with them individually in Microsoft Excel, for example, is not ideal.

The example used in this SOP demonstrates how to add data to AQUARIUS Time-Series software. This software is being used extensively by the National Park Service (NPS) and U.S. Geological Survey (USGS). Specifically, the procedures shown here outline how to use the software on the NPS server. Non-NPS users must have their own access to AQUARIUS or develop their own database or data management system. Many of the same principles will apply, but the specific steps will be different.

Supplies

- Computer with AQUARIUS Assistant remote desktop connection file installed
- Contact the AQUARIUS System Administrator in the NPS Water Resources Division to obtain the remote desktop connection file and access the online AQUARIUS NPS server.

Procedure—Enter Site Location Data into AQUARIUS Springboard

1. Start AQUARIUS software remotely, from the NPS Natural Resource Stewardship and Science Directorate (NRSS) server.

    a. Double-click on the AQUARIUS Assistant (AQAssistant.rdp, fig. 6.1) remote desktop connection file. (Make a desktop shortcut of the file, or otherwise put the file in an easily-accessible location.)

    b. If the **RemoteApp** dialog box appears (fig. 6.2), click **Connect** to launch the log-in window.

    c. Enter credentials, **PIN** and **Username hint**, if applicable, on the Windows Security log-in screen (fig. 6.3).

    d. Click **OK** at the “WARNING TO USERS…” message window (fig. 6.4).

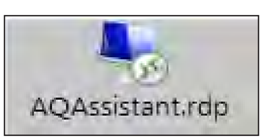

Figure 6.1. AQUARIUS Assistant desktop connection file shortcut icon.

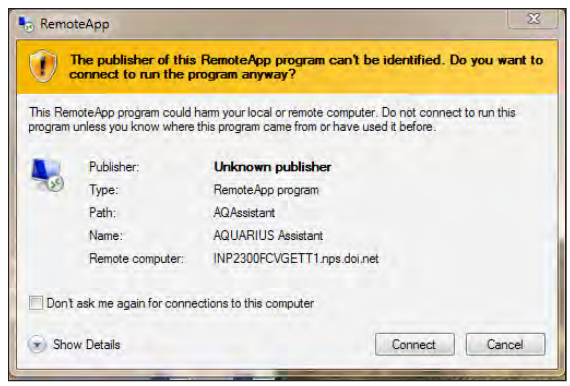

Figure 6.2. Screen capture showing **RemoteApp** connection dialog box.

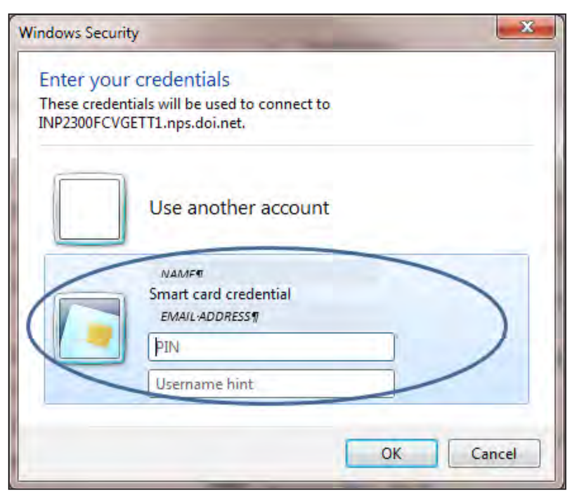

Figure 6.3. Screen capture showing remote desktop **Windows Security** dialog box. Enter log-in credentials in circled section.

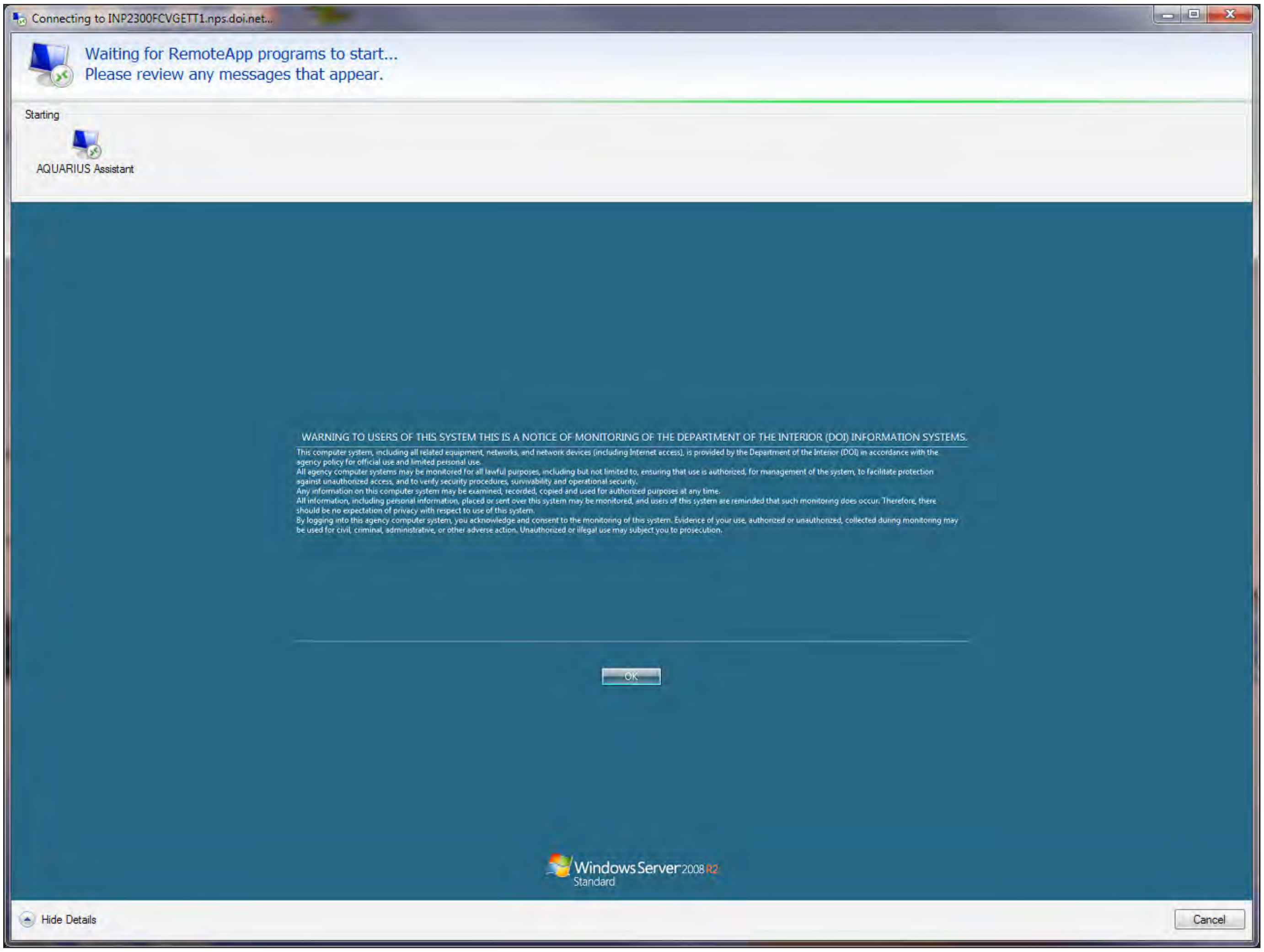

Figure 6.4. Screen capture showing "WARNING TO USERS…" security screening dialog box.

e. On the taskbar, at the bottom right of the screen near the date/time information, locate the AQUARIUS Assistant mini-icon (fig. 6.5) or look in the taskbar pop-up tray just to the left of the date/time (fig. 6.6)

f. Right-click on AQUARIUS Assistant mini-icon and select **Launch Springboard** from the pop-up menu.

g. In the **Launch AQUARIUS Springboard** dialog box, select **localhost** in the **Server:** drop-down list, then click **OK** (fig. 6.7).

h. In the **AQUARIUS Server Login** dialog box, enter Active Directory **Username** and **Password**, then click **login** (fig. 6.8).

2. Create a new project in Springboard.

   a. Create a new project folder for each separate park or monument in the relevant top-level folder (such as the "Klamath Network" folder in a NPS example; fig. 6.9).

   b. Right-click on the "Klamath Network" folder and select **New Project** (fig. 6.10).

   c. Rename the **New Folder** with the four-character code for the park or monument.

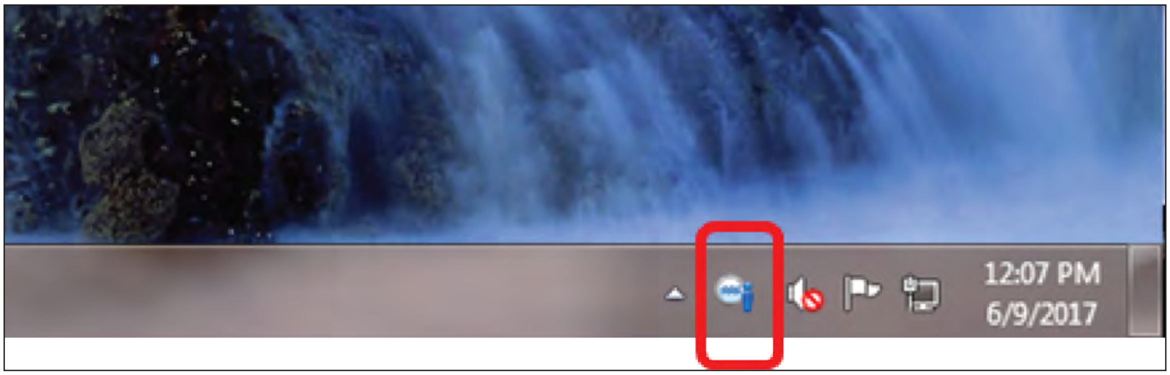

Figure 6.5. Screen capture showing AQUARIUS Assistant mini-icon on the taskbar.

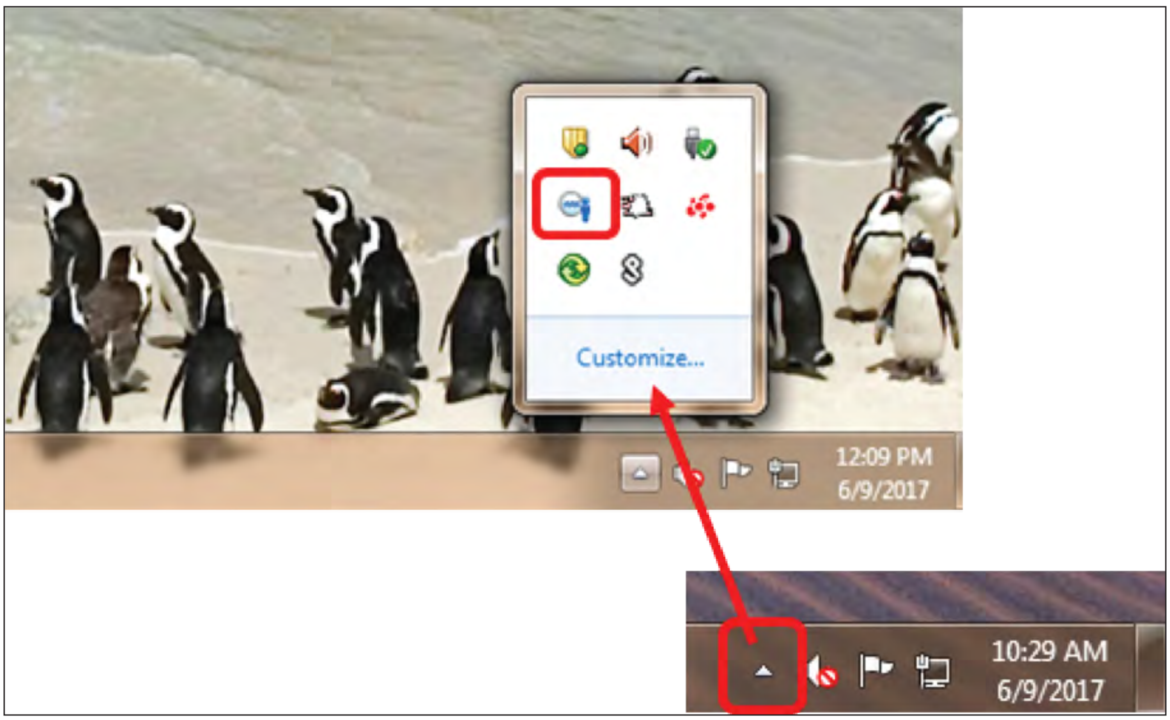

Figure 6.6. Screen capture showing AQUARIUS Assistant mini-icon in the taskbar pop-up tray.

Figure 6.7. Screen capture showing **Launch AQUARIUS Springboard** dialog box.

Figure 6.8. Screen capture showing **AQUARIUS Server Login** dialog box.

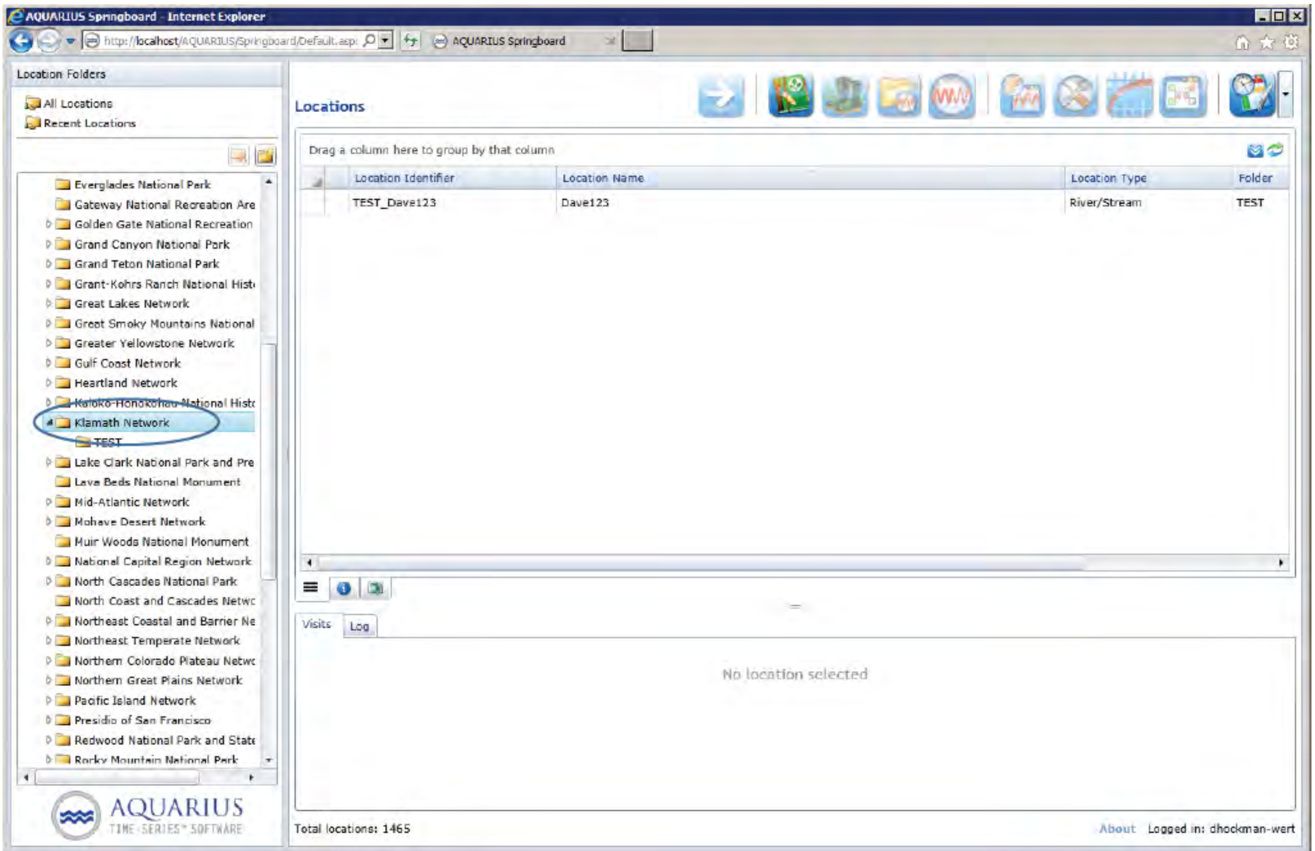

Figure 6.9. Screen capture showing **AQUARIUS Springboard**, with "Klamath Network" folder indicated.

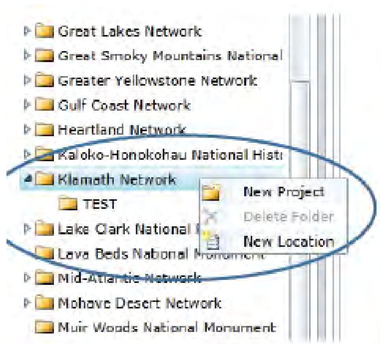

Figure 6.10. Screen capture showing AQUARIUS Springboard **Location Folders** section showing the **New Project** option under the "Klamath Network" folder.

3. Create a new location within the new project.

   a. In the navigation panel, select the new project folder, under "Klamath Network," then right-click and select **New Location** from the pop-up menu, or click the **Location Manager** icon in the top ribbon panel (fig. 6.11), to open the **Location Manager** screen.

   b. In the **General** tab, enter location metadata (fig. 6.12).

      i. Enter a unique alphanumeric name in the **Identifier** field; for the NPS, enter the four-character park/monument code followed by an underscore and something that represents the site, for example, "ORCA_TM_01." If transferring data from the Stream Temperature Data Logger Installation Form (appendix 1), enter "Site #" following the park/monument code and underscore.

      ii. Enter a location name in the **Name** field. The name should be as concise and descriptive as possible, including the waterbody name and something about the location, for example, "Snake Creek at Rt. 27 Bridge."

Figure 6.11. Screen capture showing **AQUARIUS Springboard**, with Location Manager icon indicated.

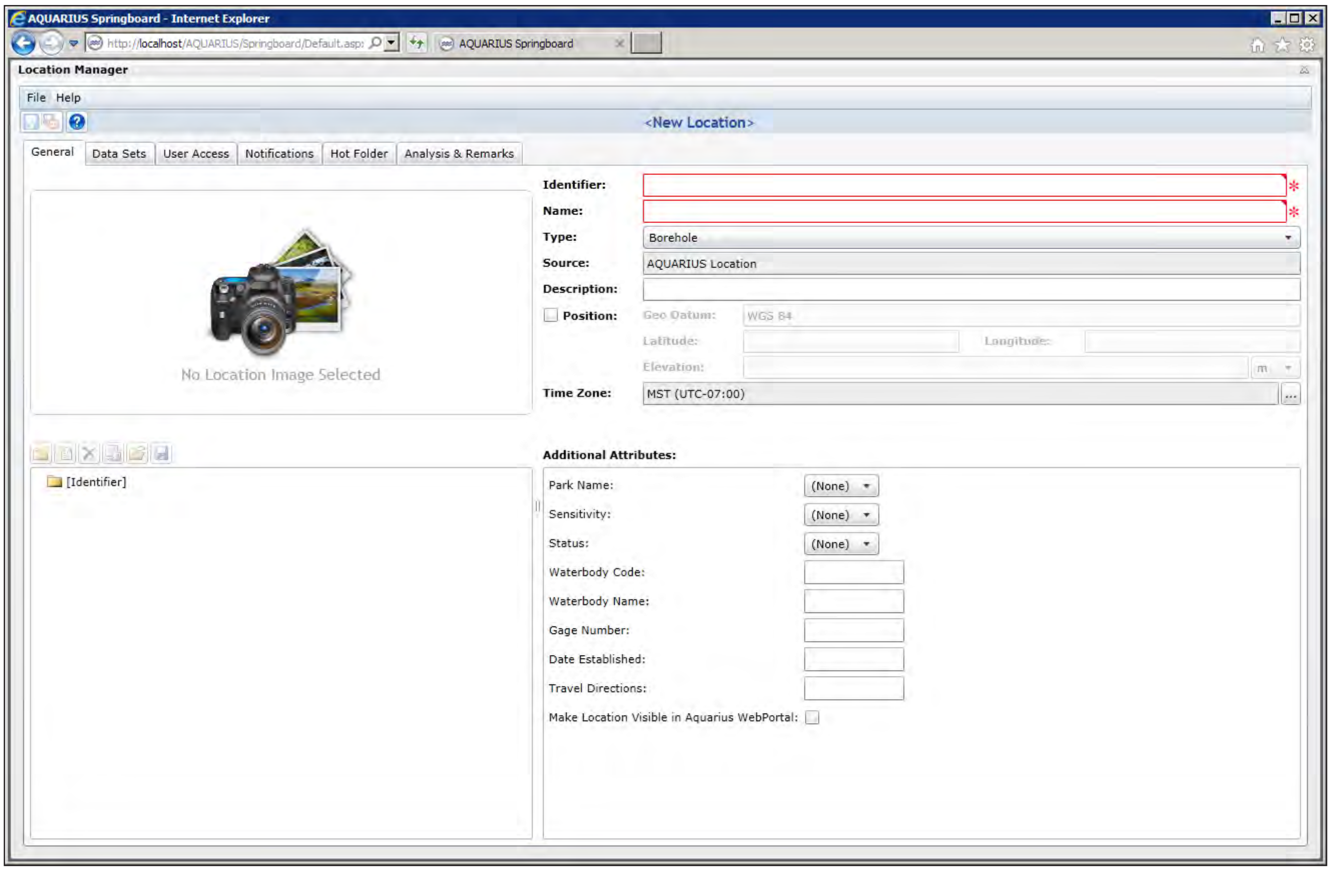

Figure 6.12. Screen capture showing **AQUARIUS Springboard Location Manager**, **General** tab.

iii. Select the correct location type from the **Type** drop-down list. This will depend on what type of sampling site it is. Most stream temperature data logger sites are going to be **River/Stream**.

iv. In the **Description** field, provide a description of the site so personnel unfamiliar with the site can easily access and locate it. If transferring data from the Stream Temperature Data Logger Installation Form (appendix 1), enter "Notes" here. This field is optional.

v. In the **Position** field, enter latitude and longitude values for the site, if available. Use negative values for the longitude to indicate Western Hemisphere. Latitude and longitude coordinates are required to use the map-based interface. If coordinates are entered, an elevation must also be entered. Enter -9999 as a placeholder if correct elevation is unknown.

vi. Ensure the time zone indicated in the **Time Zone** field is correct for the data logger. It will become the default time zone for datasets created at this location. This may not be the same as the present time zone of the office location. Using standard time throughout the year is recommended to avoid correcting for daylight saving time.

vii. Select the park name from the **Park Name** drop-down list.

viii. From the **Sensitivity** drop-down list, select **NPS Only** unless the data are to be made available to the public. If there is a reason to keep the data private from any other users, including the NPS, select **Restricted**.

ix. Select the best indicator of the present site status from the **Status** drop-down list: **Active**, **Inactive**, or **Retired**.

x. Check the **Make Location Visible in Aquarius WebPortal** box in order for the location and its time series to be visible to the public in the AQUARIUS WebPortal.

xi. Remember to save frequently when adding data or making edits by clicking on the **Save** mini-icon or the **File** menu-**Save** option.

c. Add photos of the location, to aid in revisiting the site.

i. Click on the folder named <*Identifier*> in the lower left section of the screen (fig. 6.13).

ii. Click the **New Folder** mini-icon above the main folder to create a new folder, then rename the new folder, "Site Photos."

iii. Select **Site Photos** and click the **New File** mini-icon (fig. 6.14).

iv. Select a photo to be added and click **Open**.

v. Select the photo to be displayed and click the **Set Location Photo** mini-icon to display it on the General tab in Location Manager.

d. Hard-copy field notes, such as the Stream Temperature Data Logger Installation Form, quality control documents, or other pertinent site information, can also be scanned and added in this section.

i. Click on the folder named <*Identifier*> (for example, "ORCA_TM_01") in the lower left section of the screen (fig. 6.13).

ii. Click the **New Folder** mini-icon above the main folder, then rename the new folder, "Field Visit Forms".

iii. Select the **Field Visit Forms** folder and click the **New File** mini-icon (fig. 6.14).

iv. Select the scanned file to be added, and click **Open**.

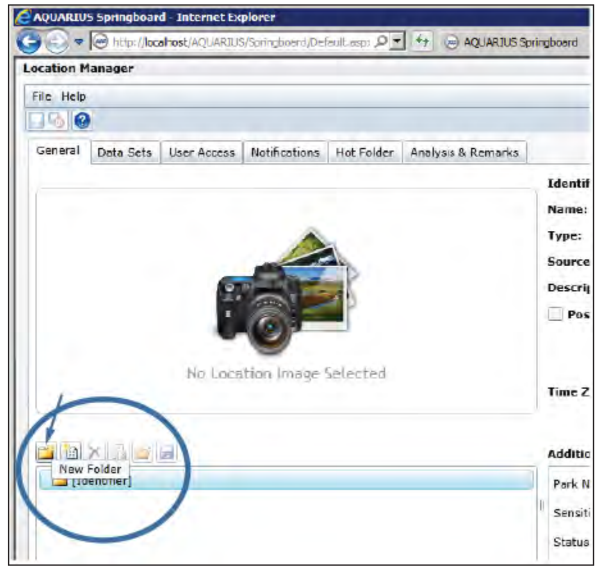

Figure 6.13. Screen capture showing **AQUARIUS Springboard Location Manager**, **General** tab. Arrow and circle indicate **New Folder** mini-icon.

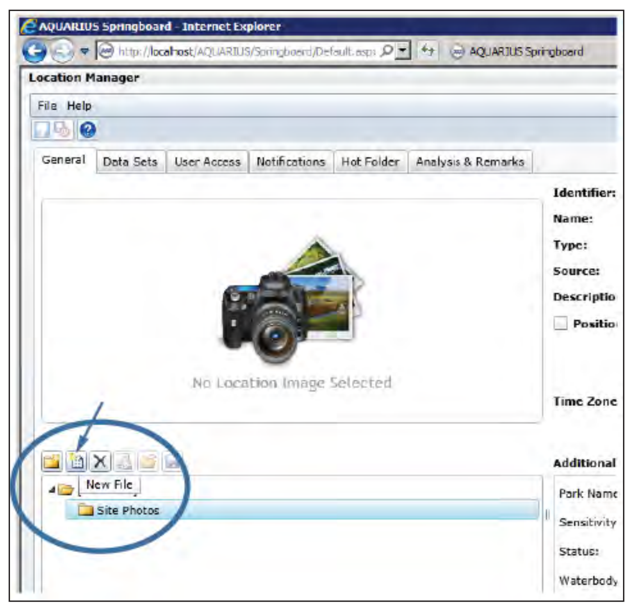

Figure 6.14. Screen capture showing **AQUARIUS Springboard Location Manager**, **General** tab. Arrow and circle indicate **New File** mini-icon.

e. To add additional location-based remarks or analysis for a particular visit, go to the **Analysis & Remarks** tab and click the green "plus" sign on the upper right. Enter the date and time applicable to the remarks, the type, and the subject. Enter remarks in the section in the lower half of the screen (fig. 6.15), then save by clicking on the **Save** mini-icon or the **File** menu-**Save** option.

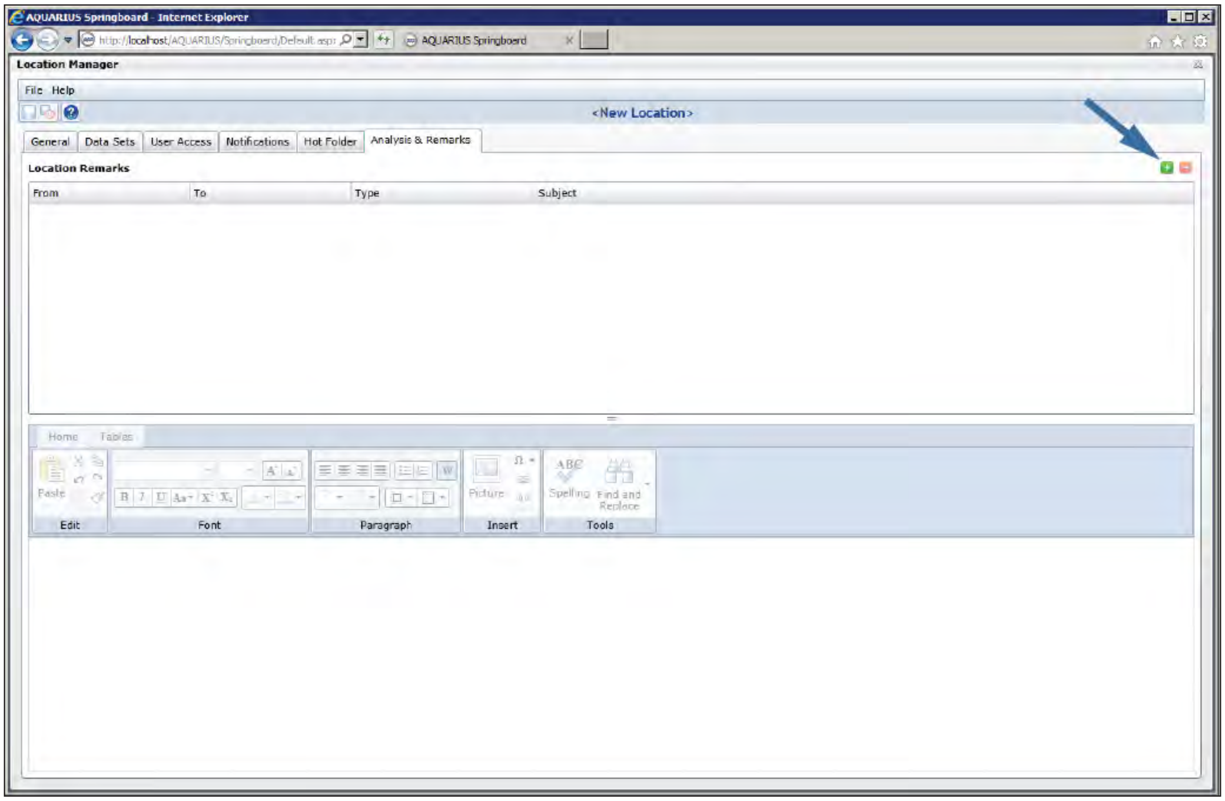

Figure 6.15. Screen capture showing **AQUARIUS Springboard Location Manager**, **Analysis & Remarks** tab. The green "+", indicated by arrow, is used to add location remarks.

Procedure—Enter Temperature Data into AQUARIUS Springboard

1. Add **Data Sets** for importing data.

   a. If not already in Location Manager, open Location Manager for the site being worked on.

      i. Select the location in AQUARIUS Springboard, and then click on the Location Manager icon.

   b. Click on the **Data Sets** tab.

   c. Click the **New** drop-down list, and select the **Time Series** option to be added (fig. 6.16).

   d. For temperature data logger data, select **Time Series – Basic**.

      i. If entering manually collected data from a site visit, select **Time Series – Field Visit**.

      ii. If setting up a site that will have multiple redundant data loggers, consider selecting **Time Series – Composite**. This option allows the user to identify which source data logger to use as the "data feed," and change this source over time, if desired.

   e. In the new Time Series, enter **Data Set Details** as required (fig. 6.17).

      i. Enter "logger" in the **Label** field.

      ii. Enter "Water Temperature" in the **Description** field.

      iii. In the **Comment** field, enter the ID of the data logger collecting the data in the related time series. Add the start and end date/time for each data logger in this time series, in case multiple loggers are used at the site. (AQUARIUS is not set up to track individual data loggers well. It is set up as a site-based database.)

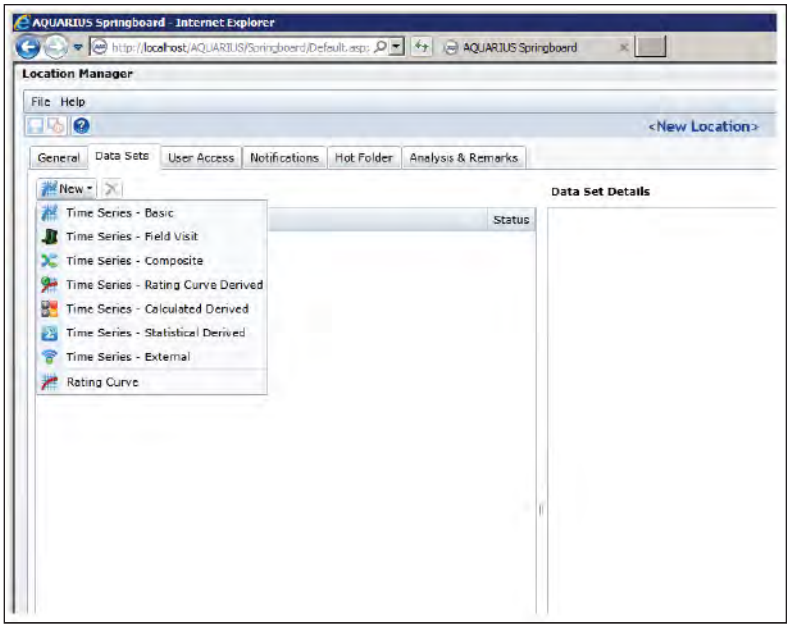

Figure 6.16. Screen capture showing **AQUARIUS Springboard Location Manager**, **Data Sets** tab, showing the **Time Series** options under the **New** drop-down menu.

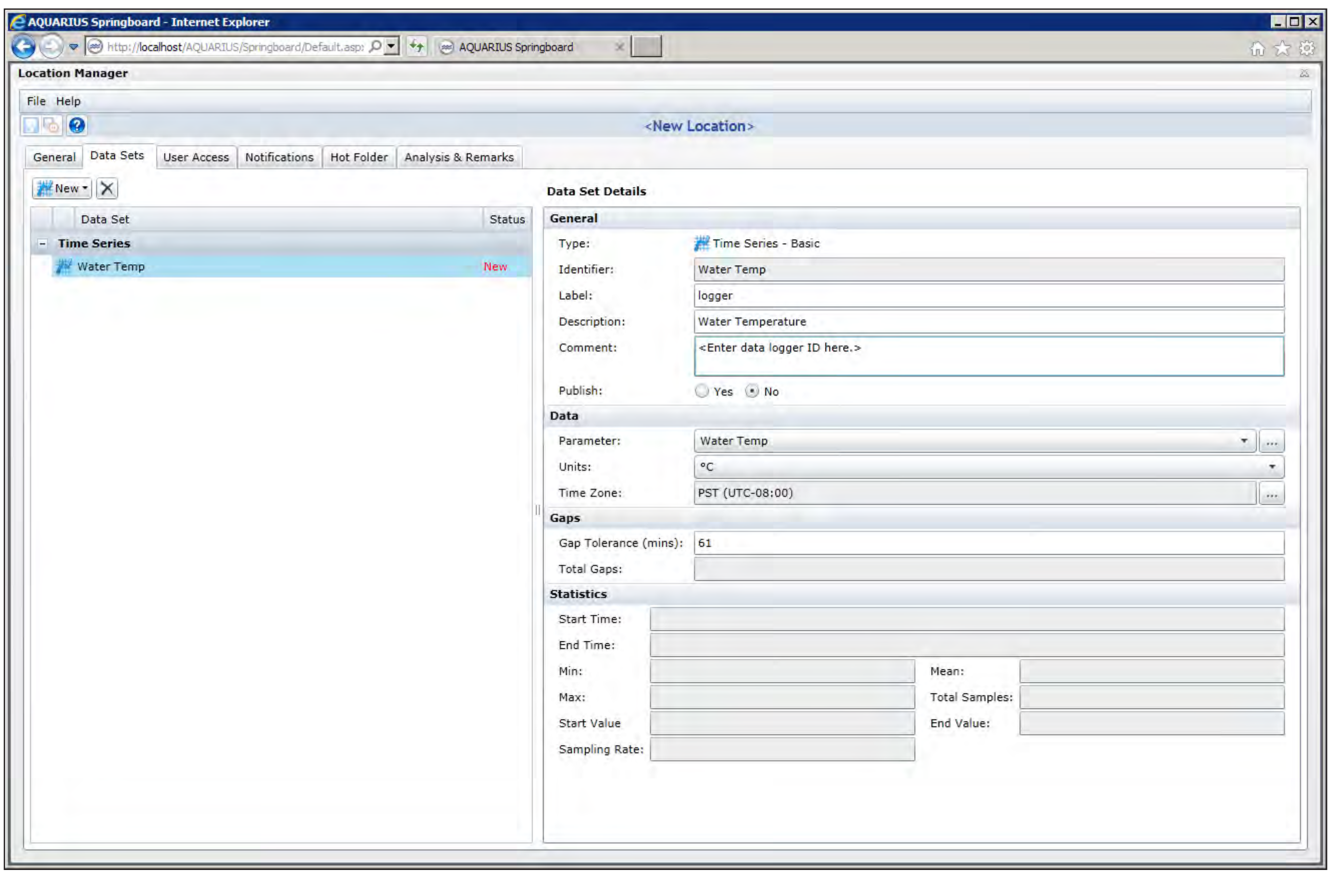

Figure 6.17. Screen capture showing **AQUARIUS Springboard Location Manager**, **Data Sets** tab, showing the **Data Set Details** of a new time series.

iv. Click **Yes** in the **Publish** field for the dataset to be available to the public on the AQUARIUS WebPortal; click **No** otherwise.

v. In the **Time Zone** field, select the time zone that corresponds to the data logger. This defaults to the location's time zone setting when creating a new dataset. The time series time zone must match the time zone of the imported file or AQUARIUS will convert the incoming data to match the time series time zone.

vi. Set the **Gap Tolerance** 1 minute higher than the interval by which the data logger is collecting data. For example, if data logger is set to collect hourly data, enter "61" for the **Gap Tolerance**.

f. Repeat steps 1.c.–1.e. to add another **Time Series – Basic** for Voltage.

g. Click the **Save & Exit** mini-icon to save edits and exit out of Location Manager.

2. Add .csv data to the Water Temperature Data Set.

a. Prior to importing data into AQUARIUS, examine the .csv data to make sure they conform to the example described in step 2.f. below. Be sure to adjust the append process based on the data as it actually is. At a minimum, the data should have the date/time and temperature.

b. Select the location to which the data will be imported.

c. Click on the Append to Logger icon in the main Springboard window (fig. 6.18) to open the Append Logger File tool in a new window.

d. Click on the "Picker" widget (three dots) to the right of **Logger File:** field and select a file to import (fig. 6.19).

e. Click on the **View Logger File** button to preview the file in Excel.

f. Click the **Config Settings…** button to open the Import from File wizard.

i. **Step 1 of 4**: Select **Text File (CSV, etc.)** from the **Time Series** drop-down list, then click **Next>>** (fig. 6.20).

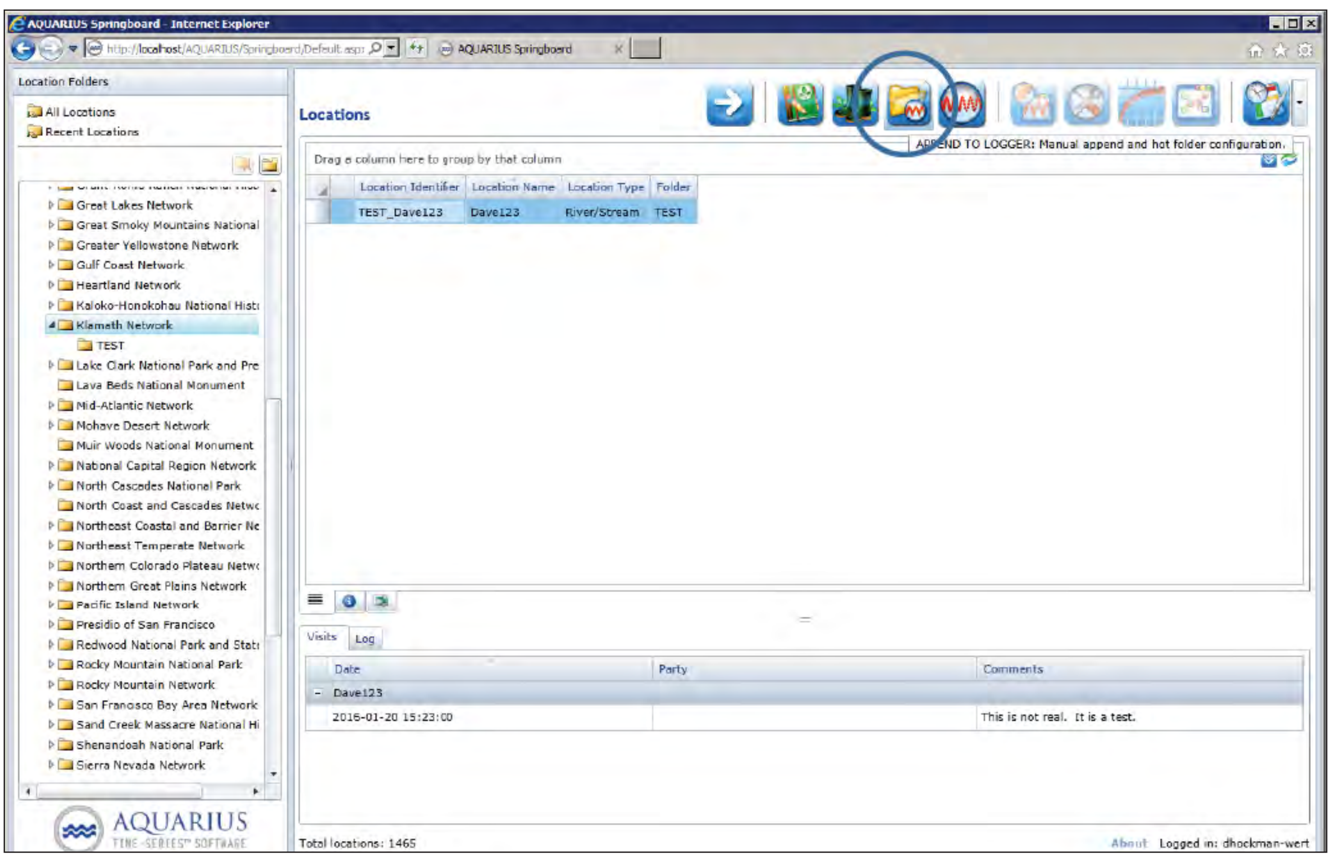

Figure 6.18. Screen capture showing **AQUARIUS Springboard**, with "Append to Logger" icon indicated.

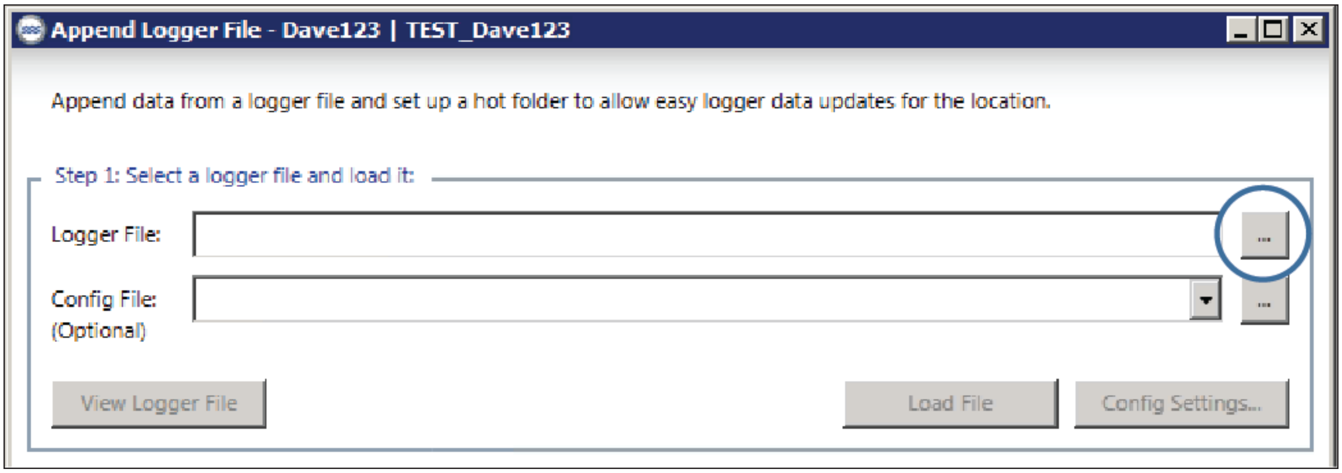

Figure 6.19. Screen capture showing **Append Logger File** dialog box, with "Picker" widget circled.

Figure 6.20. Screen capture showing **Import from File Wizard** dialog box, Step 1 of 4.

ii. **Step 2 of 4**: Enter the following values in the table (fig. 6.21):

- **Start import at row**: 3
- **Number of headers**: 2
- **Delimiters**: Comma
- Click **Next>>**

iii. **Step 3 of 4**: Select the following formats (fig. 6.22):

- Column 1: Select the **Do not import column (skip)** button, then click the blue right arrow to proceed to the next column.
- Column 2: Select the **Date/Time** button; select **mm/dd/yy HH:MM:SS PM** from the **Date/Time Format** drop-down list; select the correct time zone from the **Time Zone** field.
- Be sure the file time zone is the same as the time series dataset's defined time zone or AQUARIUS will convert the incoming file data into the time series dataset's defined time zone, which may result in incorrect times.
- Column 3: Select the **Data** button, and the **Raw** option in the drop-down list; **Parameter**: Water Temp; **Units**: °C; **Gap Tolerance**: 61 (one larger than the measurement interval); **Label**: Water Temp; **Int. Type**: 1 – Inst. Values; **Grade** and **Approval**: <unspecified>
- Column 4: Select the **Data** button, and the **Raw** option in the drop-down list; **Parameter**: Voltage; **Units**: V; **Gap Tolerance**: 61 (one larger than the measurement interval); **Label**: Voltage; **Int. Type**: 1 – Inst. Values; **Grade** and **Approval**: <unspecified>

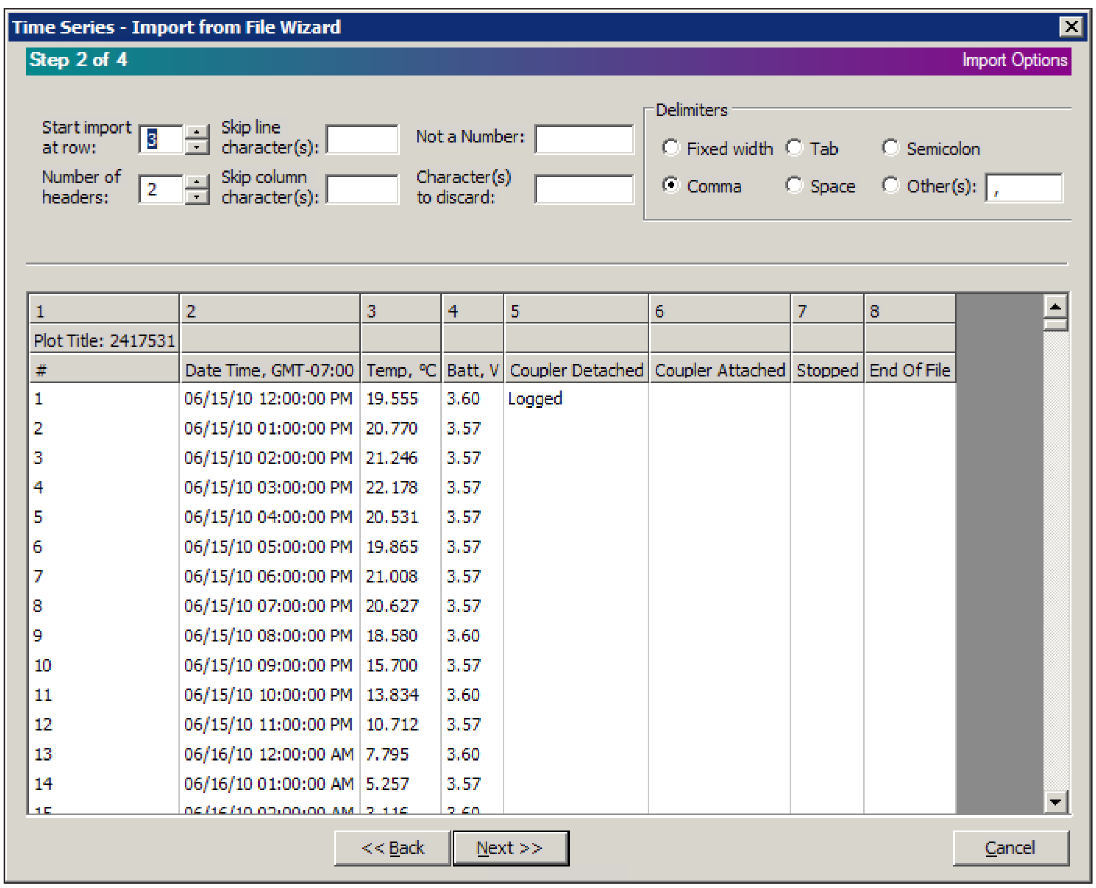

Figure 6.21. Screen capture showing **Import from File Wizard** dialog box, Step 2 of 4.

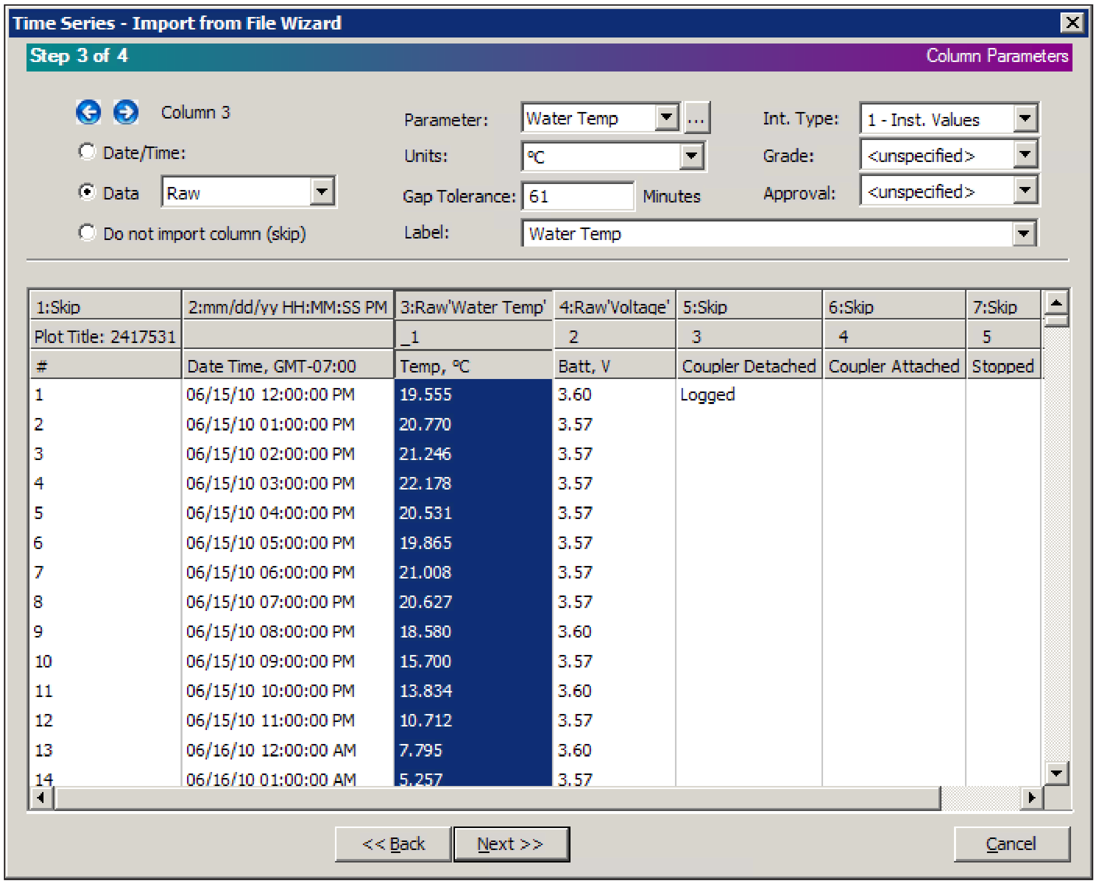

Figure 6.22. Screen capture showing **Import from File Wizard** dialog box, Step 3 of 4.

- Columns 5-8: Select the **Do not import column (skip)** button
- Click **Next>>**

iv. **Step 4 of 4**: Select **Apply Gap Processing Tolerance**.

- Save Configuration file to a location and name of one's choosing.
- Click **Finish**

g. In the **Append Logger File** dialog box, select the corresponding data sets into which to append the parameter data.

h. Click the **Append** button. Confirm that AQUARIUS appended the same number of points to each time series as was expected. There may be more points if AQUARIUS found gaps (more than 60 minutes between repeat measurements); there may be fewer points if there were redundant data, out of order data, or other problems with the file.

i. Optional: Click **Create Hot Folder** to set up a streamlined way to add future data to these data sets. See the AQUARIUS documentation for more details.

j. Note: AQUARIUS will not overwrite or delete data, but it is possible to **Undo** an Append operation.

k. Close the **Append Logger File** dialog box by clicking the X in the upper-right.

l. If all of the datasets for a location are not visible, click the right-pointing blue and white arrow to move from the location to its datasets. If already in the dataset view, click the refresh icon to requery the database in order to see newly-added datasets.

m. Double-click any dataset to view it in Quick View. One can also select a dataset and right-click on it and choose Quick View or click the Quick View icon.

Procedure—Enter Field Visit Information into AQUARIUS

1. Select the Field Visit icon at the top of the main Springboard window (fig. 6.23) to open the Field Visit Tool and enter information about or data from field visits.

    a. Click the **New** drop-down list at the top left corner of the window. Select **Field Visit**, unless a file already exists with the relevant information in one of the available formats (fig. 6.24).

    b. Enter the date and time of the field visit in the dialog box and click **Ok**.

    c. Enter the names of personnel on the work team in **Party** ("Crew" from the Stream Temperature Data Logger Installation Form; see appendix 1 for example).

    d. In the **Remarks** section, enter the following data from the Stream Temperature Data Logger Installation Form (appendix 1): Site Condition, Logger Condition, Bank, Anchor, Flagging, and Quality.

    e. Alternatively, add a scanned copy of the Stream Temperature Data Logger Installation Form or other field data forms to the **Hydrometric Field Notes** folder. (If the form has already been saved in the **General** tab of the **Location Manager**, do not save again here.) Select the **Hydrometric Field Notes** folder and click the green plus sign to add an attachment.

    f. To add a field measurement, click the **New** button and select **Measurement Activity**.

    g. Provide a **Measurement ID**. Enter sequentially starting with 1 unless another ID system is being followed. Set **Conditions** to **Control Clear** and the **Approval Level** to **Working** (fig. 6.25)

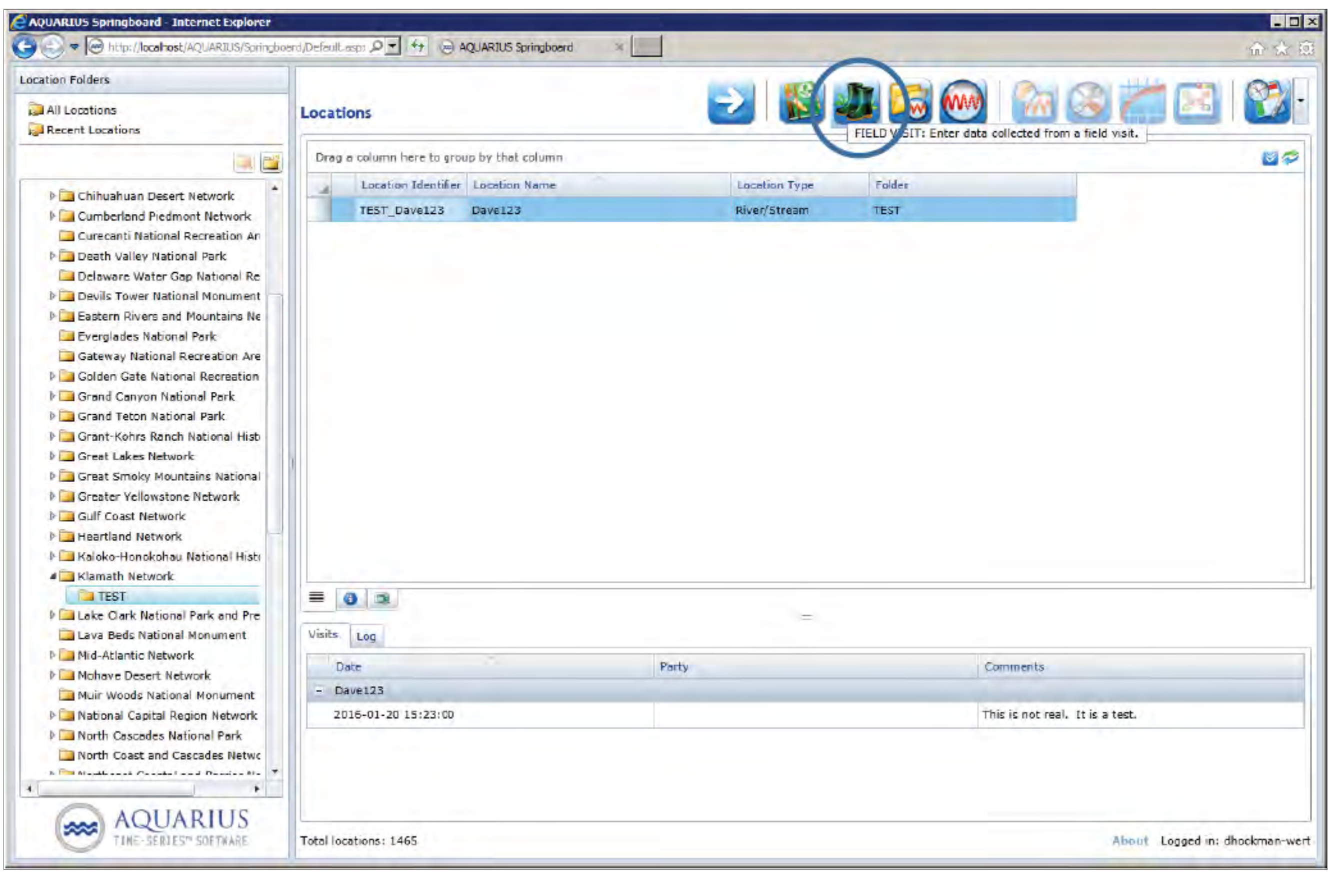

Figure 6.23. Screen capture showing **AQUARIUS Springboard**, with "Field Visit" icon indicated.

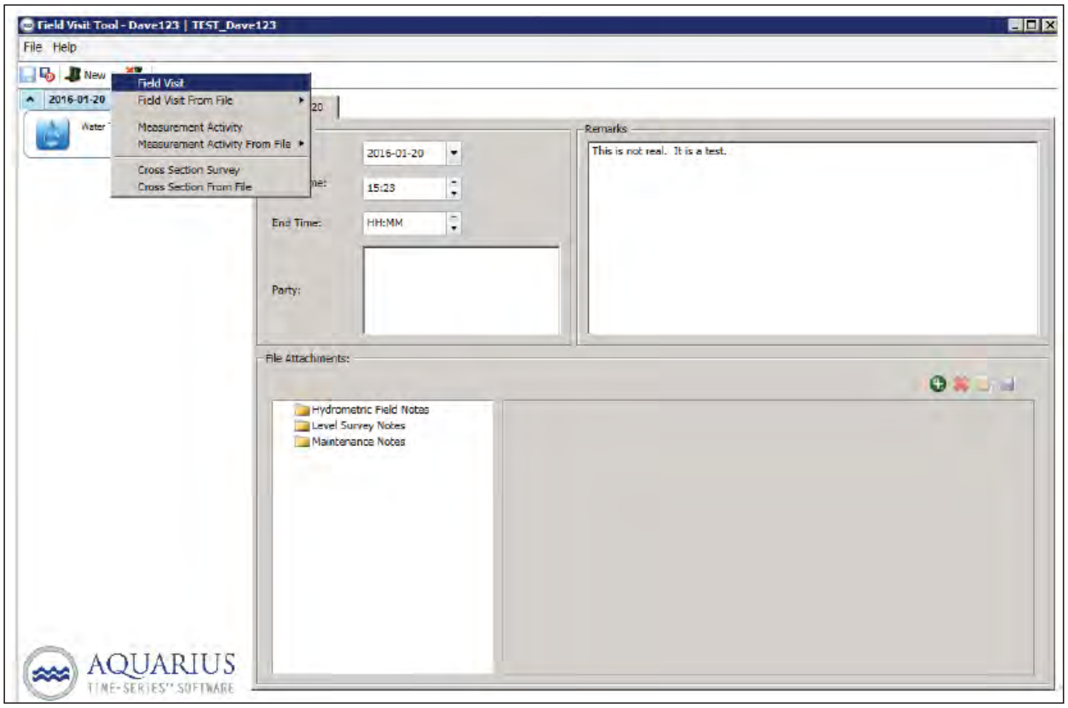

Figure 6.24. Screen capture showing **Field Visit Tool**, with the **Field Visit** option selected under the **New** menu.

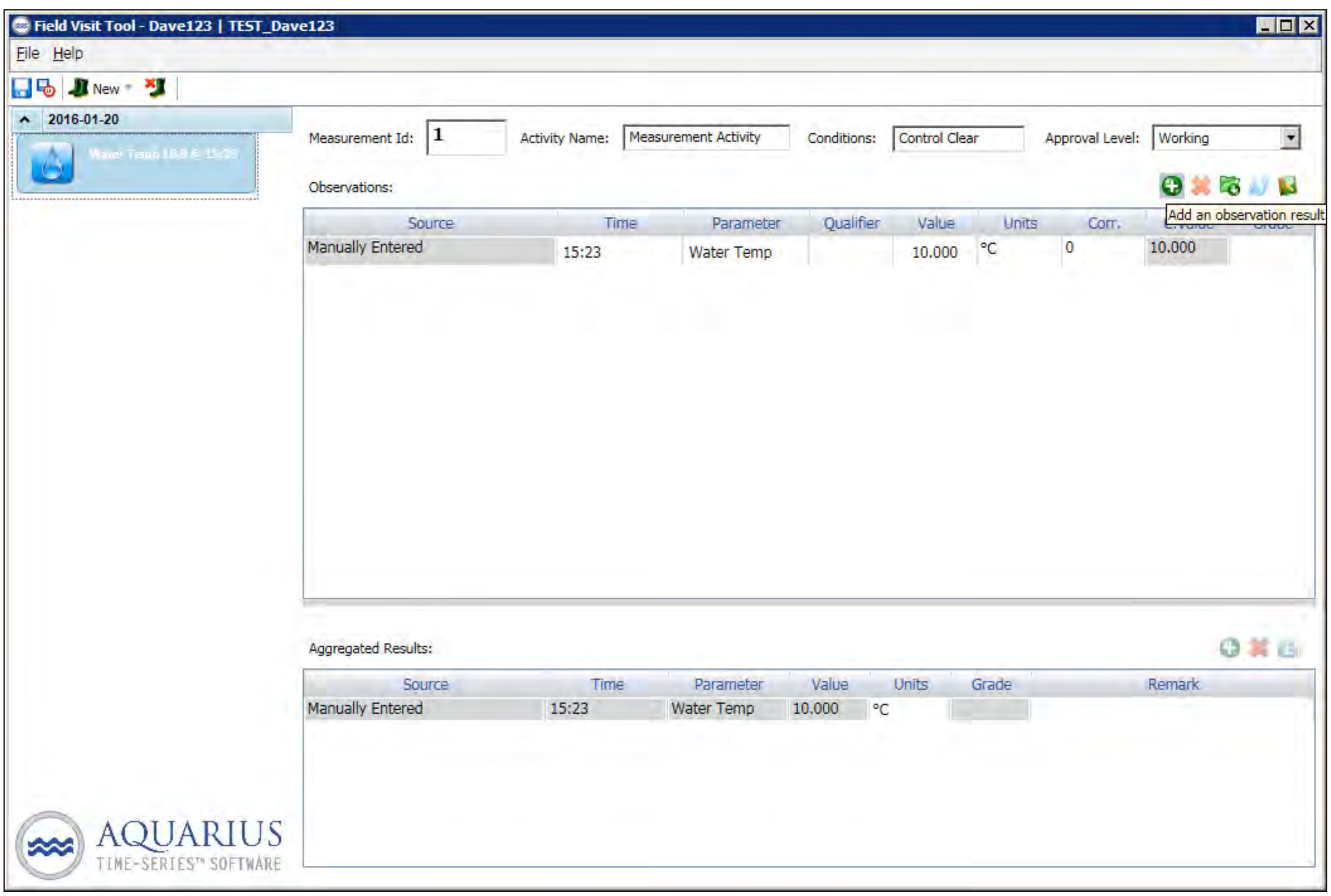

Figure 6.25. Screen capture showing **Field Visit Tool**, Measurement Activity screen.

h. Click the green plus sign to **Add an observation result** for as many values as are going to be entered. In this example, click once.

i. In the **Parameter** field, click the magnifying glass and select **Water Temp** in the **New Discrete Measurement** dialog box (figs. 6.26 and 6.27). (Use the **Search** box to filter the options.)

j. Enter measurement in the **Value** field (fig. 6.28).

k. Click the **Save Field Visit and Exit** button when finished (fig. 6.29).

2. Note that any measurement activity saved in the **Field Visit Tool** will appear in the **Data Sets** tab of the **Location Manager**.

3. To record when a field visit occurred, create a new visit file without adding any data.

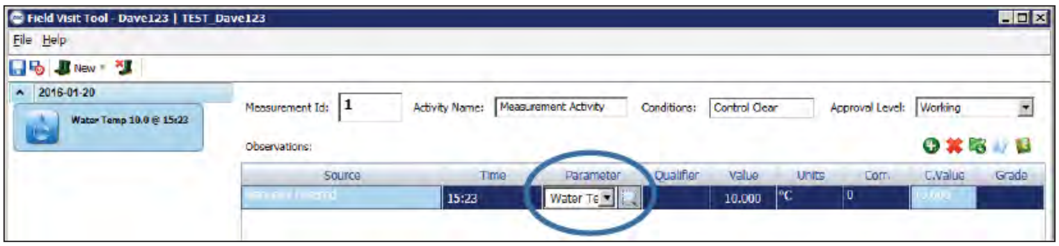

Figure 6.26. Screen capture showing **Field Visit Tool**, Measurement Activity screen. The magnifying glass in the **Parameter** field is circled.

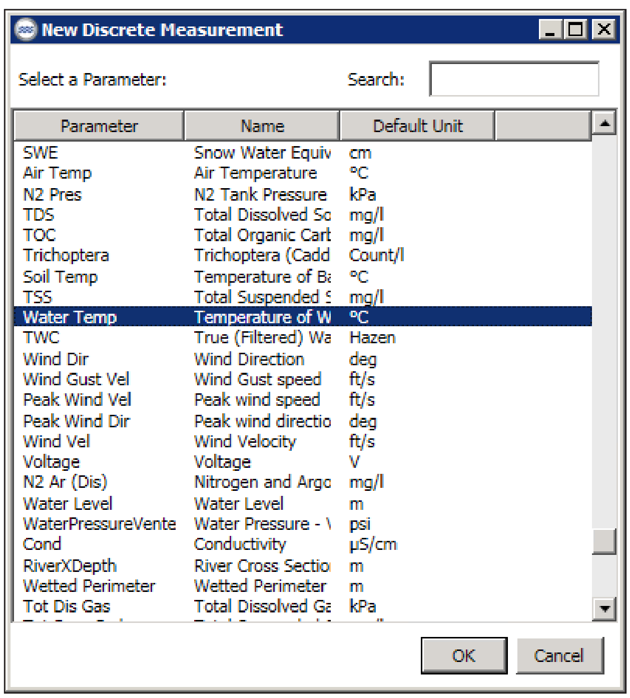

Figure 6.27. Screen capture showing **New Discrete Measurement** dialog box, with **Water Temp** parameter selected.

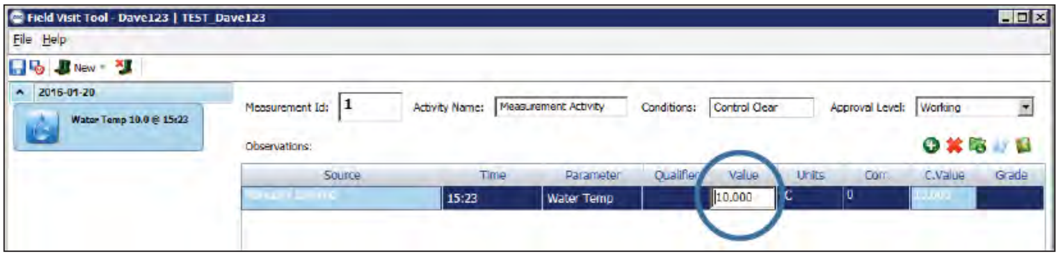

Figure 6.28. Screen capture showing **Field Visit Tool**, Measurement Activity screen. The **Value** field is circled.

Figure 6.29. Screen capture showing **Field Visit Tool**, Measurement Activity screen. The **Save Field Visit and Exit** button is circled.

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Appendix 1. Data Logger Installation and Download Forms

The blank Installation and Download Forms can be used as templates or customized to meet specific project needs. The completed Installation Form is intended to show the level of detail that should be recorded. The three completed Download Forms are intended to show the level of detail that should be recorded when a data logger is found and downloaded, a data logger is found but not successfully downloaded, and a data logger is not found.

Stream Temperature Data Logger Installation Form

Site #: ______________________ **Crew:** ______________________

Date: ______________________ **Time:** ______________________

Data Logger Serial #: ____________

Latitude: ______________________ **Longitude:** ______________________

Site Condition: **Wet** **Dry** **Water Temperature:** ____________

Data Logger Condition: Submerged Submerged at surface

Exposed at surface Dry

Bank (looking downstream): Left Middle Right

Anchor: Sandbags Rebar Cable/zip ties DUCKBILL

Flagging: Yes No

Quality: Great OK Poor

Camera ID: ______________________ **Photo #'s:** ______________________

Notes: Provide a written description or sketch of the site so it can be easily accessed and located in the future by someone who has never been there:

Stream Temperature Data Logger Installation Form

EXAMPLE

Site #: *USGS-25618* **Crew:** *Heck, Allai*

Date: *08/28/15* **Time:** *1537*

Data Logger Serial #: *9810433*

Latitude: *42.13586* **Longitude:** *-118.24100*

Site Condition: Wet Dry **Water Temperature:** ____________

Data Logger Condition: Submerged Submerged at surface Exposed at surface Dry

Bank (looking downstream): Left Middle Right

Anchor: Sandbags Rebar Cable/zip ties DUCKBILL

Flagging: Yes No

Quality: Great OK Poor

Camera ID: *Canon D30* **Photo #'s:** *1787 & 1788*

Notes: Provide a written description or sketch of the site so it can be easily accessed and located in the future by someone who has never been there:

Logger anchored to a DUCKBILL and placed ~2 m downstream of a channel-spanning willow. Upper portions of the willow are dead, burnt branches. It is the largest willow within 100 m of the site. Logger is just upstream of two boulders that protrude from the water at base flow. Access site from the right bank.

Stream Temperature Data Logger Download Form

Site #:

Data Logger Serial #:

Previous Crew:

<u>1. Locate Site</u>

Latitude: **Longitude:**

Bank **Anchor:** **Flagging:** **Quality:**

Site Condition:

Comments:

Pictures:

2. Download Temperature Data Logger

Site #: **Crew:** ______________

Date: ______________ **Time:** ______________

Data Logger Serial #:

Site Condition: Wet Dry **Water Temperature:** ______________

Found Data Logger?: Yes No

Logger Condition at Arrival: Submerged Submerged at surface

Exposed at surface Dry

Successful Download?: Yes No

Action Following Download: Reinstall Remove

Logger Condition at Departure: Submerged Submerged at surface

Exposed at surface Dry

Camera ID: ______________ **Photo #s:** ______________

Notes:

Stream Temperature Data Logger Download Form

EXAMPLE

Site #: USGS-25618

Data Logger Serial #: 9810433

Previous Crew: Heck, Allai

1. Locate Site

Latitude: 42.13586 **Longitude:** -118.24100

Bank Left **Anchor:** DUCKBILL **Flagging:** Yes **Quality:** Great

Site Condition: Wet

Comments: Logger anchored to a DUCKBILL and placed ~2 m downstream of a channel-spanning willow. Upper portions of the willow are dead, burnt branches. It is the largest willow within 100 m of the site. Logger is just upstream of two boulders that protrude from the water at base flow. Access site from the right bank.

Pictures:

EXAMPLE

2. Download Temperature Data Logger

Site #: USGS-25618

Crew: *Schultz, Jones*

Date: *08/22/16*

Time: *0912*

Data Logger Serial #: **9810433**

Site Condition: Wet Dry

Water Temperature: *11.0°C*

Found Data Logger?: Yes No

Logger Condition at Arrival: Submerged Submerged at surface Exposed at surface Dry

Successful Download?: Yes No

Action Following Download: Reinstall Remove

Logger Condition at Departure: Submerged Submerged at surface Exposed at surface Dry

Camera ID: *Canon D30*

Photo #s: *2023 - 2026*

Notes:

Logger found completely submerged. Following download, re-attached logger and PVC solar shield to DUCKBILL using new 11" cable/zip ties. Hung new orange flagging on large willow just upstream of logger. Took new pictures.

Stream Temperature Data Logger Download Form

EXAMPLE

Site #: USGS-25618

Data Logger Serial #: 9810433

Previous Crew: Heck, Allai

1. Locate Site

Latitude: 42.13586 **Longitude:** -118.24100

Bank Left **Anchor:** DUCKBILL **Flagging:** Yes **Quality:** Great

Site Condition: Wet

Comments: Logger anchored to a DUCKBILL and placed ~2 m downstream of a channel-spanning willow. Upper portions of the willow are dead, burnt branches. It is the largest willow within 100 m of the site. Logger is just upstream of two boulders that protrude from the water at base flow. Access site from the right bank.

Pictures:

EXAMPLE

2. Download Temperature Data Logger

Site #: USGS-25618 **Crew:** *Schultz, Jones*

Date: *08/22/16* **Time:** *0912*

Data Logger Serial #: **9810433**

Site Condition: Wet Dry **Water Temperature:** *11.0°C*

Found Data Logger?: Yes No

Logger Condition at Arrival: Submerged Submerged at surface

Exposed at surface Dry

Successful Download?: Yes No

Action Following Download: Reinstall Remove

Logger Condition at Departure: Submerged Submerged at surface

Exposed at surface Dry

Camera ID: ______ **Photo #s:** ______

Notes:

Data logger found completely submerged but failed to download. Re-wiped algae off the optic communications on the data logger. The status light on the Optic Shuttle blinks yellow for several seconds but turns to red. Suspect that the data logger's battery is dead. Removed data logger 9810433 and installed a new data logger at the site. Will use a "Stream Temperature Data Logger Installation Form" to document the new installation. The Site # will remain the same.

Stream Temperature Data Logger Download Form

EXAMPLE

Site #: USGS-25618

Data Logger Serial #: 9810433

Previous Crew: Heck, Allai

<u>1. Locate Site</u>

Latitude: 42.13586 **Longitude:** -118.24100

Bank Left **Anchor:** DUCKBILL **Flagging:** Yes **Quality:** Great

Site Condition: Wet

Comments: Logger anchored to a DUCKBILL and placed ~2 m downstream of a channel-spanning willow. Upper portions of the willow are dead, burnt branches. It is the largest willow within 100 m of the site. Logger is just upstream of two boulders that protrude from the water at base flow. Access site from the right bank.

Pictures:

EXAMPLE

2. Download Temperature Data Logger

Site #: USGS-25618 **Crew:** *Schultz, Jones*

Date: *08/22/16* **Time:** *0912*

Data Logger Serial #: **9810433**

Site Condition: Wet Dry **Water Temperature:** *11.0°C*

Found Data Logger?: Yes No

Logger Condition at Arrival: Submerged Submerged at surface

Exposed at surface Dry

Successful Download?: Yes No

Action Following Download: Reinstall Remove

Logger Condition at Departure: Submerged Submerged at surface

Exposed at surface Dry

Camera ID: ______ **Photo #s:** ______

Notes:

Data logger found completely submerged but failed to download. Re-wiped algae off the optic communications on the data logger. The status light on the Optic Shuttle blinks yellow for several seconds but turns to red. Suspect that the data logger's battery is dead. Removed data logger 9810433 and installed a new data logger at the site. Will use a "Stream Temperature Data Logger Installation Form" to document the new installation. The Site # will remain the same.

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