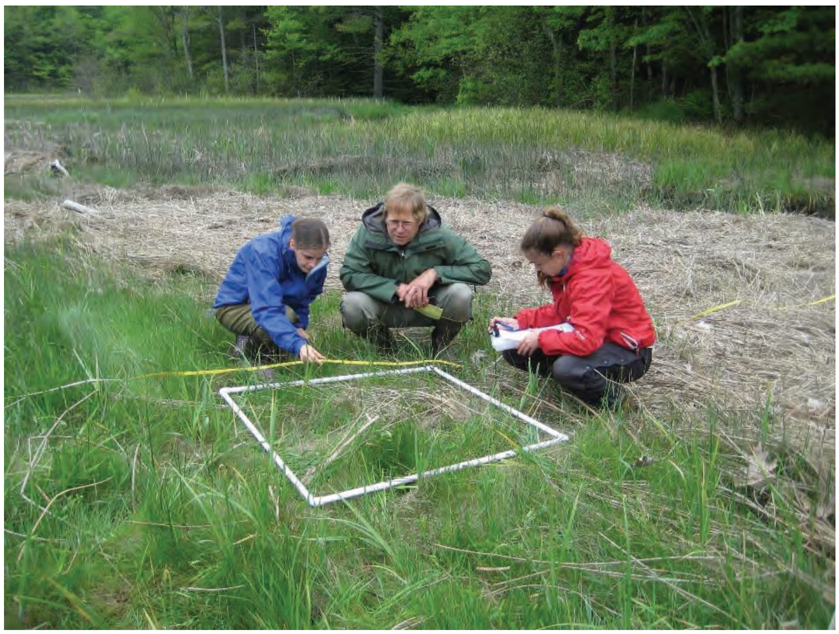
Quality Assurance Project Plan
For
Tidal Marsh Monitoring and Assessment



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Title

Quality Assurance Project Plan for Tidal Marsh Monitoring and Assessment

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1.3 Distribution List

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Table I.1 List of Acronyms & Abbreviations

Abbreviation	Meaning
APP	Appendix
CBEP	Casco Bay Estuary Partnership
CCMP	Comprehensive Conservation and Management Plan
CLF	Conservation Law Foundation
DI	Deionized (water)
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
GOMC	Gulf of Maine Council on the Marine Environment
GPAC	Global Programme of Action Coalition for the Gulf of Maine
GPS	Global Positioning System
GRTS	Generalized Random Tessellation Stratified Sample
LIDAR	Light Detection and Ranging
LTC	Level, temperature, conductivity
MDOT	Maine Department of Transportation
MEGIS	Maine Office of GIS
MNRCP	Maine Natural Resources Conservation Program
NEP	National Estuary Program
NOAA	National Oceanic and Atmospheric Administration
PI	Principal Investigator
PM	Project Manager
PSC	Plant species of concern
PSU	Practical salinity unit
USM	University of Southern Maine
QA/QC	Quality assurance and quality control
QAPP	Quality Assurance Project Plan
RTK GPS	Real time kinematic global positioning system
SAP	Site Analysis Plan
SOP	Standard Operating Protocol
WSR	Wallace Shore Road, Harpswell

1.4 Project Organization

The following individuals will carry out major responsibilities for the project's activities. An organization chart is shown in Figure 1.

Dr. Curtis Bohlen is the Principal Investigator (PI) and works with the Project Manager on protocol development and refinement. Bohlen revised and edited the QAPP. The PI reviews and approves SAPs (Site Analysis Plans), and supports data archiving, data QA/QC, data processing, and analysis. Bohlen leads vegetation monitoring.

Matt Craig, is the Project Manager (PM) for marsh monitoring and the principal QAPP author. The PM works with the PI on protocol development and refinement, and is the person primarily responsible for developing SAPs, coordinating with partners, implementing monitoring activities, managing data, reporting to funders, day to day management and training of field staff, and assessing consistency with protocols.

Bryan Hogan, EPA is the QA Officer and provides QA oversight through the QAPP development, review, approval and renewal processes.

Dr. Matthew Liebman, EPA Project Officer for CBEP, coordinates QAPP review and approval between the QA Manager and CBEP.

Project partners include funders and agencies. CBEP works with project partners to develop SAPs and ensures that SAP protocols are consistent with this QAPP.

Field Staff include graduate students, interns, temporary field staff, volunteers, and collaborating partners.

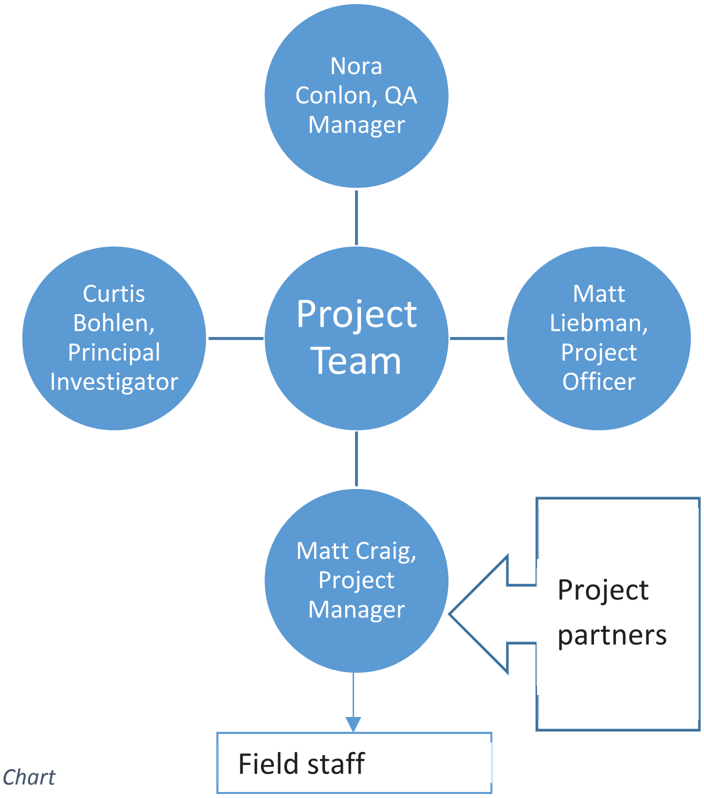

Figure 1. Organization Chart

1.4.1 Amendments or revisions to QAPP

Over time, amendments or revisions to the QAPP may be required. Revisions may be necessary (1) to reflect changes in project organization, tasks, schedules, objectives, and methods; (2) to add descriptions of additional monitoring methods; (3) to address deficiencies and nonconformance; (4) to improve operational efficiency; and/or (5) to accommodate unique or unanticipated circumstances. Requests for Amendments/Revisions will be made by CBEP to EPA via email. Any changes that significantly affect the technical and quality objectives of the project will require a revision and re-approval of the QAPP, and a revised copy will be sent to all persons on the distribution list.

1.5 Problem Definition/Background

1.5.1 Problem Statement

This Quality Assurance Project Plan (QAPP) covers work by the Casco Bay Estuary Partnership to document current condition of, and monitor changes in, tidal wetlands. Condition of tidal wetlands can change due to numerous factors, such as changes in surrounding land use, altered hydrology, sea level rise, climate change or environmental restoration. A principal purpose of CBEP's tidal wetland monitoring in the past has been to document changes in tidal wetlands in response to habitat enhancement and restoration projects whose primary objective was to increase tidal exchange by removing or replacing an existing built structure (typically, a culvert).

However, the methods described here can be used to evaluate site conditions for other reasons, or to track changes in tidal wetlands occurring in response to other sources of environmental change. Concern in the Northeast has been growing about long term changes in coastal wetlands, especially those caused by climate change and sea level rise. Methods used for documenting response of tidal wetlands to restoration and documenting response to environmental change are broadly similar.

This QAPP thus incorporates methods that can be used (1) for rapid site assessments, (2) for in –depth characterization of wetland condition, and (3) for monitoring multi-year changes in tidal wetlands, including changes that occur in response to habitat restoration or enhancement efforts.

This QAPP outlines standard protocols used in (1) desktop evaluations of site conditions, (2) preliminary and "rapid" site assessments at sites of interest, and (3) in-depth, generally multi-year monitoring programs subject to SAPs tailored to specific sites.

1.5.2 Tidal Restrictions and Ecological Restoration

Salt marshes are highly productive ecosystems that provide numerous benefits to human and ecological communities. Salt marshes remove nutrients and other pollutants from water, provide food for shellfish and finfish, provide nursery habitat for juvenile fish, provide critical habitat for certain birds and wildlife, mitigate floods and attenuate wave energy, and serve as recreational destinations for people. (Tyrell 2005; Taylor 2008).

Salt marshes maintain ecological functions and values through intrinsic processes including regular exchange and inundation of tidal water, which transports salt, nutrients, nekton, and sediments via tidal creeks, as well as via sheet flow across the marsh surface during astronomic high tides. Tidal creeks also provide freshwater drainage out of a marsh system. (Mitsch and Gosselink 2001; Taylor 2008).

Hydrologic processes can be altered when roads, railroads, utilities (water, sewer, gas), and other structures are constructed over marshes and estuaries. In Casco Bay, the exchange of fresh and salt water beneath these structures is often concentrated through culverts at the creek channel. Many undersized or poorly set tidal culverts were installed without sufficient attention to a tidal cycles, floods, storm surge and sea level rise. Consequently, tidal culverts are frequently undersized, misaligned, or set at the wrong elevation, and it is common for all three conditions to occur at a site. These deficiencies result in altered natural hydrology and associated impacts to core ecological processes, and are often described as tidal restrictions. Tidal restrictions constrain the free exchange of salt and fresh water between upstream and downstream wetlands, altering natural hydrology and associated processes, resulting in reduced duration, depth, and extent of tidal inundation; reduced freshwater drainage out of the marsh; and impoundment of surface and groundwater. Hydrologic alteration can lead to colonization by non-native species, as well as changes to plant community composition, biogeochemistry, salinity, water quality, sediment and nutrient exchange, and faunal populations. (Burdick and Roman 2012).

In some cases, the impacts associated with tidal restrictions can be reduced or reversed, and wetland communities enhanced, by partially or fully restoring natural hydrological processes. A typical tidal restoration project would replace an undersized culvert with a larger new structure. This episodic change in hydrology can, over time, enhance physical characteristics in a marsh and allow for reestablishment of plant and animal communities (*ibid*).

Tidal restoration at restricted marshes has been a priority within the Gulf of Maine for decades (Neckles and Dionne 2000; GOMC 2004), and within Casco Bay, since 1999, when CBEP and project partners launched phase I of the Return the Tides project, which inventoried tidally restricted salt marshes in Casco Bay (CLF 2000). Tidal restoration has been a focus of CBEP habitat restoration efforts since the CLF report, but CBEP capacity to lead implementation increased in 2008 and as of 2017, several tidal restoration projects have been undertaken. Protecting, restoring and enhancing key habitats in Casco Bay is one of four core goals of the *2016-2021 Casco Bay Plan*, which serves as the CCMP for CBEP. Action 1.2A of the *Plan* calls for CBEP to lead coastal habitat restoration and enhancement efforts with a focus on tidal wetlands and tidal restrictions.

CBEP has facilitated three tidal restoration projects as of 2016 and has developed and implemented site-specific monitoring plans for these sites. Integrated approaches to ecosystem monitoring provide information about project outcomes that inform future assessment and management activities. Monitoring reports are provided to project funders including MDOT, MNRCP and NOAA.

1.5.3 Long Term Changes in Tidal Wetlands

Hydrology is widely recognized as a major driver of wetland ecosystem structure and function (Mitsch and Gosselink 2001). Tidal wetlands occur in areas inundated periodically by tidal action. The ecology of these wetlands is strongly structured by environmental gradients created by the tides, especially those related to inundation and salinity.

Local projections suggest anywhere from 0.5 meter to 2 meters of relative sea level rise (SLR) in the Casco Bay region (e.g., Bohlen 2012). The 2014 National Climate Assessment offers a risk-based range of from one to four feet of global sea level rise by end of the century, while noting that historical levels of SLR in the northeast have exceeded global averages (Melillo et al. 2014, Horton et al. 2014). Impacts of SLR on tidal wetlands have been well documented, especially in areas with limited tidal range and elevated subsidence.

In recent decades, wetland managers have become increasingly concerned about the potential impact of sea level rise on tidal wetlands, and calls have increased for creation of networks of "sentinel sites" to track long-term changes in salt marshes and other coastal ecosystems (e.g., the NROC / NERACOOS Sentinel Monitoring Network, and the NERRS System Wide Monitoring Program).

SLR is not the only potential long-term driver of change in coastal wetlands. While direct filling of tidal wetlands in Maine is relatively rare due to regulatory restrictions, less direct anthropogenic impacts are widespread. Precipitation patterns the northeast have altered in recent years, leading to increases in total precipitation and a shift toward more intense storms. Those trends are expected to continue. Climate warming has shifted peak river flows earlier in the spring, and is likely to affect salt marsh ecosystems indirectly through a number of mechanisms, such as a reduction in ice scour, or increases in evapotranspiration. Deegan et al. have documented changes in tidal marsh structure and function following experimental increases in nitrogen loading (Deegan et al. 2012). Non-native green crabs, which boomed in population following the warm winters of 2012 and 2013 were widely reported to burrow into tidal creek banks, accelerating erosion. How such stressors will interact with sea level rise remains little understood.

A primary purpose of long-term salt marsh monitoring, therefore, is to observe changes in coastal wetlands to provide insight into forces driving changes in tidal wetlands, improve forecasting of future wetland condition, provide ground truth data to compare with model forecasts, and guide future discussion of potential wetland management alternatives. The goal is not short-term hypothesis-driven science, but long-term collection of data using consistent methods to provide background understanding of patterns and change.

1.6 Project Description and Schedule

1.6.1 Description

The strategies and actions outlined in the 2016-2021 *Casco Bay Plan*, (Especially Actions 1.2.A: Lead coastal habitat restoration efforts; and 4.3.B: Facilitate improved research on changes in Casco Bay) call for continued monitoring of tidal marshes in Casco Bay. The purposes of this monitoring include:

(1) assessing the impact of tidal restrictions - built infrastructure, such as roads, railroads, dikes, dams, and other structures - on tidal marsh condition;
(2) monitoring ecosystem response to restoration and enhancement activities, such as culvert replacements; and
(3) Documenting long-term changes in Casco Bay's tidal wetlands.

Monitoring results will be used to inform future assessment, restoration, and management activities.

This QAPP serves as an umbrella document for outlining protocols for data collection in tidal marshes. Procedures described here include both rapid site assessment methods used for site assessments before a long-term monitoring is established at a site, as well as methods used for long-term monitoring. Site-specific monitoring sampling and analysis plans (SAPs) are developed for project sites when the decision is made to establish long-term monitoring, based on site-specific project goals and objectives, and requirements of project funders.

Monitoring of tidal wetlands falls into three natural phases:

(1) Initial site assessment, including assessment of restoration feasibility;
(2) Documentation of baseline conditions and establishment of a framework for long-term monitoring; and
(3) Long term monitoring to evaluate changes in the marsh system over time.

Phase 1 (Site Assessment) is carried out principally using desktop assessment and rapid assessment methodologies. For evaluation of potential restoration sites, it includes collection of additional data sufficient to evaluate ecological and engineering feasibility of restoration, such as data on marsh hydroperiod and marsh surface elevation. The primary purpose of Phase 1 data collection is to provide information to evaluate sites as restoration opportunities or long-term monitoring sites. Site assessments may also be carried out to provide information (sometimes at the request of partner organizations) on condition of tidal wetlands. Phase 1 assessment methods are intended to be flexible, inexpensive, and quick, involving limited time in the field, and providing mostly qualitative information. Site assessments may or may not result in production of a formal assessment report. Phase 1 evaluations will be carried out without development of a SAP.

Phase 2 (Baseline Condition and Monitoring Framework) represents a significant investment in planning and data collection, and will typically only be carried out at sites where a decision has been made to establish long-term monitoring. Where long-term monitoring is planned, a SAP is required and will be developed before baseline monitoring begins.

Phase 3 (Long Term Monitoring) represents ongoing monitoring programs, typically continuing for three years or more. A SAP will be required before long-term monitoring begins.

1.6.2 Special Practices for Monitoring Restoration Sites

The overall goal of monitoring restoration projects is to understand the impact of restoration on ecosystem structure and function. The strategy is to document and assess tidal marsh conditions pre- and post-project, and evaluate changes to the marsh that occur as a result of tidal restoration. Monitoring results are used to inform future tidal restoration assessment and restoration project work, and to report to project partners.

To achieve that, we document and assess tidal marsh conditions pre- and post-project, both at the project site and at a nearby reference site unaffected or minimally affected by restoration. Project Site and Reference Site are defined in the SAP. Changes observed at the Project Site that are not also observed at the Reference Site are likely to be the result of restoration activity. For tidal restoration projects, the Project Area is generally immediately upstream of the structure (culvert, dam, etc.) being altered to restore tidal flow, while the reference area may be nearby or immediately downstream.

Long-term monitoring of restoration projects begins with initial site assessment (Phase 1) and formal collection of baseline data (Phase 2) at least one field season prior to project implementation. Pre-project assessment provides an essential comparison with post-project (Phase 3) monitoring.

1.6.3 Project Schedule

Field based assessment and monitoring occurs between April and October. Additional information is provided in conjunction with protocols for individual monitoring parameters. Monitoring locations and schedules are defined in site-specific Sampling and Analysis Plans (SAPs.) Current (Summer 2018) monitoring locations include:

- Appletree Marsh (Harpswell, Maine),
- High Head Road (Harpswell, Maine),
- Long Marsh (Harpswell, Maine), and
- Thomas Bay Marsh (Brunswick, Maine).

We anticipate adding additional monitoring sites and dates in the future, both for continued monitoring of restored sites and also for tracking of changes in tidal wetlands.

1.7 Quality Objectives and Criteria

Monitoring tasks are often similar regardless of the objective of the monitoring program.

Phase 1: Initial Site Assessments

Quality objective 1: Document current condition of tidal wetland (Rapid site assessment).
Task: Conduct "desktop" assessment of tidal wetland condition
Task: Conduct rapid field assessment
Task: Document visual indicators of altered hydrology from anthropogenic structures

Quality objective 2: Assess impacts of built structure(s) on marsh hydroperiod.
Task: Document visual indicators of altered hydrology from anthropogenic structures.
Task: Document the nature and physical characteristics of the tidal restriction or other structure
Task: Monitor surface water level (tidal signal) and salinity upstream and downstream of the structure.

Quality objective 3: Assess whether tidal restoration is a suitable management response to relieve or reverse impacts of tidal restrictions, to enhance ecological processes, or to promote ecological resilience.

Task: Evaluate elevation of marsh and low-lying upland areas in relation to tidal datums and water level data.
Task: Prepare hydrology and channel morphology data for hydraulic modeling associated with engineering feasibility studies.
Task: Summarize, analyze, and characterize hydrology monitoring results.

Phase 2: Baseline Monitoring

Quality objective 4: Characterize site condition

Task: Develop Sampling and Analysis Plan (SAP) for the site based on rapid assessment and other available data
Task: Document or sample vegetation communities
Task: Survey for the presence of invasive plant species
Task: Sample and monitor pore water salinity
Task: Sample/survey channel morphology
Task: Monitor surface water level (tidal signal) and salinity
Task: Sample/survey marsh surface elevation
Task: Summarize, analyze, and characterize assessment data

Phase 2: Long Term Monitoring

Quality Objective 5: Monitor Changes in Site Condition
to assess long term changes in marsh condition, or document changes to the marsh system associated with restoration.

Task: Document or sample vegetation communities
Task: Survey for the presence of invasive plant species
Task: Sample and monitor pore water salinity
Task: Sample/survey channel morphology
Task: Monitor surface water level (tidal signal) and salinity
Task: Sample/survey marsh surface elevation
Task: Survey for the presence of invasive plant species
Task: Summarize, analyze, and characterize assessment data

Table 1. Desktop and Rapid Assessment Methods, Purpose, and Data Quality. Desktop and rapid assessment methods are used during initial site assessments. Rapid assessment data support deciding whether in-depth data collection is warranted and provide information to facilitate development of a SAP.

Parameter / Measurement	Description of Method	Purpose	Data Quality Goals	Units	Comment
Site Elevation	LiDAR coverage of the Casco Bay region assembled by CBEP from NOAA and USGS Lidar Coverages. Bohlen et al. 2012	Compare marsh elevation with tidal data	Available public data; Vertical accuracy 25 cm MSE, horizontal ≤ 5m grid size.	UTM Zone 19 North, NAD83, NAVD 88	Used to calculate hydroperiod and tidal prism; and identify discrepancies between observed and anticipated vegetation
Watershed size	GIS analysis of DEMs, typically derived from LiDAR	Characterize freshwater inflows compared to tidal exchange	± 10%	Acres, square meters or hectares	Lower resolution DEMs (ca. 5 or 10m grid) can be easier to work with, and often provide similar accuracy for this purpose compared with higher resolution data.
Wetland Area	Interpretation of National Wetland Inventory data	Identify approximate wetland boundaries	± 10 m	UTM Zone 19 North, NAD83	NWI data standards call for mapping wetlands down to 1 acre (See USFWS 2004), with a positional accuracy of 10m (33 feet).
	Interpretation of aerial photographs	Identify higher resolution wetland boundaries	± 2 m	UTM Zone 19 North, NAD83	Recent georeferenced imagery is available through the MEGIS, Google Earth and ArcGIS base map layers.

Table 2. Rapid Assessment Methods, Purpose, and Data Quality (Continued)

Parameter / Measurement	Description of Method	Purpose	Data Quality Goals	Units	Comment
Surrounding development	Qualitative field observation; Analysis of aerial photography	Assess whether area surrounding the tidal wetland has a high level of development	Qualitative only	Low, Medium, or High	
	GIS analysis of land cover data	Calculate percent developed in buffer and/or in watershed	Best available data, considering date and resolution; Resolution no worse than NLCD 2011 at 30 m grid.	Percent developed	https://catalog.data.gov/dataset/national-land-cover-database-nlcd-land-cover-collection Maine's most recent land cover data is on a 5m grid, but it dates to 2004, so it is only suitable where little land use change has occurred as assessed by looking at aerial photography.
	GIS analysis of impervious cover data	Assess percent impervious in buffer and/or in watershed	Best available data, considering date and resolution	Percent impervious	Maine's high resolution impervious cover data dates to 2007, with 1 m resolution. No more recent data is available.
Vegetation	Plotless "relevé" observation of vegetation composition	Document common and dominant species	Identify common plant species and major vegetation types (e.g., low marsh, high marsh)	Presence / absence; Qualitative relative abundance	Approximate locations of observations documented with notes on paper maps and/or GPS coordinates recorded with consumer-grade GPS receivers.

Table 2. Rapid Assessment Methods, Purpose, and Data Quality (Continued)

Parameter / Measurement	Description of Method	Purpose	Data Quality Goals	Units	Comment
Spatial pattern of vegetation zones	Aerial photography interpretation	Document broad-characteristics of vegetation	± 10 feet / 3 m. Note large (> 750 sq feet / 65 sq m) inclusions	UTM Zone 19 North, NAD83	Recent georeferenced imagery is available through the MEGIS and Google Earth and ArcGIS base map layers.
	Sketch map on pre-printed site maps	Document changes in vegetation (e.g., along a salinity gradient)	Approximate locations only	UTM Zone 19 North, NAD83	
	Mapping of vegetation boundaries using GPS	Track changes in location of major vegetation zones (e.g., low marsh, high marsh)	± 10 feet / 3 m; Note large (> 750 sq feet / 65 sq m) inclusions	UTM Zone 19 North, NAD83	High quality boundaries require use of a survey-grade GIS receiver, such as the Trimble GeoXT. Consumer-grade GPS receivers do not record PDOP, making it difficult to evaluate data quality.
Indicators of altered hydrology	Site visit	Document evidence of hydrologic alteration	Approximate locations only	UTM Zone 19 North, NAD83	Indicators include, presence of scour pools, changes in vegetation, observation of restricted flow, changes in water surface elevation etc.

Table 2. Principal Parameters, Purposes and Associated Data Quality Goals. Principal parameters are measured for in-depth site characterization, and as part of long-term site monitoring of restoration sites and reference sites. Nominal method performance information is provided in table 4.

Parameter / Measurement	Purpose(s)	Data Quality Goals	Comment
Pore water salinity	Distinguish between fresh (<0.5 ‰) , oligohaline (< 5 ‰), mesohaline (< 18 ‰), polyhaline (< 30‰) and euhaline (< 36‰) conditions.	Measure salinity to ±1 ‰ below 5 ‰, and to ±2 ‰ above 5 ‰	Pore water salinity is measured on samples in the field using a refractometer, which measures in ‰ (parts per thousand). Sample volumes are not sufficient to allow use of electrochemical conductivity meters.
	Identify differences or changes in pore water salinity of 5 ‰	Measure salinity to ±2.5 ‰ throughout range	For comparisons of conditions above/below tidal restriction; before/after restoration; by time of year, etc.
Surface water salinity	Distinguish between fresh (<0.5 ‰) , oligohaline (< 5 ‰), mesohaline (< 18 ‰), polyhaline (< 30‰) and euhaline (< 36‰) waters; profile salinity upstream to downstream along tidal channels or in surface pools	Salinity to ±1 ‰ / ±1 PSU below 5 ‰ / 5 PSU, and to ±2 ‰ / ±2 PSU above 5 ‰ / 5 PSU.	While surface water salinity is principally measured using electrochemical conductivity sensors on data loggers, refractometers (reporting salinity in ‰) are used during rapid site assessments.
	Document effect of tidal restrictions on surface water salinity and assess mixing of fresh and salt water.	Accuracy, 1-2 PSU; Range <1 to 37 PSU.	Surface water salinity is principally measured using conductivity sensors on data loggers (reporting salinity in PSU). Target salinity range corresponds to specific conductance of 2,000 uS/cm to 55,0000 us/cm.

Table 3 (continued). Principal Parameters, Purposes and Associated Data Quality Goals

Parameter / Measurement	Purpose(s)	Data Quality Goals	Comment
Elevation; Channel cross section; channel profile (depth)	Link elevation of instruments to vertical datum, other instruments or to marsh surface	± 2 inches (5 cm)	This measurement influences data quality for many purposes. Accuracy of measurements made with optical levels is influenced by field conditions (wind, soil strength, etc.).
	Document relative tidal marsh elevation profiles or cross-sections	± 2 inches (5 cm); ± 8 inches (20 cm)	Profiles measured with optical levels achieve the higher precision. Available LIDAR coverage (2017) is incomplete and has high nominal error (±16.5 cm RMSE), although comparison with RTK GPS suggests performance is often better than that suggests.
	Document changes in channel depth and cross-section	± 0.1 foot (~ 3cm) vertical, ± 0.25 foot (~ 7.5 cm) horizontal; Document 20% change in cross-sectional area.	Geometric approximations introduce uncertainty in cross section estimates, which are controlled by selection of measurement points in the field

Table 3 (continued). Principal Parameters, Purposes and Associated Data Quality Goals

Parameter / Measurement	Purpose(s)	Data Quality Goals	Comment
Water surface level	Relate water surface elevation to predicted and observed tides at NOAA Tide Station at Portland, Maine	Within ±5 min of nominal; surface water elevation to ± 2 inch (5 cm); tie-in to vertical datum ± 2 inches (5 cm).	
	Relate water surface elevation to marsh surface elevations and assess hydroperiod	Measurements of surface water elevation to ± 2 inch (5 cm)	Accuracy of comparison is generally limited by quality of topographic data (LIDAR).
	Document differences in hydrology above and below tidal restrictions; document changes in hydrology in response to restoration.	1 inch (2 cm) vertical elevation, data at least every 15 minutes. Time of measurements within ±5 minutes of nominal	Tie-in to vertical datum not always practical or necessary. Precision often limited by accuracy of leveling, not precision of water level sensors.

Table 3 (continued). Principal Parameters, Purposes and Associated Data Quality Goals

Parameter / Measurement	Purpose(s)	Data Quality Goals	Comment
Vegetation community	Document composition of vegetation and changes in composition of vegetation	Record percent cover with sufficient precision to allow classification into ordinal cover classes	Given high observational errors using visual percent cover estimates, ordinal cover classes (e.g., Braun-Blanquet cover classes: Rare; ≤ 1%; ≤ 5%; ≤ 25%; ≤ 50%; ≤ 75%; ≥ 75%).or presence-absence data support more robust analyses than using percent cover values.
	Document changes in vegetation over time	Place repeat vegetation plots within~ 3 meters of nominal location	
	Document or detect change in plant species richness	Identify 80% of taxonomic units to species.	
	Document or detect change in dominant or diagnostic plant species (e.g., *Spartina*, *Typha* and *Salicornia* spp.).	Record cover of dominant and common species to ±10%. Identify at least 80% of plant cover in each plot.	Dominant species: > 50% cover in any plot Common species: present in > 10% of plots
	Document shifts in species composition (presence / absence)	Record cover of dominant and common species to ±10%. Identify at least 80% of plant cover in each plot.	

Table 3 (continued). Principal Parameters, Purposes and Associated Data Quality Goals

Parameter / Measurement	Purpose(s)	Data Quality Goals	Comment
Species of Concern	Determine whether species of concern are present on site, determine whether and where to implement invasive plant controls.	Presence/absence; Approximate location (to relocate stands in subsequent visits)	Species of concern typically include invasive plants.

Table 3. Principal parameters measured in the field, instruments and methods, with nominal method performance specification, based on instrument manuals and specification datasheets listed in App. A.

Parameter	Units	Method/ Instrument	Range	Accuracy	Precision/ Resolution	Comment
Salinity, by refractometer	‰ or PSU	Advanced Microscopy Group RHS-10ATC salinity refractometer with automatic temperature compensation (or similar)	0 to 50 ‰	± 1 ‰	1 ‰	The refractometer is used for measuring salinity in groundwater and for rapid assessment of surface waters
Salinity by data logger	PSU or ‰	Onset HOBO Salt Water Conductivity/Salinity Data Logger	2 – 35 PSU	5% of reading in ± 3,000 µS/cm waters	2 uS/cm (<< 0.1 PSU)	Salinity calculated using PSS-78, the Practical Salinity Scale 1978, in HOBOWare Pro. These values correspond to specific conductance of 5,000 to 55,000 uS/cm (high range)

Table 4 (continued). Principal parameters measured in the field, instruments and methods.

Parameter	Units	Method/ Instrument	Range	Accuracy	Precision/ Resolution	Comment
Channel cross section area; channel longitudinal profile (depth)	Ft. (NAVD 88); Ft.^{2}	Topcon AT-B3 auto level	Distance: 1 ft. to 500 ft.	Elevation: Std. dev. for 1 km double run leveling: 1.5 mm	Varies with distance	Field conditions (mud, wind; etc.) can degrade data quality below nominal instrument values
		Crain SVR-25-Tenths stadia rod	0 to 25 ft.	Varies with extension height	.01 ft (~2 mm).	
		Keson English/ Metric Open Reel Fiberglass Tape	0 to 300 ft.; 0 to 100 m	±.01 ft.; 2 mm	.01 ft.; 2 mm	
Water surface level	Ft. (NAVD 88);	Onset HOBO Titanium Water Level Data Logger; Onset Barometric Pressure Sensor	0 to 13 ft.	Typ.: ±0.01 ft; Max.: 0.02 ft	0.005 ft.	In practice, data quality is limited by accuracy of leveling, not nominal accuracy of instruments

Table 4. Principal parameters measured in the field, instruments and methods (continued).

Parameter	Units	Method/ Instrument	Range	Accuracy	Precision/ Resolution	Comment
Vegetation Community	Percent Cover	Visual percent cover estimates in 1 m^2 plots	0 - 100% (cover by species)	See Comment	± 1%	Data recorded to nearest 1%. Accuracy varies: ± 1% for cover < 10%; ± 5% for cover < 25%; ± 10% throughout range.
	Braun-Blanquet or Standard Cover Classes (App. A)	Modified Braun-Blanquet cover classes: Rare; ≤ 1%; ≤ 5%; ≤ 25%; ≤ 50%; ≤ 75%; > 75%)	Ordinal values	Ordinal values	Ordinal values	Ordinal cover classes are derived from percent cover.
	Presence / Absence	Visual observation in 1 m^2. plots	Present / Absent			Derived from percent cover. Identify 80% of species and 80% of cover in each plot
Species of Concern	Presence	Visual observations during a meander survey of the marsh or project area.	Present / Absent			
	Location (UTM Zone 19N, NAD83)	Consumer-grade GPS (e.g. Garmin) with WAAS enabled	Worldwide	± 3m (typical)	± 1 m (UTM)	
	Location (UTM Zone 19N, NAD83)	Interpretation of georeferenced aerial photographs	Depends on image availability	Depends on image quality.	Depends on image quality	Method not used if image quality cannot support accuracy of ± 5m or better

1.8 Special Training and Certifications

Field crew members will have sufficient previous training and experience to reliably conduct field data collection or they will receive training from the CBEP Project Manager, Director, and/or other scientists with relevant expertise. All field crew members will receive training on appropriate QA/QC procedures.

1.9 Documents and Records

The most current approved version of the QAPP will be provided to the appropriate personnel by the CBEP Project Manager. All data collected will be maintained in raw form (paper originals and scanned copies of original field data forms) and electronic form (database and image library) in the CBEP Project Manager's office at USM Wishcamper Center, 34 Bedford Street, Portland, Maine. The QAPP and SOPs will be dated to distinguish among different versions in case there are revisions made over the course of the project. Electronic data records, including results of the assessments and analyses, will also be maintained at CBEP for at least five years.

The Project Manager will be responsible for assuring that all parties and project personnel have the most recent version of the QAPP, any amendments to the QAPP, and any updates. The Project Manager will ensure that instrument operator manuals and standard operating protocols (SOPs) are up to date and available during the period of the project. Table 5 lists specific documents and retention protocols.

Table 4. Document and record retention information.

Document/Record	Location	Retention	Form
QAPP	CBEP, EPA	5 years	Paper/electronic
Field notebooks	CBEP	5 years	Paper
SOPs	CBEP	5 years	Paper/electronic
Data sheets	CBEP	Indefinitely	Paper/electronic
Continuous hydrology data	CBEP	Indefinitely	Electronic
Project databases	CBEP	Indefinitely	Electronic
Annual Report with data interpretation	CBEP and funding partners	Indefinitely	Paper/electronic

2 Measurement and Data Acquisition

2.1 Introduction

CBEP's in-depth marsh monitoring programs generally follow protocols outlined in the GPAC Protocols (Neckles & Dionne 2000 -- included as Appendix B; Neckles *et al* 2002), which recommend a tiered approach to monitoring of hydrology, vegetation, and other variables.

CBEP's current monitoring program emphasizes documenting changes in surface water height and salinity, groundwater depth and salinity, pore water (soil) salinity, channel morphology, and vegetation pattern. Monitoring and assessment activities occur at tidal marshes around Casco Bay, particularly those where documented structures such as roads, railroads, dams, dikes, or other structures suspected to affect the movement of water into and out of a tidal marsh. Over 80 such sites ("tidal restrictions") are present (CLF 2000; CBEP 2012) or have been identified for further assessment.

CBEP collects preliminary data ("rapid assessments") at sites that may not go on to be monitored on an ongoing basis. Results of rapid assessments help determine whether a site is suitable for tidal restoration or would make a good long-term monitoring location. Data from rapid assessments are used in preparing SAPs.

SAPs will be developed for each marsh where long term monitoring is planned. SAPs will provide site-specific sampling design details, including identification of key monitoring parameters (which may vary from site to site depending on the purpose of monitoring), sampling locations and the sampling schedule.

As part of previously completed tidal restoration projects, CBEP has developed formal Monitoring Plans for three locations. Those Monitoring Plans function as SAPs for purposes of this QAPP. The sites with existing Monitoring Plans / SAPs include:

- Thomas Bay Marsh at Adams Road in Brunswick, restoration in 8/2011
- Long Marsh at Long Reach Lane in Harpswell, restoration in 1/2014
- Appletree Marsh at Wallace Shore Road in Harpswell, restoration in 12/2014

Project monitoring is also occurring at High Head Road in Harpswell, constructed in 12/2016.

The monitoring program is structured in three phases:

(1) Initial site assessment, including assessment of restoration feasibility;
(2) Documentation of baseline conditions and establishment of a framework for long-term monitoring; and
(3) Long term monitoring to evaluate changes in the marsh system over time.

Note: Numerous tangible and intangible feasibility considerations, such as flood risks to low lying private developed areas, the presence of utilities, community sentiment, engineering or modelling, etc. factor into restoration project planning, but are not incorporated into this document.

2.2 Initial Site Assessment

Initial site assessments are carried out for a variety of purposes, such as gathering information to provide technical assistance to Partners, or assessing sites as potential restoration targets.

Since the purpose of assessment varies, so do the details of how each is carried out. A primary purpose of an initial assessment is often to evaluate whether a site merits additional monitoring effort or to gather information needed for planning restoration or long-term monitoring. Initial site assessments are carried out without the benefit of a formal SAP.

2.2.1 Desktop Assessment

Desktop assessment utilizes existing and readily available remote sensing data via GIS, Google Earth, and similar tools to inform assessment and monitoring activities, and inform where to invest staff and resources for further work. Desktop assessment may be carried out with or without rapid field assessments. Initial summary information is recorded on a data sheet (Appendix A).

Electronic data (typically geospatial data) gathered during the desktop assessment, if any, are stored in a site-specific folder on CBEP computers or servers, along with related data documentation. Documentation provides references to original sources. Formal metadata is provided when readily available from data providers. Any data manipulations beyond visual inspection carried out by CBEP are documented in a narrative report or brief "readme" file stored with the data. Since data are not intended for secondary use or publication, CBEP staff will not develop metadata that complies with metadata standards.

2.2.1.1 General Geographic Data

The following data is available via review of readily available on-line sources of geographic data and aerial imagery, such as the Maine Office of GIS (MeGIS) and Google Earth.

- Location
- Wetland boundary and area
- Ownership and parcel information
- Narrative description of adjacent land use
- Characterization of anthropogenic impacts to the marsh, such as
    - Number of visible structures on the marsh (roads, berms, dams, etc.)
    - Visual indicators of impact of tidal barriers, such as scour pools in tidal channels
- Presence of utilities (power lines, sewer lines), especially at road crossing
- Houses, freshwater wells or other infrastructure located on or near the marsh that may face potential flood or other risks if site hydrology changes

Note: location information in Google Earth is provided in unprojected geographic coordinates (latitude and Longitude), based on a WGS84 datum. Reprojection is necessary to incorporate this with data from MeGIS Historically, MeGIS has provided data principally in UTM coordinates (Zone 19 North) / NAD83, but some data layers (especially raster and image data) use other coordinate systems. Automatic reprojection by ArcGIS provides sufficient accuracy for visual inspection and rapid assessment.

2.2.1.2 Vertical control points ("benchmarks")

The ability to tie local elevations to a consistent vertical datum (NAVD 88) is often important for site assessment, restoration design, hydrological modelling, assessment of potential impacts of sea level rise, and for other purposes.

In general, CBEP will not establish a vertical control point to support rapid site assessments. CBEP will always establish vertical controls to support (1) planning of habitat restoration projects that involve alteration of hydrology, and (2) long-term monitoring. For other purposes, CBEP staff will assess whether the need for accurate vertical controls justifies the cost.

Wherever possible, CBEP makes use of existing, nearby benchmarks and transfers vertical control to a semi-permanent benchmark near the monitoring location (e.g., on a structure or bedrock adjacent to the marsh.) CBEP reviews several sources of information in order to determine whether existing benchmarks are available near field sites. These include:

- National Geodetic Data Explorer: https://www.ngs.noaa.gov/NGSDataExplorer/
- MaineDOT Survey Control Points: http://www.maine.gov/mdot/mapviewer/dataviewer/Index.html?app=survey
- Correspondence with Maine Geological Survey

Determination of whether an existing benchmark can be used depends on its location, topography, and other factors. CBEP staff will only use an existing benchmark to establish a semi-permanent benchmark (1) if it is within 150 m / 500 ft of the marsh surface and (2) the benchmark can be used directly, or a working benchmark established adjacent to the marsh using no more than two turning points.

Where suitable vertical control points are not available, vertical controls will be established by (1) hiring a qualified surveyor to establish a benchmark, or (2) estimating elevations of a semi-permanent benchmark using RTK GPS technologies.

When existing benchmarks are not available, and project purpose does not justify the expense of establishing a new local benchmark, CBEP uses approximate methods to estimate vertical elevations. Elevations may be estimated by:

1. Using available LIDAR data;
2. Matching elevation of tidal waters at the peak of a spring tide to predicted tidal elevations for the same spring tide at the Portland Tide Station;

Nominal accuracy of existing LIDAR data (~ 16.5 cm RMSE) limits value of Method 1 for all but preliminary investigations. Methods 2 can achieve better accuracy, although quantitative estimates of accuracy are unavailable. Methods 2 is well suited to sites with unimpeded tidal flow from open water, but can be misleading when applied far up a tidal creek or above tidal restrictions.

2.2.1.3 Supplementary Geospatial Data

Additional online geographic data provides supplementary insight into site characteristics. CBEP staff regularly reviews the following sources when developing narrative site descriptions:

- Maine Stream Habitat Viewer (Maine Coastal Program): presence of documented fish barriers and associated data; presence of priority fish habitats; tidal marsh area.
- http://www.maine.gov/dmr/mcp/environment/streamviewer/index.htmHistoric USGS map research: http://docs.unh.edu/nhtopos/nhtopos.htm
- Maine Geological Survey Sea Level Rise/Storm Surge maps: http://www.maine.gov/dacf/mgs/hazards/slr_ss/index.shtml

An abbreviated literature review will be conducted, to obtain and review relevant knowledge about a site. Typical sources include:

- Geomorphology and the effects of sea level rise on tidal marshes in Casco Bay (Bohlen et al 2012)
- Land Use Planning for Sea Level Rise: A Report for Planners in Casco Bay Area Communities (Bohlen et al 2013)
- “Return the Tides” data (Bonebakker et. al. 2002)
- Casco Bay Watershed Fish Barrier Priorities Atlas (CBEP 2012)
- Correspondence with Maine Natural Areas Program, Maine Coastal Program, or other state agencies
- Web search based on local place names

2.2.2 Rapid Field Assessment

A rapid field assessment provides general information for planning purposes. Rapid assessments are designed to be flexible, and responsive to site-specific and project-specific needs. Typical rapid field assessments include documentation of site surroundings, presence of tidal restrictions or other structures on the marsh, interpretation of geomorphology, informal observation of site hydrology, and documentation of general vegetation characteristics.

The basis of a rapid assessment is one or more site visits during which CBEP staff walk a site, making qualitative observations, supplemented by digital photographs. A rough plan for the site visit (identifying important locations or features of the marsh to examine) is developed in advance based on available information, including results of a Desktop Assessment, if any. The plan may be modified in the field based on site conditions or observations.

Limited field equipment (e.g., soil augers, refractometers, tape measures, consumer-grade GPS receivers) may be brought along to facilitate site characterization.

2.2.2.1 Location of Observations

Approximate location of field observations is recorded, but the method varies. They may be recorded as a narrative description (e.g., "just south of the big pine on the east side of the marsh"), by marking approximate locations on a pre-printed paper map, recorded using consumer-grade GPS receivers, or by a combination of these methods.

2.2.2.2 General Observations

While walking a site, CBEP staff record general observations that place other observations into context, and relating field observations to a Desktop Assessment, if one was carried out. Typically, these observations address large-scale questions about the marsh, such as how the site is being used by fish, birds, and wildlife; potential human impacts to the marsh; geomorphological characteristics such as sediment characteristics or topography; or characteristics of the vegetation, such as presence of invasive *Phragmites*.

These observations often include measured or estimated numerical data, such as depth of a tidal channel, surface water salinity, width of a vegetation zone, height of a plant, or area of a tidal pool. Estimated values are labeled as estimates; methods used for measuring values are described in the notes where they are not clear from context.

2.2.2.3 Hand-drawn maps

General observations may be supplemented by sketch maps that clarify spatial relationships among features on the marsh. Maps are not drawn to scale, but observations may be roughly georeferenced using GIS after returning to the office.

2.2.2.4 Assessment of anthropogenic structures

Where structures like roads or dikes cross the marsh, notes are taken on characteristics of the structure, such as width, height, and construction material. Values may be measured with tape measures, stadia rods, meter stick, etc., or estimated. Estimated values are labeled as estimates.

2.2.2.5 Surface Water Salinity

Spot checks of surface water salinity are helpful in understanding site hydrodynamics. Spot checks are made using refractometers, in parts per thousand. Location of spot checks are recorded in the field notes.

2.2.2.6 Soil and Sediment Characteristics

Characteristics of the sediments are assessed informally. Soils and sediments are accessed by (1) Collecting samples with a soil auger, or (2) observing sediment along existing channel banks. Soils are evaluated with attention to vertical structure (“horizons”), but typically without measuring the thickness of each horizon. Soils and sediments are described qualitatively based on examination of samples. Descriptions of soil layers may include reference to texture (sandy / silty / clay); moisture content (saturated / wet / moist / dry); presence of organic matter (high organic matter / low organic matter / staining); presence of organic inclusions like roots, vegetation or wood; and color (matrix color and mottles).

If higher accuracy data on sediment condition is deemed useful, soils will be collected by digging a soil test pit or with a sediment probe, Russian corer or similar sampling equipment that minimizes sample compression. Thickness of sediment horizons can then be measured with a meter stick or tape measure. Colors will be recorded using a Munsell color chart.

2.2.2.7 Vegetation

On larger sites, documentation of characteristics of the vegetation, as well as longitudinal and lateral patterns of vegetation can provide insight into processes influencing marsh condition.

During rapid field assessments, CBEP uses a simplified "relevé" method to characterize vegetation in terms of dominant and conspicuous plant species. Sample locations are selected in the field (often informed by prior Desktop Analysis) and are not randomly located. They are selected to be representative of vegetation zones or transitions between them, as described in the field notes. Zones often include salt marsh, brackish marsh, and freshwater swamp, but other divisions may be appropriate based on site characteristics.

The observer stands at one location (recorded in the notes, marked on the site map, or recorded via GPS), records all plant species readily observed in adjacent vegetation, and adds a measure of relative abundance for each (using percent cover estimates or Braun-Blanquet cover classes). The area observed is not formally defined (hence this is a "plotless" method), but left up to the judgement of the observer. In herbaceous wetlands, the area sampled will typically be under 3 meters in diameter, while in forested wetlands the implicitly sampled area may be 20 m or more in diameter. Vegetation data is always supplemented by one or more photographs.

2.2.2.8 Supplementary Observations

From time to time, an initial site assessment may benefit from collecting more in-depth information. Where that is the case, data collection will occur at pre-selected (not random) locations, but otherwise adhere to methods described in this QAPP for data collection during baseline site characterization or long term monitoring.

2.2.2.9 Sample Handling, Data Management and Analytic Methods

Formal samples are not collected during rapid site assessments. Any informal samples (e.g., soil samples, plant material used to identify plant species in the lab) are discarded.

A variety of recording methods may be used, including use of a field notebook, data sheets, voice recorder, or loose-leaf paper on a clipboard. All primary field records are dated, transcribed if necessary, and archived. Electronic records, including photographs, are stored in a site-specific electronic folder on CBEP computers or servers.

The primary products of a rapid field assessment are the raw field notes themselves and improved staff understanding of site conditions. For sites considered more important, or when results of the rapid assessment will be shared with Partners, CBEP staff prepares a narrative site description, summarizing observations and preliminary interpretations of those observations. Interpretation of observations is qualitative, with little or no analysis of numeric data. When data analysis occurs, it emphasizes graphical methods and mapping to facilitate understanding of site condition.

2.3 Baseline Site Characterization and Long Term Monitoring

Long term monitoring incorporates both monitoring of restoration sites and monitoring of wetlands to document long term change. Long term monitoring is always carried out in the context of an SAP which lays out a site-specific monitoring plan, including monitoring purpose(s), sampling frequency and locations.

Restoration monitoring is a special case of long-term monitoring. Restoration monitoring follows a classic BACI (Before-After Control-Impact) experimental design (e.g., Stewart-Oaten 1986). Each restoration site requires formal identification of a nearby (unrestored) *reference area* as well as collection of pre-project data from both the project and reference sites. CBEP has historically used the tidal marsh immediately downstream of restoration sites as the reference area, even though those areas do not represent the full ecological complexity of an entire wetland system. Identification of the reference area is an important component of the SAP.

2.3.1 Sampling Stations

The design of long term monitoring is structured around sampling at key locations around the marsh, which CBEP call "Stations".

Stations are established to monitor certain parameters, usually channel cross section, vegetation characteristics, and pore water salinity. The number of Stations on a site will vary to suit site-specific conditions, especially the size and complexity of the site. As few as three stations (lower marsh, mid marsh, and head of tide) may be established on small sites with little spatial heterogeneity. A more typical site monitoring plan will include ten Stations. Ten Stations strikes a balance between sampling spatial variability, and keeping the workload reasonable. Vegetation sampling at ten Stations typically can be completed over two days in the field, while it is possible (although sometimes difficult, depending on site geometry) to visit 10 stations to collect pore water salinity data over a single tide.

Where a formal Project Area has been specified (as is typical for restoration projects), Stations (with the exception of the reference Station or Stations) will be drawn from within that area.

Supplemental Stations may be added outside of the Project Area to help characterize system-wide response. Where no Project Area has been designated, Stations will be located within an area extending from head of tide to the valley mouth.

For restoration sites, a *reference area* will be established in an area not directly influenced by the restoration activity. The reference station will be located within the contiguous marsh system if practicable. If no contiguous marsh area exists downstream, a reference area and one or more reference Stations will be established in a nearby wetland. For tidal restoration projects, the reference area may consist only of one or more reference Stations downstream (to seaward) of the tidal restoration site.

Selection of locations for sampling Stations is based on spatially structured random sampling. The majority of Casco Bay's tidal wetland area is located in tidal wetland complexes that form in drowned glacial valleys or post-glacial erosion features carved into Presumpscot Formation silt-clay deposits. These geomorphological contexts impose strong longitudinal and lateral gradients in physical and biological environment within Casco Bay tidal wetlands. CBEP's approach to sampling couples the advantages of random sampling with sufficient structure to ensure that we sample across both longitudinal and lateral gradients.

To identify station locations, CBEP will utilize Generalized Random Tessellation Stratified (GRTS) Sampling (Kincaid and Olsen 2016), or a comparable randomized spatial sampling tool. GRTS software facilitates drawing of probability-based samples based on location. Given specific geographic locations to sample (e.g., a marsh area, or a channel network), a GRTS sample can be drawn so that all locations within a study area have well-defined (in the case of simple random sampling, equal) probability of being sampled and yet guarantee that sample points are distributed throughout possible sampling locations.

In tidal wetlands with a strong upstream-downstream gradient and a central channel (like most of Casco Bay's larger wetlands), Stations are selected as a spatially balanced sample of points distributed along a line drawn down the length of the tidal valley. Data collected at each station characterizes the wetland along a cross section from channel to upland.[1]

Once a location along the valley axis is identified using GRTS, if a central channel is present, the Station is established on one side of the channel. Where possible, the side is selected at random. However, practical considerations may prevent randomization. For example, the

[1] An area-based random sample would locate Stations proportional to area, thus concentrating them where the wetland is widest, typically at the downstream end of the marsh. A sample drawn on a linear support distributes samples more evenly along the longitudinal gradient from valley mouth to head of tide.

channel may meander close to the upland, leaving insufficient area to set up a monitoring station on one side, or one side of the channel may be inaccessible.

In tidal wetlands without a clear longitudinal axis (e.g., fringing marshes), Stations are established following a similar logic, using spatial random sampling to locate anchor points for sampling stations.

2.3.2 Pore water salinity

Monitoring pore water salinity (salinity of water samples collected between 5-20 cm below the marsh surface) provides basic information about soil salinity, which is a driver of salt marsh plant community composition (Neckles et al 2002).

2.3.2.1 Sampling Design

Soil salinity is sampled from specially designed semi-permanent pore water salinity wells set into the marsh surface. Between five and fifteen wells (typically ten) are used to monitor a contiguous marsh system. Wells allow for rapid sampling of pore water from the soil root zone at depths of 5 to 20 cm below the marsh surface.

Pore water monitoring wells are established throughout the marsh area. Wells are generally located at sampling Stations, but wells may not be located at every Station. Locations of pore water sampling wells are specified in the SAP.

For monitoring associated with restoration projects, salinity wells will be included, at a minimum at:

- One Reference Station (outside of the area affected by restoration, but as near to the restoration area as practicable);
- One Station at the downstream end of the Project Area (e.g., immediately upstream of a tidal restriction);
- One Station situated at head of tide; and
- At least one station between downstream and head of tide.

This minimum sample arrangement provides information on longitudinal pore water salinity gradients within the marsh, and allows comparison of salinity changes in the Project and Reference Areas.

A subset of Stations will include a transect of three or more wells running perpendicular from the tidal channel (or open water) to the adjacent upland. This transect will run perpendicular to the long axis of the marsh for most of Casco Bay's long, narrow tidal wetlands, but would run from open water to the adjacent bluff for a fringing marsh. One station will be established within 3-4 meters of the water, one at the upland edge, and the third approximately midway between the other two. This lateral transect allows assessment of patterns in pore water salinity across the marsh surface.

Samples are collected within 2 hours +/- of low tide, at least once per month from April to October, or more frequently during the primary growing season (April – July). Sample collection will be scheduled so that half are collected during a spring tide phase, and the remainder during neap tide (Neckles & Dionne 2000).

For monitoring associated with restoration projects, one full season of monitoring occurs prior to a restoration project, and generally, at odd years' post-project (i.e., year 1, 3, 5).

2.3.2.2 Sampling Methods

CBEP uses pore water salinity wells based on design specifications provided in the GPAC protocols (Neckles and Dionne 2000, p. 10; App. B) and sampling is conducted consistent with GPAC SOPs. Wells are built from19mm (¾ inch)diameter CPVC plastic pipe. Wells are cut to 35cm with 7-10 pairs of 4 mm holes drilled at roughly even intervals 5-20 cm below the surface. The bottom of the well is sealed. The top of the well is constructed of two 90 degree PVC elbows connected by a short section of straight PVC pipe to form an inverted U-shape in order to limit water entering the well from above. Wells are installed so that the holes are set 5-20 cm below the marsh surface. Sampling does not commence until at least 24 hours following installation. Wells are inspected annually and removed and cleaned as needed to remove accumulated sediment.

Samples are collected by removing the well cap then inserting plastic tubing affixed to a plastic syringe into the well until it reaches the well bottom, and then lifted 5 cm. A sample is extracted using the syringe, then in the field, the sample is placed upon a handheld refractometer to take salinity readings. The optical handheld refractometer is calibrated with DI water prior to use. Salinity is measured in parts dissolved salts per thousand. Three replicate measurements are recorded from a single sample.

For comparison, surface water samples are collected at the adjacent tidal creek or open water when pore water samples are collected. Salinity is measured in surface water samples using the refractometer following the same methods used for pore water samples.

CBEP's narrative field instructions for this parameter are included in Appendix F.

2.3.2.3 Sample Handling and Custody

Following measurement, samples are discarded in the field. All salinity measurements, sampling times, and other site visit and anecdotal observations are recorded on a site-specific salinity monitoring data sheet (App. A). Data sheets are stored at CBEP. Field data are transferred to a site specific Excel database.

2.3.2.4 Analytic methods

Summary statistics (mean, minima, and maxima) are computed for use in graphical or map displays. Standard statistical methods ("t" tests, linear models or non-parametric equivalents) are used to evaluate long term or seasonal trends, comparisons between pre-restoration and post-restoration conditions, and comparisons between restoration and reference areas.

2.3.3 Channel morphology

Changes in creek channel morphology frequently occur as a result of restoration activities or changes in site hydrology. Assessment of channel morphology is used to:

- Document existing conditions or monitor long-term changes;
- Assess geomorphological impacts of tidal restrictions on channel shape, depth, and capacity;
- Inform development of hydraulic capacity estimates for conceptual design alternatives;
- Evaluate how hydrological modifications affect sediment transport; and
- Monitor post-project geomorphological response to restoration and enhancement projects.

Channel morphological parameters include: monumented cross sections; longitudinal profiles; and photo stations. SOPs for monitoring channel morphology are taken directly from the *Stream Barrier Removal Monitoring Guide* (Collins *et al* 2007 p. 27; App. B).

Parameter	Source/Page	Location
Monumented cross sections	Collins *et al* 2007 (p. 27-30)	App. C
Longitudinal profiles	Collins *et al* 2007 (p. 31-32)	App. C
Photo stations	Collins *et al* 2007 (p. 36-37)	App. C

2.3.3.1 Monumented cross sections

Channel cross sections are transects that bisect a channel and run perpendicular to it, extending from the high marsh on one side of a channel to the high marsh on the opposite side. They are used to characterize changes in the geometry of a tidal channel, including width, depth, cross-sectional area, and channel form.

Sampling Design

Monumented cross sections are established adjacent to selected Stations within the project area. To the extent practicable, cross section transects are located on relatively straight channel reaches rather than on meander bends. Semi-permanent monuments are set into the high marsh surface and georeferenced. Sampling occurs once per season.

If monitoring is of a restoration project, at least one monumented cross section will be located within the Reference Area. Cross sections are surveyed at least once prior to a tidal restoration project, and either at odd years post-project (i.e., year 1, 3, 5), or annually. This detail is specified in an SAP.

Sampling Methods

Detailed information on SOPs is provided in Collins *et al* 2007, p. 27-30 (App. C). CBEP's narrative field instructions are included in Appendix F. CBEP maintains equipment used for surveying cross sections, including an auto level, tripod, stadia rod (decimal feet), and fiberglass tape reel (decimal feet). Equipment is stored at CBEP and periodically inspected for wear and tear, and maintained or replaced as needed, to maintain accuracy and functionality.

Semi-permanent monuments are set to mark the start and end of a transect. Monuments are typically hollow PVC pipes or wooden stakes set into the high marsh surface and extending approximately 20 cm above the marsh surface. Monuments are set on the high marsh surface an adequate distance away from the creek edge to accommodate for channel evolution over the monitoring period, as specified in SAPs. Monuments are sometimes lost over the winter due to ice scour, and cross sections are re-established in subsequent monitoring years by reference to photographs, GPS coordinates, and the memory of field staff.

Survey equipment is set up on one side of the transect, and a measuring tape is run from one monument to the other. Measurements are collected by a team, with one person operating the level and recording measurements, and one person setting the stadia rod laterally along the transect and reporting transect distance to the recorder. The stadia rod is held vertical by use of a rod-level, and the rod is always held on the opposite side of the tape. Lateral distances are referenced to river left (i.e., the left monument, looking downstream, is zero on the tape).

The level operator reads the center crosshair of the level to obtain the stadia rod measurement. No other information from the level is recorded. The first reading will be at the left monument and the last reading at the right monument. Measurements emphasize documentation of visible breaks in slope and significant geomorphic features such as top of channel bank, toe of channel bank, water depth, and the thalweg. In the absence of clear breaks in slope, elevations are recorded at a pre-determined interval equal to 1/20th of the total transect length. Elevations are tied into a local vertical control point, through back-sighting if necessary.

Sample Handling and Custody

Field data are recorded on data sheets (App. A), which are stored at CBEP. Rough sketches are drawn onto the datasheet showing the location of the cross section in relation to anecdotal observations and contextual information such as submerged aquatic vegetation (e.g., *Ruppia maritima*), overhanging channel banks, woody debris, and channel bank slumping.

Analytic methods `

Field data are entered into a copyrighted Excel spreadsheet tool, The Reference Reach Spreadsheet, developed by the Ohio Department of Natural Resources (Mecklenburg 2006). This tool is widely used for storing and analyzing channel survey data. Cross section data are entered into the Dimension tab, and the spreadsheet automatically plots a channel profile. Cross sectional area, channel width, mean depth, maximum depth, and other metrics are calculated for use in comparison between pre- and post-project conditions, as well as comparison between the project area and reference site.

2.3.3.2 Longitudinal profile

Sampling Design

Longitudinal profiles are established as a continuous transect of the channel thalweg. At tidal restoration sites, the profile runs through a built structure from a downstream cross section station to at least one upstream cross section station, and preferably more. This monitoring reach is established to show representative channel depths downstream and upstream of a structure, and inclusive of the depth within the structure itself. At other monitoring sites, the longitudinal profile spans at least two cross section stations, and preferably more.

Longitudinal profiles are surveyed at least once prior to a restoration project, and generally, at odd years post-project (i.e., year 1, 3, 5). Timing of samples will be specified in the SAP.

Sampling Methods

Detailed information on SOPs is provided in Collins *et al* 2007, p. 31-32 (App. C), and CBEP's narrative field instructions are included in Appendix F. CBEP maintains equipment used for surveying longitudinal profiles, including an auto level, tripod, and stadia rod (decimal feet). Prior to set up, flags or other temporary markers are used to denote the start and end points of the transect. Typically, these markers will be located at intersections with monumented cross sections. These points are georeferenced with a GPS unit.

Set up involves positioning the auto level in such a way (i.e., atop a road shoulder) that to the extent practicable, an unobstructed view of the monitoring reach, as well as a benchmark/elevation control point, is provided. If only part of the reach is within a continuous sightline, it may be necessary to conduct a partial survey from this location, then using fore-sighting and back-sighting, relocate the level to another position that allows for completion of the survey. No tape measure is used.

Measurements are collected by a team, with one person operating the level and recording measurements, and one person setting the stadia rod along the transect. The stadia rod is held vertical by use of a rod-level. The benchmark is surveyed in as one of three reference locations outside of the transect, and at the benchmark, the angle of the level is set to 0°. The other reference locations should be fixed objects.

For all measurements, including the reference objects, the level operator notes the angle of a shot, as well as the height on the stadia rod of three cross hairs (mid, upper, and lower).

The transect survey begins at the downstream flag and is continuously surveyed until the upstream markers are reached. For sites containing road crossings or other structures, the survey includes measurement of key elevations associated with the structure, including the outlet invert, height to the top of the culvert, one or more measurement atop the structure (typically at the crown of a road) and the inlet invert. During the survey, all visible breaks in grade are surveyed. In the absence of clear breaks in slope, elevations are recorded periodically to show continuity in the plotted profile.

Sample Handling and Custody

Field data are recorded on data sheets (App. A). Descriptive information, such as changes in stream bed material, soft sediments, rip-rap, and other features are noted. Data sheets are stored at CBEP.

Analytic methods

Field data are entered into an Excel spreadsheet developed by MDOT that transforms field coordinates into survey points and calculates vertical elevation and distance along the transect, with 0' at the downstream marker. The transformed data are then transferred into an Excel spreadsheet tool, The Reference Reach Spreadsheet, developed by the Ohio Department of Natural Resources (Mecklenburg 2006). Longitudinal profile data are entered into the Profile tab, and the spreadsheet automatically plots a channel profile (example below). The location of cross sections, culvert inverts, and other features can be added to the plot and the slope of the monitoring reach is calculated. The plot allows for graphical comparison between pre- and post- project conditions, as well as comparison between the project area and reference site.

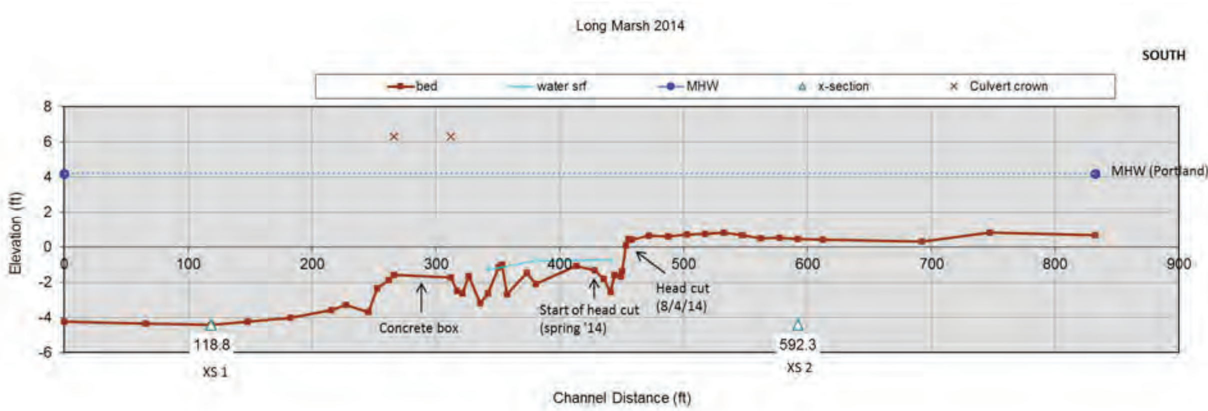

Figure 2. Example longitudinal profile.

2.3.4 Hydrology

2.3.4.1 Sampling Process Design

Automated continuous monitoring of surface water level and salinity is conducted over a period of 4-6 weeks to create a contiguous dataset that includes at least one lunar cycle, and which documents water levels through at least one full neap and one full spring tide phase. Site specific monitoring objectives are outlined in SAPs and will inform deployment location. At tidal crossings, monitoring for assessment of tidal restriction requires deployment of monitoring equipment upstream and downstream of a structure. Multiple units can be deployed upstream of a structure to show change deeper into a system, but typically only one unit is deployed downstream.

For restoration monitoring, at least one surface water hydrology data set is collected prior to a project, and a second is collected after a project is completed. Instruments are programmed to continuously record measurements once every 6 minutes starting on the top of the hour, allowing for synchronization with Portland Tide Gauge monitoring (station 8418150). Temperature and conductivity data are simultaneously collected.

2.3.4.2 Sampling Methods

This section describes the methods for monitoring water level and surface water salinity at tidal marshes using continuous data loggers.

CBEP utilizes Onset HOBO water level, temperature, and conductivity logging systems. Methodology is outlined below. Links to detailed equipment specifications, operating manual, and processing software are provided in Appendix D (Onset).

Equipment

a) HOBO U20 titanium water level and temperature logger

Parameter	Range
Temperature	-20 to 50ºC (-4 to 122ºF)
Pressure/level	0-4m (13 ft)

b) Barometric pressure sensor with micro station data logger

Parameter	Range
Barometric pressure	660 to 1070 mbar

c) HOBO salt water conductivity/salinity data logger

Parameter	Range

Actual conductivity	5,000 to 55,000 µS/cm
Salinity	0 to 42 ppt
Temperature	-2 to 36ºC (28 to 97ºF)
Pressure/level	0-4m (13 ft)

Deployment

The Onset water level logger and the conductivity logger units are deployed in PVC stilling wells set slightly above the channel bottom and secured to a post, consistent with methods described in the National Park Service report, *Continuous water level data collection and management using Onset HOBO data loggers: A Northeast Coastal and Barrier Network methods document* (Curdts 2017; App. E). The stilling wells are installed beyond the visible influence of roads or other hydrologic anomalies (e.g., scour pools), and at least 20m upstream or downstream of any road crossing or other structure. Loggers are suspended from well caps using stainless steel cable. The barometric pressure unit is installed along the upland edge of the marsh, off the ground attached to a wooden board and positioned in such a way that the instrument is shielded from frequent temperature and weather changes caused by exposure to direct sunlight and inclement weather. Additional information on deploying the Onset system is provided in field instructions (App. F).

Calibration and cleaning

The Onset equipment was calibrated by the manufacturer, and no further calibration is required or recommended by Onset. Best practices for cleaning equipment follow Onset's recommendations provided in the Product Cleaning Reference Guide (App. E).

Sampling methods

A field data sheet is used to document conditions, locations, parameters, and other accompanying data for the deployment site by site basis (App. A). Instruments are programmed using proprietary software, HOBOWare Pro. Data sets are assigned unique site and log names. Measurements are logged at an interval of 6 minutes. At least two times during a deployment period, water levels are surveyed using the auto level and stadia rod in order to tie water level data into a known vertical datum. Also, at least two times during the deployment period, grab surface water samples are collected and salinity measurements taken using a refractometer. A scheduled start time is entered, but not a stop time, ensuring that the instrument will continue to log measurements until manually stopped. The instrument removal time is noted.

Sample Handling and Custody

Instrument logs are stopped, and data sets are downloaded, in the office using HOBOWare Pro. Water level (raw absolute pressure) data are integrated with barometric pressure data using HOBOWare Pro, and water levels are post-processed using a tool provided with the software to compensate for changes in barometric pressure over the monitoring period. The processed water level data sets are exported to Excel. Data recorded when the instruments were out of the water is flagged and removed during an initial QA/QC review while data sets are exported to Excel. Both raw data and exported Excel data sets are archived with CBEP. Water levels are converted to a known vertical datum (e.g., NAVD 88) using the surveyed water level data tied to a vertical reference. Surface water salinity spot samples are used to detect any drift in conductivity data. Data from the Portland Tide Gauge are downloaded in NAVD 88 for comparison and integrated into the database. Twenty-four hour precipitation totals are downloaded from the nearest available rain gauge over the duration of the monitoring period. Currently, the Portland Jetport is the only the only weather station in our region with precipitation data consistently and publically available on line. All data sets are plotted. Water level data points that outlie adjacent data are flagged and removed if needed. Data are examined for anomalies such as straight lines, gaps, or single outlying data points, and attempts to explain anomalies are made. If it is determined that data are erroneous, the associated data points are flagged and removed from further analysis.

2.3.4.3 Analytic methods

Analytic methods are comparable for the two equipment systems.

Water level data are plotted in various timeframes to illustrate the degree of tidal restriction caused by a structure during different tide phases as indicated by muted tide range, lag in tides, impoundment and other indicators. If available, marsh surface elevation is included in analysis for evaluation of hydroperiod and the location of the marsh surface in comparison to known datums. Tidal metrics are developed for the data set according to definitions used by NOAA (https://tidesandcurrents.noaa.gov/datum_options.html) including highest observed water (HOW), mean higher high water (MHHW), mean high water (MHW), and mean tide level (MTL), allowing for quantitative comparison of upstream and downstream data sets, as well as comparison of pre- and post- project data sets. Beyond these summary statistics, additional analysis and plotting may be performed to further understand and quantify differences between data sets at a high resolution. At selected locations, water level data will be used in conjunction with LIDAR data to analyze hydroperiod and the area flooded associated with site specific tidal metrics and produce hypsometric curves.

Salinity data are plotted along with 24 hour rainfall data in various timeframes to illustrate differences upstream and downstream of a structure during different tide phases, and to associate changes in salinity with precipitation events. Summary statistics (mean/minima/maxima) are prepared allowing for quantitative comparison of upstream and downstream data sets, as well as comparison of pre- and post- project data sets.

2.3.5 Vegetation

2.3.5.1 Sampling Process Design

Vegetation and other cover types (wrack, bare ground, water, litter) are monitored along a single transect set up at each station. Sampling occurs once annually during the middle of the growing season (July or August). A marker (stake) is established approximately 10 meters from the tidal creek. For consistency of sampling from year to year, transects are laid out along designated compass directions. Specific compass directions are determined in the field the first time samples occur, but each transect will be laid out approximately perpendicular to the axis of the marsh. At time of sampling, a transect is established by running a 100m fiberglass reel tape through that marker perpendicular from the tidal creek to a marked location at the upland edge of the marsh – typically, a tree. If it is more than 100m to the edge of the marsh, a second stake is placed at 100 meters, and the transect is continued along the same direction to the edge of the marsh. Compass directions and transect lengths are checked and recorded during each subsequent year of monitoring.

2.3.5.2 Sampling Methods

Vegetation is sampled using 1m^2 quadrats set on the marsh surface adjacent to the tape at set distances. Species composition and cover types are recorded at each plot location, and an estimate of percent cover is provided.

Observers are trained by senior staff to use standard methods to estimate percent cover. A percent cover reference sheet (Carlisle *et al* 2002, App. A) is used to promote consistency. Quadrats are constructed out of PVC pipes. Additional design specifications for quadrats are provided in Carlisle *et al* 2006, p. 6.

The number of plots per transect is typically ten, located equidistant along each transect, with spacing between quadrats determined by the distance between channel and edge of wetland (e.g., the transect length). Some variation in the number of plots sampled, and the distance between them, may occur based on unique characteristics of a specific transect, but plots are monitored at identical locations along a transect from year to year Plots are placed no more closely together than 2 meters on center, so transects must be a minimum of 20m long. Although past practice has been to end transects where clear transitions to upland communities are present (e.g. forest cover), future monitoring will establish the upland end of vegetation transects where there is a clear elevation break, so that the end of the transect lies approximately 1-2 meters vertically above the level surface of the marsh, in order to develop data within the projected elevation of future sea level rise. Two photographs are taken at each transect, looking toward the upland, and toward the creek channel.

Transects are monumented or documented in the field using a variety of methods, depending on constraints imposed by site conditions. Semi-permanent PVC or wooden stake monuments at the edge of the tidal channel have proven unsatisfactory, as they tend to be dislodged by eroding channel banks or winter ice. Low monuments (< 20 cm in height) located away from the channel tend to persist better, but can be difficult to find in taller vegetation. When possible, transects are designed to pass adjacent to groundwater monitoring wells or other long-term monitoring equipment. GPS coordinates are collected for each end of the transect (using consumer –grade GPS receivers, with WAAS enabled), and data is recorded on transect length and direction. These numerical data are combined with a brief narrative description (e.g., "From the center of a small point on the tidal channel to the large oak just east of a birch"). Each transect is documented with photographs. Where landowners permit it, trees at the upland end of a transect may be marked with paint or forestry flagging to facilitate relocating transects in subsequent years. Following these procedures, we estimate that, with few exceptions, transects are located within one to two meters of nominal position from year to year, with the largest errors introduced by channel migration, which alters the length and baseline of the transect.

For each transect, a cover sheet is used to record information pertaining to the transect. Observations of percent cover by species and cover type at each plot is recorded on a vegetation plot data sheet (App. A).

2.3.5.3 Plant Identification

Plant identification follows Haines and Vining 1998. Identifications in the field are made by experienced observers, based on general plant characteristics, and sometimes with the use of a hand lens. Field staff must spend at least two days in the field with experienced observers and pass an informal assessment of their ability to identify common salt marsh plants before being allowed to collect vegetation data on their own. CBEP maintains a "Cheat Sheet" of common tidal wetland species, with useful field characteristics to help facilitate identification and year-to-year consistency in plant identifications.

Samples of any plant species not readily identified in the field are collected for later identification in the laboratory. Samples are placed in plastic bags, which are labeled by the site, station, and plot in which the species was observed. Each unknown species is given a temporary identification (e.g., "Unknown grass # 3") so that data on its relative abundance can be collected even in the absence of definitive identification. Once in the laboratory, unknown plants are identified with the aid of a dissecting microscope. Once identifications are confirmed by senior project staff, the field data sheets are amended in pen (all field data are recorded in pencil) to add the correct identification. Plants that cannot be identified are recorded as unknown.

Not all plants or even species need to be identified. Vegetation structure is dominated by common and dominant species. Furthermore, uncommon species can create mathematical instabilities in some statistical methods used to analyze vegetation data, so are often pooled in subsequent analyses. For vegetation data to be of acceptable quality, all dominant species (cover > 50% in any plot) and all common species (present in more than 10% of plots) will be identified, and at least 80% of plant species and 80% of plant cover will be identified to species.

2.3.5.4 Sample Handling and Custody

Field data are entered into site-specific Microsoft Access databases and data are independently reviewed by a second party for QA/QC. An independent plant species database interfaces with the site-specific vegetation databases. The plant database is reviewed and updated annually, so that any updates to nomenclature or classification are noted and integrated into the site data. Data sheets and databases are archived at CBEP.

2.3.5.5 Analytic methods

Analysis of the vegetation data follows standard analytic methods. Analyses focuses on responses of individual species and the vegetation as a whole to restoration. Analyses will document any changes in species abundance and vegetation composition at each monitoring station and examine spatial patterns of vegetation along the axis of the marsh.

Vegetation in a given plot is characterized, with regards to flood tolerance and salinity tolerance, using weighted averages of species-specific indexes. Each plant species' Wetland Indicator Status (US Army Corps of Engineers 2016; Lichvar et al. 2016) is used as an index of relative flood tolerance, while a salinity tolerance index (based on Verrill 2017) indicates relative tolerance to salt, by grouping plant species into halophytic (salt tolerant), brackish, and glycophytic (not salt tolerant) categories.

Analysis of vegetation data employs multi-dimensional statistical methods, coupled with a variety of data visualizations to facilitate interpretation. Currently, vegetation data is analyzed using the 'vegan' package, in R (Oksanen 2017), but may in future be analyzed with other suitable software. Ordination methods (principally nonmetric multidimensional scaling) are used to characterize vegetation pattern by reducing multi-dimensional vegetation data to two or three synthetic dimensions that offer the best[2] summary of pattern. Ordinations are based on simplified abundance classes derived from the percent cover data (e.g., Braun-Blanquet vegetation cover classes), or presence-absence data. Ordination output is used principally for visualizations, but also for formal statistical tests of vegetation change. Groups of plots that share similar vegetation are identified using clustering algorithms. A primary purpose of clustering is to provide objectively-defined groups that can be used to aid interpretation of ordination output. Clusters can generally be interpreted in terms of widely recognized

[2] Different ordination methods use various definitions of what it means to offer the "best" summary of multivariate data.

vegetation types or dominant species. These methods are known to provide robust results with vegetation data, readily illustrating shifts in species composition along major inundation and salinity gradients.

2.3.6 Plant species of concern

Additional vegetation surveys throughout the marsh ensure that the presence, location, distribution and quantity of plant species of concern (PSC) is documented for reporting and management purposes.

2.3.6.1 Sampling Process Design

A thorough meander survey of the marsh is undertaken to detect PSC. A meander survey is a semi-structured site visit, in which investigators walk the marsh examining vegetation in all areas of suitable habitat, looking for PSCs. The survey occurs in late July or early August during the typical flowering season for targeted species. The area surveyed includes the entire project area up to and including the upland edge, and if visible, the high water mark from an astronomic high tide event. Indications of high water might include wrack accumulation, sediment deposition on plants and woody vegetation, displaced leaf litter, or stress indicators for terrestrial species (e.g., orange needles on *Pinus strobus*). The survey does not extend into the adjacent upland. For restoration sites, the survey includes both the Project Area and the Reference Area.

2.3.6.2 Sampling Methods

Plant species of concern fall into two categories: 1) non-native/invasive plants, typically including *Phragmites australis* (common reed) in salt marsh, and salt tolerant or intolerant species such as *Lythrum salicaria* (purple loosestrife) or *Berberis thunbergii* (Japanese barberry) in or adjacent to brackish and fresh marshes; and, 2) stands of native or cryptogenic species that often form large, monotypic stands on the marsh surface, such as *Typha latifolia* (broad-leaf cattail).

Prior to the survey, monitors are trained to identify targeted species through review of: 1) fact sheets developed by the Maine Invasive Species Network (University of Maine Cooperative Extension 2017); 2) species identification cards developed through the Vital Signs program (Gulf of Maine Research Institute 2017); and 3) techniques for differentiating invasive from native *Phragmites* (Swearingen and Saltonstall 2010).

The survey occurs by walking the entire project area, meandering through remote areas and densely vegetated areas. If a PSC is observed, the observation is photographed and georeferenced using a GPS. Data are recorded onto a field data sheet (App. A), and include species identification, contextual description of location, size of population, assessment of a monoculture vs. mixed stand, and the presence of seed heads or flowers.

Phragmites observations are distinguished as native, introduced, or mixed with detailed accompanying photographs. If a stand of *Phragmites* is present, the perimeter of the stand is documented using GPS. If a monoculture stand of *Typha latifolia* is present, the perimeter of the stand is documented using GPS.

Field staff document the general size and location of each stand by walking the stand's perimeter, and recording locations of several points on the edge of the stand. Typically, between four and ten points are used. The exact number depends on stand geometry and is left to the discretion of the field staff.

Positions are recorded using consumer-grade, hand-held GPS receivers, with WAAS enabled. Positions are recorded after allowing the GPS unit to average positions for at least 30 seconds, providing positional accuracy on the order of 2-5 meters under typical conditions.

2.3.6.3 Sample Handling and Custody

In some cases field samples may be collected for further identification. Field data are entered into site-specific Microsoft Excel databases and data entry is reviewed by a second party for QA/QC. Data sheets and databases are archived at CBEP.

2.3.6.4 Analytic methods

A map of PSC is prepared, and the area of any monoculture stands is calculated. Observations of *Phragmites australis* are immediately conveyed to project partners for management consideration.

2.3.7 Photo stations

Standardized photographic monitoring of tidal restoration project allows for a visual record of changes associated with a tidal restoration project, beginning with baseline (pre-project) conditions. Detailed SOPs for photo stations are provided in Collins *et al* 2007, p. 36-7 (App. C).

Photo stations are established using georeferenced points on the ground that are associated with the project site and monitoring stations. Photos are framed in the landscape format for year to year consistency. Photo station locations include:

- Project site, with views toward: 1) inlet, 2) outlet, 3) upstream channel, 4) downstream channel, 5) road approach right, 6) road approach left. Photos are taken at low tide.
- Channel morphology - cross sections, views toward: 1) river left, 2) river right, 3) upstream, 4) downstream. Photos are taken at low tide, during cross section surveys while the tape is across the channel, with the tape in the foreground. Photo numbers are recorded on cross section data sheets. Additional opportunistic photos are taken to document the longitudinal profile survey, including the start and end of the transect, as well as the

location of head-cuts, collapsed peat, large woody debris, sediment deposition or other distinctive geomorphic features.

- Vegetation surveys: 1) view from the channel (start of transect) to the upland edge, 2) view from the upland edge (end of transect) toward the channel. Photos are taken during vegetation surveys, usually while the tape is laid out along the transect and thus visible in the foreground. Photo numbers are recorded on cross section data sheets.
- Surface water hydrology: 1) view of instrument(s), showing location within the channel during low tide, a) at time of deployment, and b) time of removal if possible.

3 Assessment/Oversight

3.1 Assessments and Response Actions

The Project Manager tracks assessment status and progress. The Project Manager reviews field data weekly at the start of the field season to assess consistency with protocols. After making the determination that protocols are being followed for each parameter, assessments are conducted monthly for the remainder of the field season. The Project Manager will notify the field crew of findings and instruct field crews of any changes that need to be made in practices to comply with protocols.

The Project Manager will flag questionable data and using best professional judgement, determine whether to discard data and/or resurvey a specific parameter.

The Project Manager will maintain a log of assessment dates, findings, and outcomes.

3.2 Reports to Management

Reports regarding assessment status will be made available to management, EPA, and project partners upon request.

4 Data Validation and Usability

4.1 Data Review, Verification and Validation

The *in situ* instrument sensors used in this project are factory calibrated by their respective manufacturers.

All data obtained from *in situ* sensors which are supported by appropriate quality control data and meet the measurement performance specification defined for this project will be considered acceptable and used in the project.

4.2 Data Validation and Verification Methods

Quality control of data has been described for each parameter above. Additional checks of data quality, are an integral part of data preparation, analysis, and report preparation. In particular, data is checked for observations outside of expected ranges. Data are plotted and scanned to identify points that represent possible anomalies in context. Multivariate data are plotted in pair-wise plots to highlight unusual combinations of values. All potentially problematic points are investigated to determine corrective actions. Corrective actions may include a range of possibilities, from correcting typographical errors, to removing data entirely. All corrective actions are documented.

4.3 Reconciliation with User Requirements

Project partners may require that SAPs include specific performance measures for hydrology signal, erosion control, pore water salinity, invasive species or other parameters to assess project outcomes against objectives defined through criteria specified in the SAP. In these cases, CBEP will include a separate summary section within a monitoring report that reiterates project objectives and performance standards. A table is prepared that lists the performance standard, summarizes an annual report of findings, and makes a determination of whether the performance standard has been met.

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Available at: https://www.pwrc.usgs.gov/resshow/neckles/Gpac.pdf

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6.3.1 Stream Barrier Removal Monitoring Guide (Collins et al 2007) available at:
http://www.habitat.noaa.gov/pdf/Stream-Barrier-Removal-Monitoring-Guide-12-19-07.pdf

6.3.2 The Reference Reach Spreadsheet (Mecklenburg 2006) is available at:
http://www.agri.ohio.gov/divs/SWC/docs/Reference_Reach_Survey_4_3_L.xlsm

6.3.3 Stadia rod specifications: Crain SVR-25-Tenths, Model #98010

- 25 feet long, fully extended
- Measurements to the hundredth of a foot
- Six extendable sections

6.3.4 Automatic level specifications: Topcon AT-B3 Automatic Level

- 28x magnification
- Accuracy 1 km
- Double level run: +/- 1.5 mm
- Coarse sighting: Peep sight
- Weight: 3.75 lbs.
- Other Specifications: http://www.forestry-suppliers.com/Documents/1206_msds.pdf

6.3.5 Tape reel specifications: Keson English/Metric Open Reel Fiberglass Tape

- Graduated both sides meter/cm/2 mm; feet/tenths/hundredths other side

6.4 Appendix D – Hydrology & Conductivity/Salinity SOPs, Onset HOBO

6.4.1 Manufacturer:

Onset Computer Corporation
470 MacArthur Blvd.
Bourne, Massachusetts 02532
www.onsetcomp.com
1-877-564-4377

6.4.2 Manuals

- Onset HOBO U20 Water Level Logger: User manual available at: http://www.onsetcomp.com/files/manual_pdfs/12315-E-MAN-U20.pdf
- Onset HOBO U24 Conductivity Logger Manual: http://www.onsetcomp.com/files/manual_pdfs/15070-C-MAN-U24x.pdf
- Onset HOBO USB Micro Station Data Logger: http://www.onsetcomp.com/files/manual_pdfs/20874-C%20MAN-QSG-H21-USB.pdf
- Onset Smart Barometric Pressure Sensor: http://www.onsetcomp.com/files/manual_pdfs/12291-F%20MAN-S-BPB.pdf

6.4.3 Software:

- HOBOWare User's Guide Available at: http://www.onsetcomp.com/files/manual_pdfs/12730-W%20HOBOware%20User's%20Guide.pdf
- HOBOWare Pro Barometric Compensation Assistant User's Guide: http://www.onsetcomp.com/files/manual_pdfs/Barometric-Compensation-Assistant-Users-Guide-10572.pdf
- HOBOWare Pro Conductivity Assistant User's Guide: http://www.onsetcomp.com/files/manual_pdfs/Conductivity-Assistant-Users-Guide-15019.pdf

6.4.4 Cleaning:

Onset Product Cleaning Reference Guide:
http://www.onsetcomp.com/files/manual_pdfs/15667-D-Product-Cleaning-Reference-Guide.pdf

6.4.5 Deployment:

National Park Service report: Continuous water level data collection and management using Onset HOBO data loggers: A Northeast Coastal and Barrier Network methods document.
https://irma.nps.gov/DataStore/DownloadFile/563851

6.0 Appendices

Appendix A – Data Sheets

Contents:

- Desktop analysis data sheet
- Equipment check list
- Pore water salinity data sheet (Appletree Marsh example)
- Cross Sections
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- Vegetation transect cover sheet
- Vegetation plot data sheet
- Percent cover reference sheet
- Invasive plants
- In-Situ logger deployment check list
- In-Situ logger deployment data sheet
- HOBO logger deployment check list
- HOBO logger deployment data sheet

Deployment Check List

SITE:____________________________

LOGGER SN:____________________

LOGGER SN: ____________________

DEPLOYMENT DATE:______________

ONSET HOBO Loggers

Pre-Deployment

- ☐ Notation of serial number and location to be placed
- ☐ Removal of all data on loggers
- ☐ Removal of all data on shuttle
- ☐ Programming (delayed start, 6 minute intervals)

Deployment

Bring into the field:

- ☐ Clipboard with datasheets & pencil
- ☐ GPS
- ☐ Camera
- ☐ Stadia Rod (English, decimal feet)
- ☐ Auto level
- ☐ Tripod

Deployment equipment:

- ☐ Water level loggers (2)
- ☐ Conductivity loggers (2)
- ☐ USB Micro station
- ☐ Barometric pressure sensor
- ☐ Needle nose pliers
- ☐ 2 posts (short)
- ☐ ½" PVC housing (4)
- ☐ ¾" PVC housing (4)
- ☐ 6" zip-ties
- ☐ Mallet
- ☐ Homer Bucket
- ☐ Knife/scissors to cut zip-ties
- ☐ Micro station housing
- ☐ Screws for installation of micro station
- ☐ Regular screwdriver
- ☐ Refractometer
- ☐ DI Water
- ☐ Syringe & tubing
- ☐ Signs with CBEP contact info.

Retrieval

- ☐ Homer Bucket
- ☐ Knife/scissors to cut zip-ties
- ☐ Regular screwdriver
- ☐ Refractometer
- ☐ DI Water
- ☐ Syringe & tubing

Post-Deployment

- ☐ Clean loggers
- ☐ Clean housing
- ☐ Download data
- ☐ Export data to N: drive
- ☐ Correct elevation to benchmark
- ☐ Graph and QA/QC data

HOBO BARO-LOGGER DEPLOYMENT DATA SHEET

SITE INFORMATION

Site ID# (TR &/or Barrier ID):		**Waterbody:**	
Town:		**Street/Structure:**	

LOGGER INFORMATION

Micro Station S/N #:		***Location (UTM, Zone 19 N, NAD 1983):***		Easting: _ _ _ _ _ _	Northing: _ _ _ _ _ _ _
Sensor S/N #:		**Deployed by:**		**Logging Start Date/Time:**	
Site Conditions:					
Description of deployment site:				**Photo #:**	
				Photo #:	
Deployed as part of a broader data set?				**Co-located with other instruments?**	Yes / No S/N #:
General monitoring objective(s):					

Sketch Plan View

Upstream	Downstream

Provide a simple sketch of the general form of the channel upstream and downstream of the deployment location. Show location of the logger in relation to the road/structure. Sketch significant features.

ACTIVITY LOG

Date / Time:	Action:	Personnel:	Notes:
	☐ Deployment ☐ Replace batteries ☐ Cleaning ☐ Data download ☐ Retrieval		

Date / Time:	Action:	Personnel:	Notes:
	☐ Deployment ☐ Replace batteries ☐ Cleaning ☐ Data download ☐ Retrieval		

Date / Time:	Action:	Personnel:	Notes:
	☐ Deployment ☐ Replace batteries ☐ Cleaning ☐ Data download ☐ Retrieval		

POST-DEPLOYMENT NOTES / OBSERVATIONS (QA/QC, ETC.)

Casco Bay Estuary PARTNERSHIP

HOBO CONDUCTIVITY/SALINITY LOGGER DEPLOYMENT DATA SHEET

6014080SITE INFORMATION

Site ID# (TR &/or Barrier ID):		**Waterbody:**	
Town:		**Street/Structure:**	

LOGGER INFORMATION

Logger S/N #:		***Location (UTM, Zone 19 N, NAD 1983):***		Easting: _ _ _ _ _ _	Northing: _ _ _ _ _ _ _
Programmed By:		**Date Programmed:**		**Logging Start Date/Time:**	
Logger Type:	Water Level / Conductivity	**Relation to structure:**	Upstream / Downstream	**Station #:**	
Site Conditions:					
Description of deployment site:				**Photo #:**	
				Photo #:	
Deployed as part of a broader data set?				**Co-located with other instruments?**	S/N #:
General monitoring objective(s):					

Sketch Plan View

Upstream	Downstream

Provide a simple sketch of the general form of the channel upstream and downstream of the deployment location. Show location of the logger in relation to the road/structure. Sketch significant features.

ACTIVITY LOG

Date / Time:	**Action:**	**Personnel:**	**Notes:**
	☐ Deployment ☐ Salinity check ☐ Cleaning ☐ Data download ☐ Retrieval		
Refractometer (calibrated) – measured salinity @ time (twice, at least 6 min. apart):		____ (PPT) @ ___:___ (time) ____ (PPT) @ ___:___ (time)	

Date / Time:	**Action:**	**Personnel:**	**Notes:**
	☐ Deployment ☐ Salinity check ☐ Cleaning ☐ Data download ☐ Retrieval		
Refractometer (calibrated) – measured salinity @ time (twice, at least 6 min. apart):		____ (PPT) @ ___:___ (time) ____ (PPT) @ ___:___ (time)	

HOBO CONDUCTIVITY/SALINITY LOGGER DEPLOYMENT DATA SHEET

ACTIVITY LOG

Date / Time:	**Action:**	**Personnel:**	**Notes:**
	☐ Deployment ☐ Salinity check ☐ Cleaning ☐ Data download ☐ Retrieval		
Refractometer (calibrated) – measured salinity @ time (twice, at least 6 min. apart):		____ (PPT) @ ___:___ (time) ____ (PPT) @ ___:___ (time)	

Date / Time:	**Action:**	**Personnel:**	**Notes:**
	☐ Deployment ☐ Salinity check ☐ Cleaning ☐ Data download ☐ Retrieval		
Refractometer (calibrated) – measured salinity @ time (twice, at least 6 min. apart):		____ (PPT) @ ___:___ (time) ____ (PPT) @ ___:___ (time)	

POST-DEPLOYMENT NOTES / OBSERVATIONS (RAINFALL, QA/QC, ETC.)

HOBO WATER LEVEL LOGGER DEPLOYMENT DATA SHEET

SITE INFORMATION

Site ID# (TR &/or Barrier ID):		**Waterbody:**	
Town:		**Street/Structure:**	

LOGGER INFORMATION

Logger S/N #:		***Location (UTM, Zone 19 N, NAD 1983):***		Easting: _ _ _ _ _ _	Northing: _ _ _ _ _ _ _
Programmed By:		**Date Programmed:**		**Logging Start Date/Time:**	
Logger Type:	Water Level / Conductivity	**Relation to structure:**	Upstream / Downstream	**Station #:**	
Site Conditions:					
Description of deployment site:				**Photo #:** **Photo #:**	
Deployed as part of a broader data set?				**Co-located with other instruments?**	Yes / No S/N #:
General monitoring objective(s):					

Sketch Plan View

Upstream	Downstream

Provide a simple sketch of the general form of the channel upstream and downstream of the deployment location. Show location of the logger in relation to the road/structure. Sketch significant features.

ACTIVITY LOG

Date / Time:	**Action:**		**Personnel:**	**Notes:**
	☐ Deployment ☐ Water level check ☐ Cleaning ☐ Data download ☐ Retrieval			
Surveyed stadia rod measurements				
Benchmark elevation:	Start: ____ (ft.) @ ___:___ (time)	**Benchmark description:**		
Water surface (twice, at least 6 minutes apart):	____ (ft.) @ ___:___ (time) ____ (ft.) @ ___:___ (time)	**Channel bottom** (at instrument):	____ (ft.) @ ___:___ (time)	

Date / Time:	**Action:**		**Personnel:**	**Notes:**
	☐ Deployment ☐ Water level check ☐ Cleaning ☐ Data download ☐ Retrieval			
Surveyed stadia rod measurements				
Benchmark elevation:	Start: ____ (ft.) @ ___:___ (time)	**Benchmark description:**		
Water surface (twice, at least 6 minutes apart):	____ (ft.) @ ___:___ (time) ____ (ft.) @ ___:___ (time)	**Channel bottom** (at instrument):	____ (ft.) @ ___:___ (time)	

HOBO WATER LEVEL LOGGER DEPLOYMENT DATA SHEET

ACTIVITY LOG

Date / Time:	**Action:**	**Personnel:**	**Notes:**
	☐ Deployment ☐ Water level check ☐ Cleaning ☐ Data download ☐ Retrieval		

Surveyed stadia rod measurements			
Benchmark elevation:	Start: ____ (ft.) @ ___:___ (time)	**Benchmark description:**	
Water surface (twice, at least 6 minutes apart)**:**	____ (ft.) @ ___:___ (time) ____ (ft.) @ ___:___ (time)	**Channel bottom** (at instrument):	____ (ft.) @ ___:___ (time)

Date / Time:	**Action:**	**Personnel:**	**Notes:**
	☐ Deployment ☐ Water level check ☐ Cleaning ☐ Data download ☐ Retrieval		

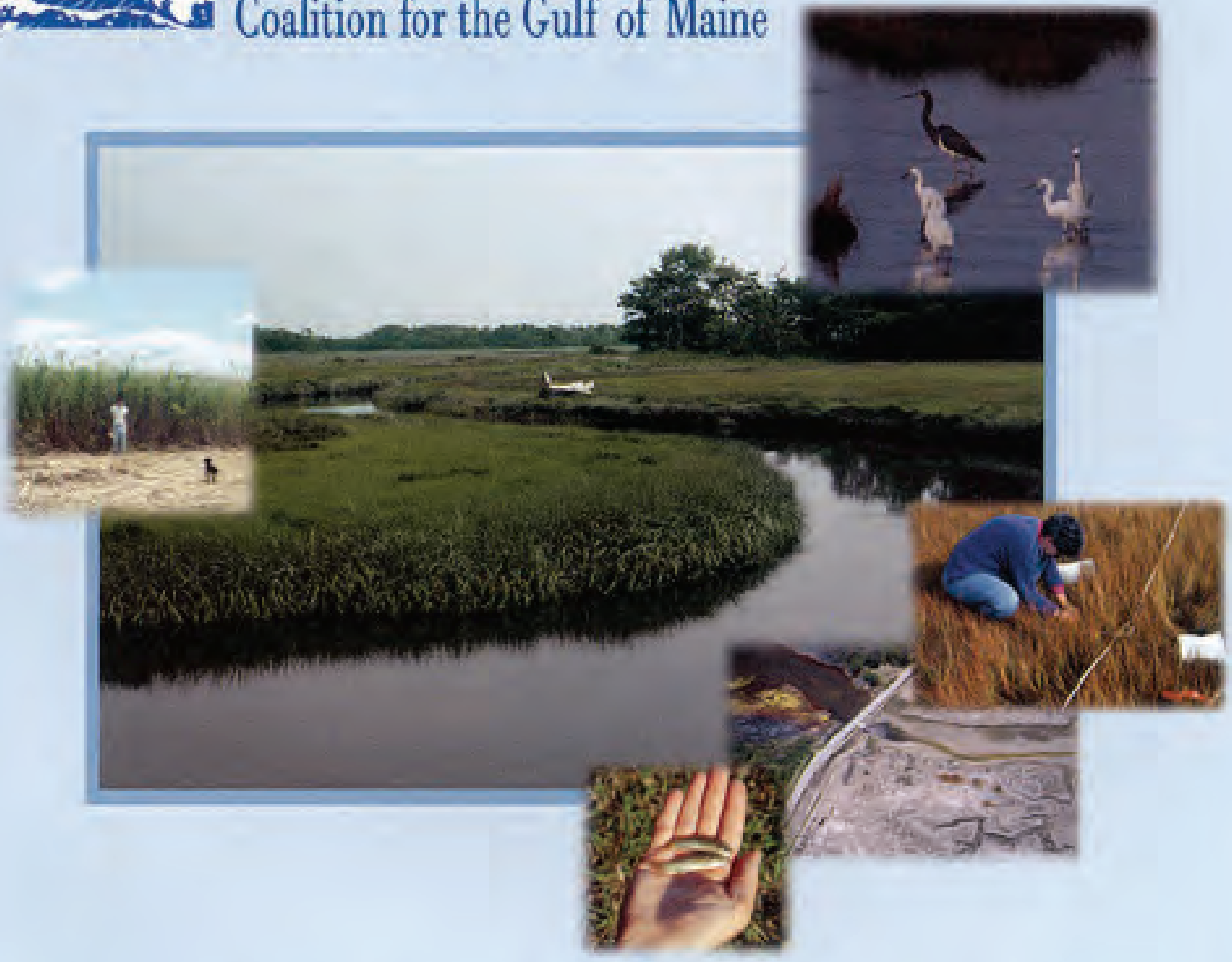
Surveyed stadia rod measurements			
Benchmark elevation:	Start: ____ (ft.) @ ___:___ (time)	**Benchmark description:**	
Water surface (twice, at least 6 minutes apart)**:**	____ (ft.) @ ___:___ (time) ____ (ft.) @ ___:___ (time)	**Channel bottom** (at instrument):	____ (ft.) @ ___:___ (time)

POST-DEPLOYMENT NOTES / OBSERVATIONS (QA/QC, ETC.)

Appendix B – Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine

Available at: https://www.pwrc.usgs.gov/resshow/neckles/Gpac.pdf

Global Programme of Action
Coalition for the Gulf of Maine



Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine

A GPAC Workshop Report

Wells National Estuarine
Research Reserve
June 2-3, 1999

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Internet: http://www.cec.org

Cover Photo Collage

Background photo: mid-tide in an unaltered salt marsh (i.e., no tidal restrictions). Foreground photos clockwise from top right: wading birds foraging in a salt marsh panne; volunteer sampling vegetation on high marsh (orange color of grass indicates a fall rather than a summer sample date); road crossing with undersized culvert alters hydrology, functions and values of upstream marsh (photo taken at low tide in early spring); the mummichog *(Fundulus heteroclitus)* plays an important role in the marsh food web; *Phragmites australis* (commonly referred to as Phrag), a brackish marsh plant that can become invasive in salt marsh areas where elevations and/or hydrology have been altered. Credits: wading birds by B.A. King, aerial photo by J.List, others by M. Dionne.

Illustrations on pages 5 and 9 by Thomas R. Ouellette, 57 Hany Lane, Vernon, CT 06066 (860) 872-6180

Report Photo Credits: M. Dionne unless otherwise noted.

Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine

A GPAC Workshop
June 2-3, 1999

Report Edited By
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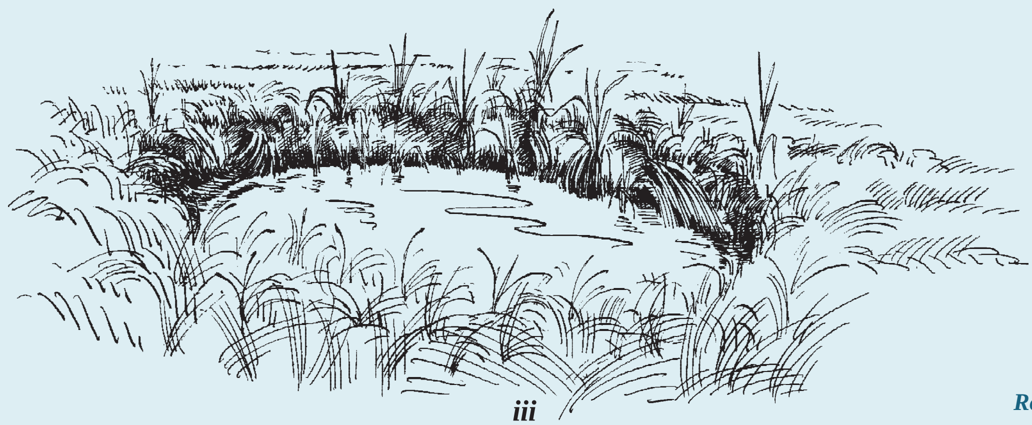


Robert Shetterly

Preface

The Global Programme of Action Coalition for the Gulf of Maine (GPAC) was brought together by the commission for Environmental Cooperation (CEC), a North American organization which fosters environmental cooperation on transboundary issues between the United States, Canada, and Mexico. This binational effort is in response to the United Nations Environment Program's global action plan to reduce degradation of marine and coastal environments. It is internationally recognized that about eighty percent of marine pollution is caused by human activities on land. GPAC has been working for over two years to facilitate the implementation of the United Nations' global plan through the various communities, organizations, industries, and governments of the Gulf of Maine.

In 1998 GPAC engaged in a series of broad discussions via two regional workshops to identify the primary land-based threats to the Gulf of Maine marine environment and to develop actions for reducing or eliminating their impacts. These discussions highlighted the importance of tidal wetlands to the ecology, economy, and sustainability of coastal ecosystems and some critical gaps in their conservation, restoration, and management throughout Gulf of Maine jurisdictions. The workshop on "Regional Standards for Identifying and Evaluating Tidal Wetland Restoration in the Gulf of Maine" was supported by GPAC as an initial effort to address some of these gaps on a regional scale.

On behalf of GPAC, we would like to extend our sincere thanks to all who participated in the workshop and who contributed to its success. We particularly thank the Workshop Steering Committee for adding substance to GPAC's vision and the Wells National Estuarine Research Reserve for graciously hosting the workshop.

The results of the workshop presented in this volume provide the basis for developing some binational programs to enhance tidal wetland restoration across the Gulf of Maine. We are pleased to have been able to help in establishing an international network that has been greeted with enthusiasm on both sides of the US-Canada border, and we wish you continued success as these programs are implemented throughout the region.

GPAC Co-chairs:

Joe Arbour
Environment Canada

Katie Ries
National Ocean Service, National Oceanographic and Atmospheric Administration

Acknowledgements

We thank the Commission for Environmental Cooperation, the Laudholm Trust, and the Wells National Estuarine Research Reserve for sponsoring the "Regional Standards to Identify and Evaluate Tidal Wetland Restoration in the Gulf of Maine" workshop, held on June 2-3, 1999. This workshop and report represents the culmination of research planning efforts initiated at a 1996 New England Estuarine Research Society Symposium on the ecology of marsh-estuarine ecosystems in the Gulf of Maine, funded by planning grant BIR-95222314 from the National Science Foundatin to the Wells National Estuarine Research Reserve.

We also express our sincere appreciation to the Workshop Steering Committee for the months spent in organizing the workshop (see Appendix B for a complete listing). Special thanks go to committee members Arnold Banner, Robert Buchsbaum, David Burdick, Ted Diers, Eric Hutchins, and Charles Roman for leading work group breakout sessions and contributing their respective summaries to this report, and to Kim Hughes for focusing discussions on the concluding day of the workshop. Patrick Ewanchuck and Erno Bonebakker provided very helpful comments during final document review. In addition, we thank workshop speakers Katie Ries, of NOAA's National Ocean Service and GPAC, and Jeffrey Benoit, of NOAA's Office of Ocean and Coastal Resource Management, for their inspiring remarks.

We are extremely grateful to the Wells National Estuarine Research Reserve (WNERR) for hosting the workshop. Without the enthusiastic and professional support of Kent Kirkpatrick, Director of the WNERR, and Kathryn Davis, President of the Laudholm Trust, this workshop would not have been possible. Most importantly, we thank workshop coordinator Nancy Bayse for making the workshop and this report a reality. Her expert management and production skills, dedication, and unfailing good humor were the key ingredients to workshop success.

Finally, we thank the participants who generously devoted the time to attend the workshop. Their input forms the basis of this report.

Workshop Co-Chairs:
Hilary Neckles, US Geological Survey, Patuxent Wildlife Research Center
Michele Dionne, Wells National Estuarine Research Reserve

Citation Information

Neckles, H.A. and M.Dionne, Editors. 2000. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME. 21 p. plus appendices. Chapter authors are identified within the report. Individual chapters should be cited as, e.g. Burdick,D.M. 2000. Ecosystem indicator:hydrology. p 7-9 in H.A. Neckles and M.Dionne, Editors. Regional standards to identify and evaluate tidal wetland restoration in the Gulf of Maine. Wells National Estuarine Research Reserve Technical Report, Wells, ME.

Introduction

Restoration of tidal marshes in the Gulf of Maine has gained considerable momentum during the last ten to fifteen years. (Dionne et al. 1998) Following several centuries of human activities that have altered, degraded, or destroyed a large proportion of the tidal marshes in the region, the emphasis of many federal, state, provincial, and nongovernmental programs is now on restoring the natural hydrology and functional values of these systems. Restoration efforts include proactive projects that increase the amount and improve the quality of coastal habitats, and mitigation projects to compensate for permitted impacts

Undersized culverts significantly reduce tidal flow into marsh systems.

to tidal wetlands. Despite this emphasis, however, the overall effectiveness of tidal marsh restoration in the Gulf of Maine is uncertain. Contributing to this uncertainty are a lack of comprehensive baseline information on sites available for restoration, widely varying degrees of restoration project monitoring, inconsistencies in monitoring data collection, and a paucity of scientifically defensible criteria for determining restoration success.

In 1999, the Global Programme of Action Coalition for the Gulf of Maine (GPAC) initiated a regionally coordinated project to address these needs. The goals of the projects are to develop a Gulf of Maine-wide inventory of potential salt marsh restoration sites and a regional monitoring network of restored and reference salt marshes. On June 2-3, 1999, a workshop was hosted by the Wells National Estuarine Research Reserve in Wells, Maine to develop the common protocols needed to establish these regional programs. Over the course of a day and a half, resource managers, scientists, and members of community organizations from the United States and Canada reached consensus on standard methods for inventorying restoration opportunities and for monitoring restoration efforts.

This report summarizes the resulting tidal marsh inventory model and monitoring protocols for the Gulf of Maine.

Dionne, M., D. Burdick, R. Cook, R. Buchsbaum, S. Fuller. 1998. Scoping Paper 5: Physical alterations to water flow and salt marshes. Commission for Environmental Cooperation. Montreal, Canada. 57p. and appendices.

Overview of the GPAC Initiative

The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) was developed under the auspices of the United Nations Environment Programme to assist national and regional authorities in reaching the goal of "sustainable seas". The three North-American countries – Canada, Mexico, and the United States – were among the more than 100 signatories who agreed in 1995 to strengthen national, regional and global arrangements for addressing marine degradation from land-based pollution and activities.

The Commission for Environmental Cooperation (CEC) was established in 1994 by Canada, Mexico, and the United States under the North American Agreement for Environmental Cooperation to address transboundary environmental concerns, help prevent potential trade and environmental conflicts, and promote the effective enforcement of environmental law. The agreement complements the environmental provisions of the North American Free Trade Agreement (NAFTA).

In pursuing its mandate, the CEC is promoting two pilot projects in North America to help implement the GPA. The Gulf of Maine was selected as the focus of one of those projects. To carry out this binational effort, the CEC helped establish GPAC, a broad group of individuals from Canada and the United States with interest in the Gulf of Maine and the GPA. This group includes representatives of the federal governments of Canada and the United States, governments of the provinces (New Brunswick and Nova Scotia) and states (Maine, New Hampshire, and Massachusetts) bordering the Gulf of Maine, Native American tribes, First Nations of Canada, industry, community action groups, environmental advocacy groups, and research and academic institutions.

GPAC is intended to form the basis for continued regional cooperation and joint actions in marine and coastal areas of the Gulf of Maine. GPAC set a strategic course based on the principles of the GPA and is working toward the following vision for the future:

"A healthy marine and coastal environment in the Gulf of Maine where human use and biological diversity thrive in harmony."

To help implement the GPA in the Gulf of Maine, GPAC draws from and builds on the existing work of the Gulf of Maine Council on the Marine Environment, the Regional Association for Research in the Gulf of Maine, the CEC, and other organizations and individuals committed to the protection of this shared public resource of world-class cultural, economic and ecological value.

In 1998, GPAC sponsored two workshops to identify threats from land-based activities to marine and coastal habitats of the Gulf of Maine and determine strategies and measures to address these threats. Participants representing a broad range of disciplines, interests, and organizations developed a list of priority pollution and habitat issues requiring Gulf-wide action at the first workshop, which was held in Saint John, New Brunswick on April 27-28. These priority issues were combined into 5 broad categories, one of which focused on Physical Alterations to Water Flow and Salt Marshes. At the subsequent workshop in Portland, Maine on November 15-17, participants reviewed existing activities in the Gulf of Maine region related to these priority issues, identified gaps in current environmental protection and land-use programs, and proposed a series of actions to protect the coastal and marine environment from pollution and disturbance arising from land-based activities. Through this process, the need for a Gulf-wide inventory of potential tidal marsh restoration opportunities and regionally applicable standards for evaluating tidal marsh restoration projects emerged as high priorities. The workshop described in the following pages represents the next step toward addressing these needs on a regional basis.

Workshop Process

Workshop deliberations occurred within groups devoted to one of four topics: site inventory, monitoring marsh physical characteristics, monitoring plants and habitat mapping, and monitoring animals.

Workgroup discussions were guided strongly by existing information. For example, various tidal marsh inventory models are in use within specific jurisdictions of the Gulf of Maine region, each including certain site characteristics to be evaluated with varying degrees of overlap (Appendix C). Similarly, a number of protocols also exist for monitoring restored tidal marshes in the region, some of which emerged from previous workshops on the same subject (Appendix C). This information provided a critical springboard for work group discussions.

Inventory work group participants used existing databases to propose data fields for inclusion in the regional site inventory database model. To be selected as a field for the regional database structure, the required information was determined to be regionally applicable, reasonably available, and relevant to making decisions on costs and benefits of potential and completed restoration actions.

Existing protocols for monitoring restoration projects were distilled into a list of potential variables for consideration by the monitoring work groups. Work group participants evaluated potential variables in terms of critical information gained, feasibility, cost (in U.S. dollars), the skill level required for measurement, and spatial and temporal sampling frequency. In recognition that application of a lengthy, complex monitoring protocol on a large scale would be cost prohibitive, participants were asked to reach consensus on a minimum number of core variables to include in a standardized, regional protocol. Participants also recommended the "best" protocol by identifying additional variables, techniques, sampling periods, etc. to be included in a monitoring project as resources allow.

Product Design

The protocols developed at the workshop are intended to serve as springboards for assessments of Gulf of Maine salt marshes that are either likely candidates for restoration or that are being restored. To be most successful, these assessments will involve the combined efforts of practicing environmental professionals and members of volunteer, community based organizations. The products of this workshop are intended for use by professionals to plan inventory and monitoring projects, and for professionals and volunteers working in partnership to actually undertake projects. Consequently, the level of detail presented here assumes professional involvement. As presented, these methods will assure the consistency of data collection efforts required for implementation on a regional scale. We expect that in most cases, more detailed procedures of field techniques will be compiled to guide on-the-ground data collection.

Database Model for Restoration and Reference Site Inventory

Work Group Participants

Summary by: Eric Hutchins-NMFS, Arnold Banner-USFWS, John Catena-NMFS, Lou Chiarella-NMFS, Pascal Giasson-NB DNRE, Jennifer Graham-Ecology Action Center, Kim Hughes-NB Dept. of the Env., Chuck Katuska-MA Wetlands & Banking Program, Tim Purinton-Northeast Wetlands Restoration,Vic Pyle- Restore America's Estuaries, Aviva Rahmani-Ghost Nets, Bob Rutherford- NS Dept. of Fisheries & Oceans.

Rationale

The work group agreed on the following database structure to inventory existing and potential tidal marsh restoration sites. Data fields were selected based on regional applicability, availability of information, and relevance for making decisions on costs and benefits of completed and potential restoration actions. A Regional Inventory Data Sheet and list of regional inventory coordinators are included in Appendix D.

Aerial View of Webhannet Marsh, within Wells NERR and Rachel Carson NWR, Wells, ME

Core Variables

- **Site I.D.:** two letter state/province ID followed by consecutive numerals, max. of five characters, e.g. MA1, MA2, MA3,….MA99
- **Project Name:** subjective name, maximum of forty characters, e.g. Conomo Point
- **Town/City:** town, city, maximum of forty characters, e.g. Manchester-By-The-Sea
- **Waterbody:** closest waterbody identified from a 1:24,000, 7.5 minute quadrangle map produced by the US Geological Survey or a 1:50,000 map produced by Energy, Mines, and Resources, Canada, maximum of forty characters, e.g. Saratoga Creek
- **Latitude/Longitude:** a point near center of restoration site, including degrees, minutes and seconds, e.g. 40° 18' 23" N, 70° 34' 45" W
- **Owner:** public and/or private, and/or Non-Profit Organization; enter owner acronym or abbreviation if known, otherwise use PUB/PRV/NPO, maximum of 15 characters, e.g. USFWS/PRV/NPO
- **Historic Condition:** pre-impact National Wetlands Inventory Classification (US) or Canadian Wetlands Atlas Classification (Can) or specific species, maximum of 30 characters, e.g. E2EM/S.patens
- **Nature of Alteration:** select from following list: tidal restriction, fill, stormwater, bulkhead, ditching, salt hay, other; maximum of 40 characters, e.g. tidal restriction/stormwater
- **Impacts:** consequence of alteration from following list: drained marsh, impounded, flooded, invasive vegetation, other; maximum of 40 characters, e.g. drained marsh/invasive vegetation
- **Area:** practicable area of enhancement/restoration in square meters; this is the area improved, not just the area worked on (e.g. dam removal area would be large, but the area restored could be small) maximum 12 characters, e.g. 8,000 m^2
- **Restoration Action:** select from following list: fill removal, stormwater treatment, culvert enlargement, ditch plugging, other, maximum 40 characters, e.g. fill removal/ stormwater treatment
- **Estimated Cost:** three ranges, (<10K), (10K – 100K) or (>100K), maximum 10 characters, e.g. 10K – 100K
- **Actions:** check all that apply from the following list and record date of entry: none, pre-monitoring, permitted, implementation, post-monitoring, e.g. pre-monitoring, permitted, implementation, 9/00
- **For More Information:** two names and contact info. for additional information, e.g.John Catena, NMFS, 1 Blackburn Drive, Gloucester, MA 01903, P: 978-281-9313, Email: John.Catena@noaa.gov

Baseline Habitat Mapping

Work Group Participants

Summary by: Charles Roman-USGS, and Ted Diers-NH Coastal Program, Sarah Allen-Normandeau Assoc., Bruce Carlisle-MA CZM, Carolyn Currin-NOAA, Pam Morgan-UNH, Frank Richardson-NH DES, Peter Shelley-Conservation Law Foundation, Lee Swanson-NB DNR.

Rationale

The base map provides a foundation for monitoring activities. The purpose of the core variables defined below is to provide the basic minimum information on the location and fundamental features of the restoration site (locus map, key physical and cultural features, latitude and longitude), the general ecological condition of the marsh (cover type mapping), and potential stresses on the marsh (adjacent land use). The base map provides a template for location of specific sampling sites and offers a baseline for spatial change analyses (e.g. cover type changes over time).

Core Variables

- **Locus Map:** state, province, city or town of salt marsh monitoring site
- **Key locator and cultural features associated with monitoring site:** e.g. rivers, roads, culverts
- **Delineated wetland area/cover types:** salt marsh, fresh/brackish marsh, forested wetland, shrub dominated wetland, open water (creeks, pannes, pools, ditches), invasive species or species of interest, e.g. Phragmites. If available, National Wetland Inventory (US) or Canadian Wetlands Atlas (Can.) delineations would be appropriate
- **Manipulations:** pre- and post-restoration, e.g. culverts, dredging, removal of fill, excavations, addition of fill, etc.
- **Sampling locations:** pre- and post-restoration monitoring (transects, plots, etc.)
- **Base map documentation:** sources of base map (USGS or Canadian topographic maps, aerial photographs including scale, type, and date, tax maps, National Wetland Inventory database, other), scale of map and north arrow, latitude and longitude

Great Blue Heron, *Ardea herodias and*
Snowy Egret, *Egretta thula*
Photograph by B.A. King

Mapping Methods

Methods used to prepare the base map will be directly dependent on the capabilities and facilities available to the site participants. The most fundamental base map would be intitiated with a 1:24000 scale topographic map, whereas more sophisticated maps would use an orthophoto base and geographic information systems (GIS) capabilities. A base map developed with a GIS platform will have the greatest long-term utility and will be easily modified as data sets become available. It is strongly recommended that GIS be utilized if possible.

There are several approaches to cover type mapping. First, the US Fish and Wildlife Service National Wetland Inventory (NWI) database or the Canadian Wetlands Atlas may have mapped wetland cover types for the monitoring site. State and provincial resource managment agencies are also good sources of cover type maps. The NWI maps are presented on a 1:24,000 base. Oftentimes these maps are based on older photography (i.e., 1970's-80's) and may need to be field verified for accuracy. Recent aerial photographs (preferably vertical) are another highly useful source for developing or verifying the cover type base, but on-site ground truthing is always required. State and provincial agencies can also be good sources of aerial photography.

Skill Level

All components of the base map, except for cover type mapping, can be accomplished by volunteers, with minimal initial guidance by professionals. Cover type mapping will require involvement of professionals with training in photointerpretation and field ground-truthing; however, with training and oversight, volunteers could accomplish these tasks. The more sophisticated base maps or series of base maps will be developed through GIS platforms for which extensive training and computer facilities are required.

Cost

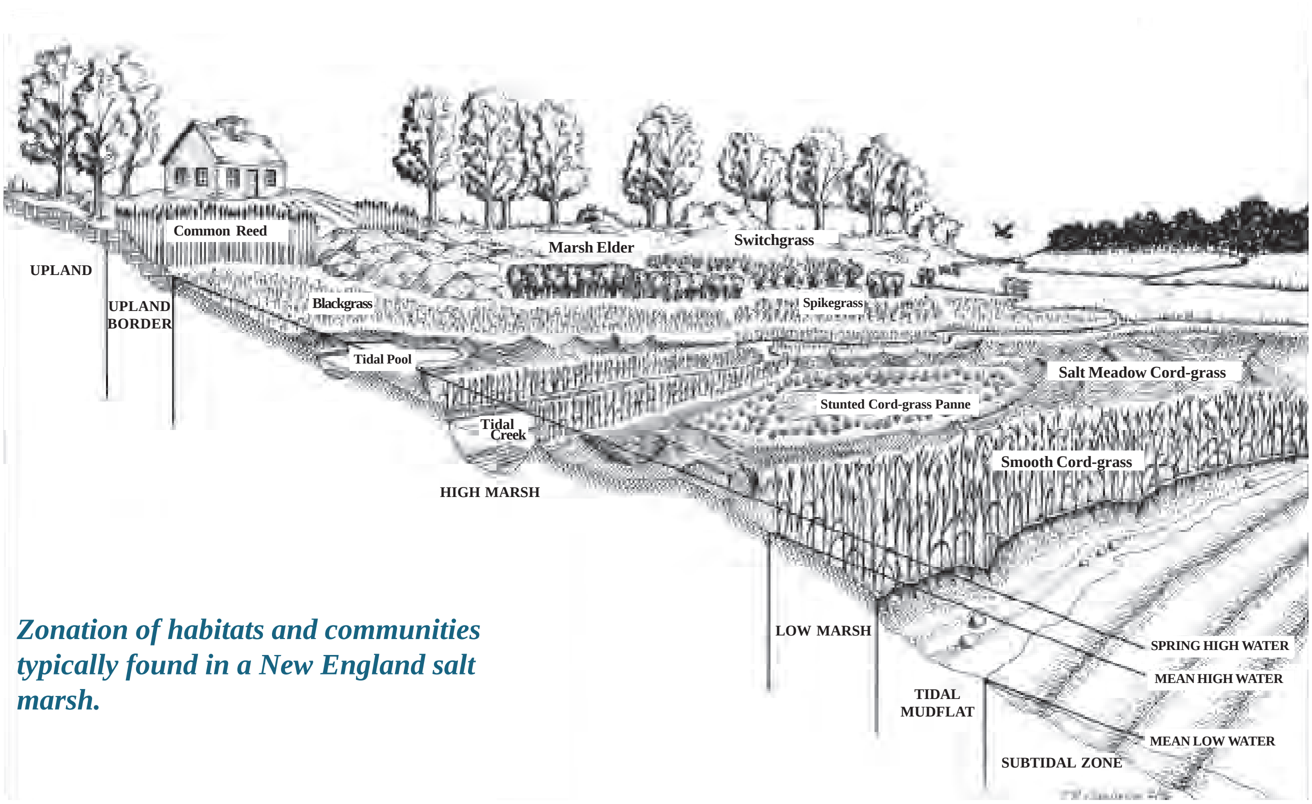
Costs for development of the base map will vary depending on the degree of professional involvement. It would be ideal to engage the time and facilities of a GIS professional for development of the base map. University environmental labs and environmental state, provincial, and federal agencies all have excellent GIS capabilities. The minimum base map could be prepared in 4-6 weeks time by a GIS professional at an estimated cost of up to $5,000 - $10,000. This includes compiling the spatial data, interpreting aerial photography, and ground-truthing. The cost could be reduced significantly through the use of trained volunteers. In addition, it may be possible to involve a GIS professional as a public agency's contribution to total project costs.

Additional Variables

Some sites and investigators with access to extensive map files, aerial photography libraries, and GIS capabilities may develop comprehensive base maps. Given these capabilities, it may be appropriate to include additional information on the base map including: detailed cover-type mapping, ownership boundaries, elevation contours, soil organic content, and 100 yr floodplain boundary.

Selected References

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States FWS/OBS-79-31. 103p.



Zonation of habitats and communities typically found in a New England salt marsh.

Thomas R. Ouellette

Tidal Marsh Restoration Monitoring

The following monitoring protocol for tidal wetlands is based on a set of core variables within broad categories of wetland structural and functional responses to restoration. In selecting core variables, work group participants considered the integrative properties of various potential measures and the ease and cost of application on a regional scale. In some cases, certain variables and sampling schemes emerged as ideally suited for regional implementation; in others, trade-offs between information content and expediency were required.

The variables and methods identified here represent only one of several ways to characterize marsh response. Collectively, these variables provide a cost-effective and scientifically valid approach for monitoring restoration projects in a consistent manner throughout the Gulf of Maine region.

The core variables included in the protocol are the minimum deemed necessary to evaluate responses of tidal marsh ecosystems to restoration. These variables should be monitored at all sites included in the regional network. Restoration projects differ in goals, scope, and availability of resources for monitoring, so that additional monitoring of individual projects may be warranted. Additional variables are recommended within each monitoring category for application to specific projects. Each section also lists several key references that provide more thorough background and rationale for variable selection and some overviews of sampling methods.

Restoration sites should be paired with "undisturbed" natural reference marshes for monitoring, and ideally, restored and reference systems should be monitored both before and after the restoration is completed. Natural wetlands are not true controls, but serve as reference systems for determining whether restoration goals are being met, and they may be essential for distinguishing responses to restoration from natural background variability.

Natural marshes used as reference systems must be in a similar physical setting as the restoration projects to which they are being compared. Thus salt marsh reference sites should be selected to be similar to restoration projects in terms of uncontrolled variables such as temperature, geomorphology, potential tidal range, elevation, landscape position, adjacent land use, and water quality. Many restoration efforts in the Gulf of Maine focus on removing obstructions to tidal flooding caused by roads, dikes, or undersized culverts. In some instances, an appropriate reference site may be found downstream from the tidal restriction, although it is recognized that downstream and upstream portions of marshes may exhibit different salinity regimes and support different ecological communities. A well-studied marsh may also serve as an appropriate reference.

Robert Shetterly

Valid statistical comparisons between pre- and post-restoration conditions and between restored and reference marshes depend in large part on the independence of replicate samples and consequent experimental error terms. More generally, statistical models assume zero correlation among experimental replicates. Truly random sampling provides necessary and sufficient insurance against violating this assumption. All of the sampling methods described here that depend on statistical tests to make inferences about the marsh ecosystem assume some type of random sample allocation. The number of samples needed depends on the size and complexity of the marsh being described, the variability of the parameter being measured, and the desired precision of the estimate. If preliminary sampling is possible, then the number of observations needed to achieve a certain statistical power can be based on the estimated population variance. Practically, given that the precision of estimates increases with sample number, more samples are usually better. In general, the sample sizes included in the protocol were intended for typical Gulf of Maine marshes up to about 20 ha in size. Large systems with complex hydrologies and broad elevational ranges may require greater sampling efforts.

Ecosystem Indicator: Hydrology

Work group Participants

Summary by: David Burdick-UNH Jackson Estuarine Lab., Kim Hughes-NB Dept of Environment, Hilary Neckles-USGS, Richard Orson-Orson Environmental Assoc., Edward Reiner- US EPA, Henry Rines-Applied Science Associates, Inc., Jan Taylor-USF&WS, Larry Ward-UNH Jackson Estuarine Lab.

Rationale

The fundamental control on the structure and function of salt marsh habitat is flooding with salt water. Hydroperiod is the amount of time, in terms of frequency and duration, that the area is flooded. The hydroperiod within a marsh is determined by the tidal signal and elevation.

The most common impacts to salt marshes in the Gulf of Maine are caused by hydroperiod alterations resulting from tidal restrictions caused by roads, railroads, or other obstructions to tidal flow; restoration focuses on increasing tidal exchange. Hydroperiod alterations can also result from mosquito ditching, an extensive practice in Gulf of Maine marshes. Methods are being developed to restore natural hydrology to ditched marshes.

Although tidal predictions may be available for astronomical tides affecting coastal areas close to the restoration site, local variation (naturally and resulting from human activities) makes it imperative to obtain actual measurements at the specific location to be restored. Similarly, the elevation of the marsh surface relative to the tidal height must be measured.

The monitoring methods outlined are appropriate for many types of salt marsh restorations. Because of the prevalence of tidally restricted marshes in the Gulf of Maine, data collection for this type of restoration is stressed.

Tidegates deprive salt marshes of essential tidal flow. These gates, on Back River Creek, Woolwich, ME have been removed.

Robert Shetterly

Core Variables

- **Tidal Signal:** The pattern of water level change (maximum of 15 minutes between measurements) with respect to a reference point
- **Surface Elevations:** Marsh surface elevation (contour intervals of 15 cm or less)

Sampling Methods

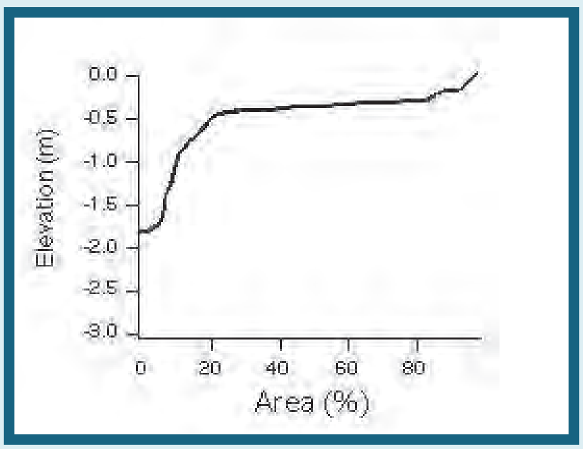
Two types of data are needed to describe the hydroperiod; each must be collected within the entire area affected by the planned restoration. These data will be used to assess the potential hydroperiod, to understand the relationship between flooding and habitat type and to predict the habitat that could result under different restoration and management options.

Tidal Signal

Automatic water level recorders should be operated simultaneously for a minimum of two weeks, i.e., one lunar cycle of spring and neap tides (one month, or two lunar cycles is better) near the source of tidal influx. For tidally restricted marshes, recorders should be installed both upstream and downstream of the tidal restriction. Either a water level gauge or pressure transducer would produce a tidal curve yielding the necessary data. Lacking access to an automated water level recorder, 10-minute measurements over 13-hour periods using a simple tide staff (a vertical ruler fixed in the tidal channel) for three spring and three neap tides would provide adequate information. Using either method, the elevations of the upstream and downstream devices are required, preferably referenced to NGVD (National Geodetic Vertical Datum). At a minimum, the relative elevations of the water level recorders in the impacted and reference marshes must be known.

Surface Elevations

There are two acceptable approaches to obtain this second type of data needed to calculate hydroperiod. Both require the skills of professionals. The preferred approach is to produce a contour map of marsh elevations throughout the entire area to be restored, e.g. both upstream and downstream of a restriction. The contours must be at 15 cm intervals or smaller to make meaningful predictions regarding habitat. The area of marsh flooded by a particular tide or the amount of time it is flooded per month can then be calculated (hydroperiod). Lacking the resources to produce such a map, relative elevations of 40 to 100 randomly selected points can be used to produce a hypsometric curve. These points can be obtained by taking measurements at regular 5-10 m intervals, e.g. every 5 meters along transects running across the marsh from high tide line to high tide line, as delineated by the wrack line around the marsh perimeter. Application of the hypsometric curve to marsh surface area provides an estimate of the amount of marsh area flooded for any particular tidal height and, coupled with the tidal signal, can yield the hydroperiod.



Example of a hypsometric curve.

Sampling Design

Tidal signal data should be collected for a period of 2-4 weeks prior to the restoration and soon after restoration. The number of elevation data points needed to generate a contour map or hypsometric curve will depend on the area and the morphology of the marsh. Elevations need to be measured only once, but close to the date of restoration. Subsequent measures of tidal signal or surface elevations can be left to the discretion of the responsible management agency, but should be performed at least every 5 years. For tidally restricted marshes, information should be obtained both above the restriction and in an adjacent area of marsh below the restriction.

Skill Level

Tidal signal measurements using pressure transducers or tidal gauges require professionals for installation, data collection, data reduction and interpretation. Tidal staffs installed by professionals may be read and recorded by volunteers, but data should be reduced and interpreted by professionals. Marsh surface elevations and correction to NGVD as well as map or hypsometric curve generation require professionals.

Cost

Costs are estimated for work performed in one sampling period (e.g. pre-restoration, post restoration year one, year five, etc.) at a site no larger than 10 hectares (22 acres). For variables that require more sampling at larger sites, costs will be greater. Collection of tidal signal data using 2 automated recorders requires about $1500 for equipment, 2-4 days of professional work for deployment and data collection and 1-3 days of professional work for data processing. Alternatively, use of tide staffs would require about $200 for equipment, and 2-4 days of professional work for data processing. Generating a contour map requires about $1500 for equipment, 3 days of field work and 2-4 days of professional work. Alternatively, generating a hypsometric curve of marsh elevations requires about $500 for equipment, 2 days of field work, and 2-4 days of professional work. Survey and other equipment can often be borrowed from agencies or academic institutions.

Additional Variables

Tidal Creek Cross-Sections

Cross-section profiles of major tidal creeks can be measured prior to restoration and at 2-3 year intervals post-restoration. Profiles are measured using standard survey techniques, with special care not to damage the escarpments. The position of the profile should be carefully marked so that the identical cross-section can be monitored following restoration.

Downloading water quality data collected by data logger

Water table depth

Under circumstances where an important goal of the restoration project is to increase tidal flooding to reduce invasive upland or wetland species, water table depth monitoring is recommended. Changes in water table can be monitored with wells or piezometers (wells open only near the base for the sole purpose of observing groundwater levels) placed deep enough in the soil to intersect the water table during drier periods. Piezometers can be constructed from PVC pipe with a screened, perforated interval that intersects the water table. Stations should be placed according to recommendations given for soil salinity stations (see Soils and Sediments section) as well as along the upland edge of the marsh or in populations of plants that should be affected by the restoration action. Sampling should occur at low tide about 6 times a year in the early to mid growing season and include neap and spring tides. Volunteers can assist with sampling.

Surface water quality, salinity, and other characteristics

If an important goal of the restoration is to improve water quality, water quality parameters should be included in project monitoring. Sample stations could be established along the main stem of the channel. Measurements of dissolved oxygen, salinity, temperature and pH may be accomplished using an automated data logger. Manual data collection can be accomplished with portable dissolved oxygen and pH meters. These should include pre-dawn and noon measurements collected on outgoing spring and neap tides. Carefully trained volunteers can measure surface water quality with a high degree of accuracy and precision.

The salinity of the water within tidally-restricted marshes should increase following tidal restoration. Stations could be established along the main stem of the channel and salinity measured in the flooding waters on spring and neap high tides. The water column is assumed to be unstratified (this should be verified on a flooding tide) and can be collected by canoe using a bucket or tube. Salinity can be measured using a temperature-corrected optical refractometer to the nearest 2 ppt or a hydrometer and thermometer in a graduated cylinder (nearest 1 ppt). Volunteers can collect water samples and measure salinity.

Current profiles in main channel

Knowledge of the tidal current in the main channel can be useful when designing the tidal conduit for a tidal restoration and to assess the function of the structure as-built. Tidal current should be assessed over several tidal cycles and can be measured with a recording current meter.

Extent of tidal flooding

If the hydroperiod (as described above) cannot be measured, it is useful to determine the high water mark. The perimeter of the flooded area can be walked and mapped at high tide during both spring and neap tides. Other methods can also be used to determine the extent of flooding such as measuring the height of water on sticks inserted near the high tide line and coated with cork dust, poster paint, or craft glue. The flooding water will make a line on the stick corresponding to the high water mark. Much of this work can be performed by volunteers.

Key References

Boumans, R.M.J., D.M. Burdick and M. Dionne. *In review*. Modeling habitat change in salt marshes following tidal restoration. Restoration Ecology.

Mitsch, W. J., and J. G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold, New York.

Roman, C. T., R. W. Garvine and J. W. Portnoy. 1995. Hydrologic modeling as a predictive basis for ecological restoration of salt marshes. Environmental Management 19:559-566.

U.S.EPA. 1993. Volunteer estuary monitoring: a methods manual. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, Washington, D.C. EPA 842-B-93-004.

Water table salinity monitoring well, with refractometer for measuring salinity and modified meter stick to measure water level

Ecosystem Indicator: Soils and Sediments

Work Group Participants

Summary by: David Burdick-UNH Jackson Estuarine Lab., Kim Hughes-NB Dept of Environment, Hilary Neckles-USGS, Richard Orson-Orson Environmental Cons., Edward Reiner- US EPA, Henry Rines-Applied Science Associates, Inc., Jan Taylor-USF&WS, Larry Ward-UNH Jackson Estuarine Lab.

Rationale

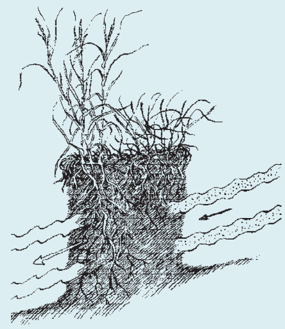
Soil salinity determines, to a large extent, the distribution and abundance of plant species in salt marshes. Many restoration projects are initiated with the goal of reestablishing plant communities characteristic of salt marshes, which also involves simultaneously reducing the abundance of fresh water plants, including invasive species like *Lythrum salicaria*, or *Phragmites australis*. Following restoration, plant distributions are expected to change in response to increased soil salinity. Measuring salinity several times during the early to middle growing season would provide the best indicator of changes in environmental conditions regulating plant growth, distribution, and abundance.

Core Variable

- **Pore Water Salinity:** parts dissolved salts per thousand (to the nearest 1 ppt); referenced against a Practical Salinity Scale

Sampling Methods

A minimum of five stations should be established for sampling soil salinity. Soil salinity could be sampled any number of ways (soil core, sipper, well), but wells may be the most efficient since there should be about six collection dates a year. Soil water should be collected from 5 to 20 cm depths (0 to 5 cm samples are not practical except with soil cores). Wells to determine soil salinity are constructed from 19mm diameter CPVC plastic pipe with 7 pairs of 4 mm holes at sediment depths between 5 and 20 cm. The base of the 35 cm pipe is sealed and the top is capped with two right angles in sequence. Salinity may be measured on site or at a laboratory using either a temperature-corrected optical refractometer (nearest 2 ppt) or a hydrometer and thermometer in a graduate cylinder (nearest 1 ppt). Sampling may be performed by volunteers once stations and methodology are established.



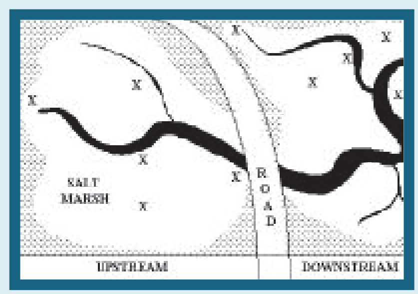
Robert Shetterly

Sampling design

Soil salinities should be obtained throughout the entire area to be restored and at an appropriate reference marsh. Sampling should be performed at low tide about six times a year between the beginning of the growing season (April or May) to mid-season (July or August) including both spring and neap tides. Sampling could be scheduled each year, but if annual assessments show positive results from the restoration, it could be omitted in some years (for example: pre-restoration, year 1, 2, 4, 5, 7 post-restoration).

A very simple layout of five stations per marsh unit (upstream and downstream of tidal restoration) should be established as a minimum for sampling soil salinity in areas restored by increasing tidal exchange. Along the axis of the main channel one station would be placed close to the restriction, one near the predicted head of tide (after restoration) and one equidistant between the two. These three stations would be located in high marsh approximately 3 to 4 meters from the tidal channel. Two more stations would be placed between the central station and the upland, in high marsh. In a simple circular or rectangular marsh, the stations would form a cross.

Example of a layout of site locations for soil and salinity samples



Skill Level

Once sample locations and methodologies for sampling and measurements are demonstrated, volunteers can collect the samples and measure soil salinity. Volunteers can also help organize this data for preparation of data reports.

Cost

Estimated costs for one sampling interval at a site no larger than 10 hectares (22 acres) include $200 for equipment, 1.5 days of professional work to build wells and establish stations, 4 days of volunteer or professional work to collect and reduce data, and 2 days of professional work to report data. Costs will be greater at complex sites requiring a larger number of stations.

Additional variables

Organic Matter

Both flooding and salinity control the decomposition rate of organic-rich sediments (i.e., peat) and rapid sediment rebuilding following restoration may be due to influx and deposition of inorganic sediments as well as growth of underground storage organs of plants (rhizomes). Thus determination of soil organic matter can reveal insights regarding pre-restoration impacts to the marsh (subsidence due to oxidation of organic matter in the sediments) and the process of recovery following restoration. Soil cores to 20 cm depths should be collected from the soil salinity stations and sectioned into 5 cm segments. Soil moisture (% of wet weight) and organic content (% of dry weight) are measured by weight loss after drying, then burning at 450° C, respectively. Soil organic matter should be determined once prior to restoration and as needed following restoration (e.g. years).

Sediment Accretion

Accretion of inorganic and organic material deposited onto the surface of marshes by flooding waters and vegetation is one of the important processes that allows marshes to build vertically, offsetting the rise in sea level. Accretion is most commonly measured using a marker on the horizon. A horizon marker is established by applying a known, identifiable material such as feldspar dust to the surface of the marsh. The amount of material that has accumulated above the marker can be measured from a sediment core taken at the same site at a later date. The sediment accreted can be reported in mm year $^{-1}$, or following drying and combustion, in g dry weight m^{-2} year $^{-1}$ of inorganic and organic components.

Sediment Elevation

Net balances in critical soil processes that allow salt marshes to persist over time may be assessed by measuring the surface elevation of the marsh. Loss in elevation indicates peat degradation, whereas gains may be due to accretion at the surface or peat development below the surface. Standard survey techniques are unable to measure short term changes in elevation (2 to 3 years), but are adequate for documenting long term change (10 years or greater). Short term changes in the sediment elevation of salt marshes around the world are being monitored using Sediment Elevation Tables (SET). Installation of the SETs is difficult and requires professionals. Usually only 2 to 4 stations are installed in a single marsh. In New England, more than 30 stations exist in several salt marshes from Rhode Island to Maine. Data are being collected to provide baseline information, assess projects to restore tidal flow, and assess impacts from dredging. These stations are located 10 meters from the high marsh edge of tidal channels or embayments and human traffic is kept to a minimum.

Redox Potential

The degree of chemical reduction/oxidation (redox) in the soil can provide information regarding paths (and relative rates) of organic matter decomposition in the peat soils of marshes. Redox potential is measured using commercially available or home-made half cell platinum probes calibrated prior to field deployment and equilibrated 30 minutes in the sediment. The potential is measured with a hand-held voltmeter connected to a calomel half cell. Raw data are corrected to obtain Eh values (the standard hydrogen electrode) by adding +242 mV to the raw readings. Redox potential should be measured at 1 cm and 15 cm depths at the same stations where soil salinity and organic matter are measured.

Sulfide Concentrations

Due to the great variability of redox potential, measurement of sulfide concentrations provides better information than Eh regarding oxygen status of the soils. Water extracted from soils can be fixed in a zinc-acetate solution and processed at a laboratory to yield sulfide concentrations using a spectrophotometer.

Soil salinitity tested using a refractometer

Key references

Boumans, R.M.J. and J.W. Day, Jr. 1993. High precision measurements of sediment elevation in shallow coastal areas using a sedimentation-erosion table. Estuaries 16:375-380.

Burdick, D.M., M. Dionne, R.M. Boumans and F.T. Short. 1997. Ecological responses to tidal restorations of two northern New England salt marshes. Wetlands Ecology and Management 4: 129-144.

Chambers, R.M. 1997. Porewater chemistry associated with *Phragmites* and *Spartina* in a Connecticut tidal marsh. Wetlands 17:360-367.

Portnoy, J.W. and A.E. Giblin. 1997. Effects of historic tidal restrictions on salt marsh sediment chemistry. Biogeochemistry 36:275-303.

Ecosystem Indicator: Vegetation

Work Group Participants

Summary by: Ted Diers, NH Coastal Program, and Charles Roman-USGS, Sarah Allen-Normandeau Assoc., Bruce Carlisle-MA CZM, Carolyn Currin-NOAA, Pam Morgan-UNH, Frank Richardson- NH DES., Peter Shelley-Conservation Law Foundation, Lee Swanson-NB DNR.

Rationale

The goal of vegetation monitoring is to track trends in plant abundance and species composition of the marsh community over time. A protocol for monitoring restoration projects must be capable of detecting changes in the vegetation of the restoring marsh and a reference marsh in the years following restoration actions, and of determining whether and how the vegetation of the restoring marsh differs from that of the reference system over that time period. In addition, frequently the purpose of a restoration project focuses on a specific plant species such as *Phragmites australis* or *Spartina alterniflora*. In these cases, more detailed information on individual species of concern may be warranted. The methods described below should be applied routinely to the marsh plant community in general, with additional data collected on species of concern as appropriate.

Core Variables

- **Abundance:** cover class per m^2, by species
- **Composition:** identity of species per m^2
- **Height of species of concern:** mean height of 3 tallest individuals of each species of concern per m^2
- **Stem density of species of concern:** # shoots per m^2, plots restricted to species of concern, by species

Sampling Methods

Plots

The general marsh community and species of concern are sampled using 1 m^2 quadrats. All sampling should be accomplished at the time of maximum standing biomass, in mid-summer (mid-July through August).

At each plot, take the following measures:

1) Identify all plant species (i.e.,species composition).

2) For each species, estimate percent cover by visual examination. Estimate percent bare ground as well.

   The estimate should be an integer number that can be categorized within standard Braun-Blanquet cover classes (<1%, 1-5%, 6-25%, 26-50%, 51-75%, >75%). Estimating cover by visual examination can be somewhat subjective; however, it has been demonstrated that these measures of cover are comparable to the more time intensive, quantitative measures of relative abundance, such as point intercept counts (Kent and Coker 1992).

3) Measure and then average the height of the tallest three individuals of each species of concern within each plot.

In addition, for plots restricted to species of concern (see Sampling Design, below), determine the stem density by species within a subsampled area of the plot.

Photo stations

Photographs taken from permanent stations can provide qualitative information on the changes in the plant community over time. Stations should be indicated on maps and with permanent field markers. The stations should include views of the restoration activity or structures. Two kinds of photo stations should be established – landscape or panoramic views and close-ups of plots. Landscape photos are taken at several compass bearings to cover a panorama of the entire marsh. For stands at the site of a tidal restriction, bearings showing the downstream marsh are desirable as well. Landscape photographs should include a person or an object for height scale. Close-ups are oblique views of a select number of the permanent vegetation plots. The corners of the plots should be identified with orange flagging and the photo taken from a height of about 1.2 m (4 ft). Photos should be taken at the time of vegetation sampling.

Salt marsh hay-
Spartina patens

Robert Shetterly

Sampling Design

Marsh Community

The marsh plant community should be sampled using permanent plots positioned along transects in a systematic sampling design, following Elzinga et al. (1998). Use of permanent plots (re-sampled at each sampling interval) allows the application of powerful statistical tests for detecting change. Systematic sampling allows relatively easy positioning and relocation of quadrats and insures a fairly uniform distribution of quadrats throughout the study area.

Volunteers using transect to monitor vegetation

The marsh study area, or areas, should be identified and mapped. This may include a marsh that is bisected by a causeway, with one marsh area under the influence of reduced tidal exchange and another area open to full tidal exchange. Within each marsh study area, transects will be established perpendicular to the main marsh tidal creek; transects begin at the creek bank and extend to the upland. So that transects are dispersed fairly uniformly across the marsh, transects are positioned randomly within contiguous marsh segments. Divide the marsh into equal-sized segments along the axis of the main tidal creek, and randomly locate transects within marsh segments. Quadrats are then systematically located along transects. For each transect, the location of the first quadrat is selected randomly within the low marsh zone, or within the first 3 meters if no zone is apparent. Subsequent quadrats are located at consistent distance intervals along the transect. Given that the transects are established in a random manner, and assuming that there is adequate spacing between quadrats (>10 m) to insure that the plant communities of nearby quadrats are not correlated with each other, each quadrat can serve as a single sample unit (similar to a simple random sampling design).

The map or aerial photographs should be used to lay out the marsh segments, transects within segments, and quadrats along transects to achieve an appropriate dispersion of sample plots. In the field, the exact starting location of transects and quadrats can be determined using a random numbers table and meter tape.

What should be the total number of 1 m^2 quadrats sampled within each marsh area? This question should be resolved before the transects and quadrats are established. The ideal way to determine the appropriate number of plots required would be to conduct a power analysis. Using this approach, if the variability associated with the measurement and the desired level of change detection (i.e., subtle vs. major changes in the marsh community) are known, then the number of replicates required can be determined. A power analysis specific to New England salt marsh vegetation studies has been completed by the USGS-Biological Resources Division and is under review. Recognizing that this analysis is not yet final, and does not necessarily apply to all Gulf of Maine salt marshes, preliminary findings suggest that twenty plots within each study area of up to 50 ha would be adequate to detect subtle changes over time. Moreover, after several years of data have accumulated from specific restoration and reference sites, the investigator will be able to determine the level of variability at the site and then adjust to an appropriate number of replicates.

Vegetation should be sampled before restoration, 1 and 2 years following restoration, and every 3-5 years thereafter. There are several data analysis techniques that can be applied to detect changes in the vegetation community over time. Ordination techniques, such as Detrended Correspondence Analysis, or an analysis of similarity, are just two of the techniques that can be used (see Kent and Coker 1992).

Species of Concern

There are two ways to monitor species of special concern, such as *Phragmites* or *Lythrum*. First, in the routine vegetation community sampling described above, the height of the 3 tallest plants species of concern should be measured in all quadrats in which it occurs. If species of concern are not adequately represented in the marsh community samples, then a minimum of 5 additional 1 m^2 plots should be permanently established within distinct stands. Data on all core variables are then collected from these plots as well during vegetation sampling.

Skill Level

Vegetation sampling can be done by trained volunteers. A professional should design the monitoring plan and assist with training.

Cost

Sampling equipment is inexpensive, including compasses, tape measures, PVC piping to construct quadrats, some permanent marker stakes, and some meter sticks. Total equipment cost is less than $500. More expensive is the camera equipment and film developing cost for the photostations. The most expensive aspect of the vegetation sampling may be the aerial photography analysis to locate species of concern and marsh water bodies. If the photography is not available, then the area may have to be flown. Two to three days of professional involvement are needed for designing the sampling regime and interpreting data. Aerial photo interpretation would require additional professional involvement.

Additional Variables

Additional measurements to determine vegetative response to restoration include aboveground biomass, stem density, and proportion of stems that are flowering.

Key References

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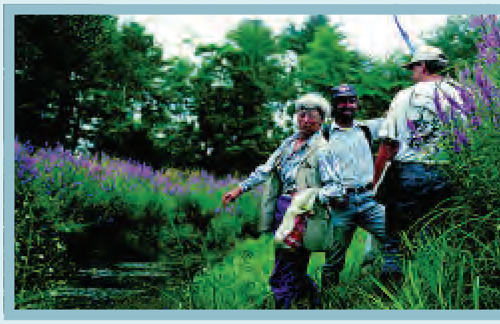
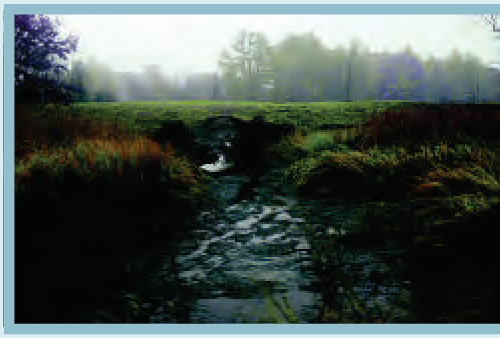
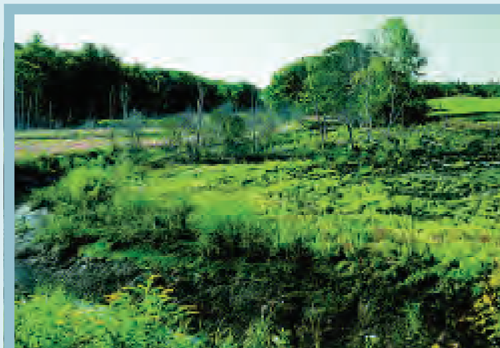






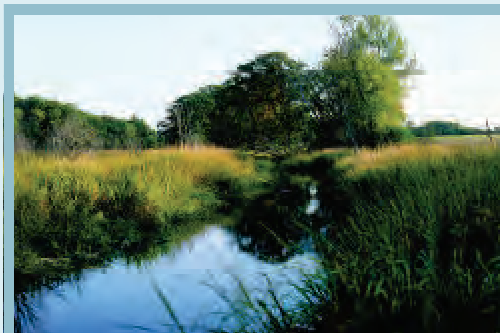


Photo series to the right shows restoration of tide-gated salt marsh on Mill Brook in Stratham, NH. Sequence from top to bottom: abundance of purple loosestrife prior to restoration; tide-gate replaced by culvert in October, 1993; saltwater flooding of fresh marsh, spring,1994; colonization by salt marsh plants, summer, 1994; low marsh and high marsh well established by October, 1999.

Ecosystem Indicator: Nekton

Work Group Participants

Summary by: Michele Dionne-WNERR, Robert Buchsbaum-MA Audubon, Sean Ballou-SWAMP, Inc., Alan Hanson-Waterfowl & Wetlands Ecology, Env. Can, Eric Holt-MA Audubon, Mike Morrison-SWAMP,Inc., Judy Penderson-MIT Sea Grant College Program, Kenneth Raposa-URI, Chris Rilling- CT DEP, Greg Shriver-SUNY College Env. Sci., Jan Smith-MA Bays Program, Geoff Wilson-Northeast Wetlands Restoration, Ray Whittemore-Ducks Unlimited

Rationale

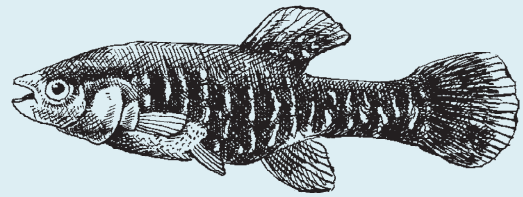
Fish are useful indicators of tidal marsh ecosystem functions. Their placement in the upper levels of the marsh food web, the wide age and size range of species occuring in marsh habitats, and the wide range of food and habitat resources utilized, are all characteristics that serve to integrate salt marsh ecosystem elements, processes and productivity. Fish and other nekton (e.g. macrocrustaceans) also serve as important ecological links with fisheries in nearshore and potentially offshore waters in the Gulf of Maine.

Core Variables

- **Identity:** genus and species of each animal sampled (number of fish and crustaceans by species)
- **Density:** # of animals per area of sample, by species
- **Length:** total animal length/width of individual fish to the nearest 0.5 mm, by species
- **Biomass:** wet weight of animals in sample, by species
- **Species Richness:** # of nekton species represented

Sampling Methods

Fish are highly mobile vertebrates that spend all or much of their time in the water column. In general their senses of sight, hearing, and touch are well developed. These attributes make them a challenging group when it comes to quantitative sampling, especially in vegetated salt marsh habitats.



Mummichog -*Fundulus heteroclitus*

After discussing numerous fish sampling techniques, the throw trap was selected for sampling in the open water of creeks and channels and the fyke net for use on the vegetated marsh surface.

Throw Trap

The trap is a 1 m^2 x 0.5 m high frame made of thin aluminum bar (2.5 cm width flat stock) with 3 mm mesh hardware cloth surrounding the four sides, open at the top and bottom. A 0.5 m wide apron of flexible 3 mm bar mesh netting can be attached around the top of the box, with a float line fixed to the upper edge. This allows sampling in water up to 1 m deep. To deploy the trap, the sampling station is approached slowly from the marsh surface, and the trap is tossed 3-4 m through the air into the water. The bottom of the trap is immediately pushed into the substrate to prevent animal escapement. All animals are removed with a 1 m x 0.5 m dip net (1 mm mesh) that fits snugly into the trap, dipping from all four sides of the trap. After three consecutive net passes devoid of nekton, the trap is considered empty. Animals are placed in a bucket of water for identification and measurement, and then released. Water depth is measured (to the nearest cm) to determine the volume of water sampled. This sampling method works best for smaller fish. Larger fish (> 15 cm) are unlikely to be captured.

Fyke Net

This is a nylon mesh net consisting of a series of four compartments held open by square frames or fykes, with 15 m wings attached to the first and largest (1.2 m X 1.2 m frame) fyke opening. After the first compartment, each compartment contains an internal net funnel connected to the previous fyke frame, with the smaller end of the funnel emptying into the middle of the compartment, 3 inches from the bottom. This design channels fish into the net's cod end with little chance of escape. The wings and first three compartments are made of 1.27 cm bar mesh, with the final cod end made of 0.63 cm bar mesh. To measure fish use of the marsh surface, the net is set at low tide at the lower edge of the marsh with wings at 45°, fykes upright, and cod end and wings anchored. The wing top line is buoyed and set so that nekton can enter the marsh area by the side. At high tide, the area of flooded marsh to be fished by the net is staked to calculate the area fished.

The catch is placed into buckets of water once the tide has receded below the level of the first funnel. To measure fish use of creeks, the net is set at slack high tide across the creek mouth, to fish the outgoing tide, and the volume of water sampled by the net is estimated from creek dimensions. This sampling method works equally well for both small and large fish.

For both the throw trap and fyke net, decapod crustaceans will be captured as well as fish. When captured, identity, density, size and biomass of crabs and shrimp should be included in the results.

Data Collection

Species Identity and Richness

Each individual fish and crustacean collected is identified to genus and species. A list of species likely to occur in Gulf of Maine salt marsh estuaries is included in Appendix E.

Density

In order to quantitatively compare fish use of different marsh sites, fish abundance is adjusted to reflect the volume of water sampled with the throw trap, and the area of vegetated marsh fished with the fyke net. Fish numbers per sample are divided by the appropriate volume (m^3) or area (m^2).

Length

Individual fish length is measured from the tip of the snout to the tip of the caudal fin (total length), recorded to the nearest 0.5 mm. When possible, 30 individuals of each fish species should be measured, selected haphazardly from the sample bucket with an aquarium net. For shrimp, length is measured from the tip of the rostrum to the tip of the telson. For crabs, maximum carapace width is measured.

Biomass

The relationship between length and biomass can vary considerably depending on species identity and individual condition. Biomass provides an estimate of standing stock, and can be used to calculate fish condition (length/biomass), providing a more complete interpretation of fish size data. Total wet weight of all individuals for each species is recorded to the nearest gram with an electronic field balance. The number of individuals for each species is also recorded.

Sampling design

The occurrence of smaller fishes at mid-tide in marsh creeks is estimated with randomly placed throw trap samples, 10 samples each in restoration and reference sites, on each of two dates in August during the spring tide cycle. Larger fishes using the creeks are sampled with fyke nets set across small creeks (up to 15 m wide) at slack high tide on the same two dates in August, as well as on two spring tide dates during the spring migrations of diadromous fish. Fish using the marsh surface are sampled with fyke nets on one date in August during the spring tide cycle. A pair of nets should be used so restoration and reference marshes can be sampled at the same time. Until results from long-term monitoring define the appropriate time frame, we suggest a minimum of one year pre-restoration data, and data from years 1,3 and 5 post-restoration.

Fyke Net

Skill Level

Fish are relatively easy to identify and handle, and the data described above can be collected by volunteers after training. Throw traps can be used by a single person, but fyke nets are bulky and best transported and deployed by a team of two or three.

Cost

Throw traps are inexpensive to construct (<$50) and allow rapid collection of a large number of samples. Estimated personnel costs are less than $500 per year. Fyke nets can be purchased for about $500 each. Since they are passive sampling devices, most of the time associated with their use is in the set up and take down of the nets. Other sampling (such as throw trap sampling) can be conducted while the fyke nets are fishing. Estimated cost for a team of one technician/student and two volunteers to collect 8 channel samples and two marsh surface samples annually is $600.

Additional Variables[1]

Fish Growth

Further understanding of fish growth trajectories over time can be obtained by calculating fish condition (length/biomass) within size classes for selected species. This requires that fish be graded by size class (a surrogate for age class) and each size class weighed separately.

Fish Diet

An assessment of fish gut contents would indicate whether diets of fish captured in restored marsh sites differed from that of fish in the reference marshes. Differences in diet would indicate differences in the availability of food resources. Similarities in diet would suggest similarity in food resources between restoration and reference marshes. However, if many reference and restoration sites are close together, fish captured in one site may well have obtained their food from the other site. The source of the food eaten by the fish would need to be determined before gut contents could be used to infer similarity between restoration and reference sites in regards food availability.

Larval Mosquitos

Although the distribution of most tidal marsh invertebrates is too patchy in time and space to obtain accurate density estimates given the sampling effort envisioned for these protocols, larval mosquitos can be used as indicators of some aspects of tidal marsh hydrology. Information on mosquito densities is particularly warranted for restoration projects that include mosquito control as a primary goal.

Salt marsh mosquito species reproduce in shallow standing water on the high marsh surface, with the larvae of different species occurring in fresh, brackish and higher salinity water. The larvae can only persist in pannes that do not contain fish, due to the lack of spring tidal flooding, or due to the loss of standing water through drainage and evaporation. Salt marshes that have been invaded by cattail (*Typha sp.*) or *Phragmites* often harbor freshwater mosquito species, while *Aedes cantator* is typical of brackish water and *Aedes sollicitans* is typical of higher salinities. Larval mosquitos are sampled with a white cup on a long handle known as a “dipper” which is used to scoop up water from the marsh surface. Sampling should occur weekly from April through August along transects that intersect standing water on the marsh. The number of dips, the number of positive dips, and the number and species of mosquito larvae in each dip are recorded. The distribution and abundance of mosquito species relative to the distribution and abundance of standing water can be mapped and used to indicate patterns of tidal flooding on the marsh surface.

[1] We include here one variable based on sampling of salt marsh mosquitos.

Additional Methods

To obtain a more complete picture of fish utilization of restored and reference sites, lift nets can be used to sample the marsh surface. These nets enclose a relatively large area of marsh (6 m x 6 m), and are folded into a trench on the marsh surface, beneath rigid vertical supports. At high tide, ropes are used to raise the netting vertically on the supports to trap fish. As the tide recedes, fish are captured in a cod-end set into a pit dug in the marsh surface. Cost estimate for one lift net is $300. Once constructed, they are relatively easy to use and maintain, so that personnel costs are low (1-2 person-hours per sample).

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Ecosystem Indicator: Birds

Robert Shetterly

Work group Participants

Summary by: Robert Buchsbaum-MA Audubon, Sean Ballou-SWAMP, Inc., Michele Dionne-WNERR, Pascal Giasson-NB DNRE, Alan Hanson-Waterfowl & Wetlands Ecology, Env. Can, Eric Holt-MA Audubon, Mike Morrison-SWAMP, Inc., Judith Penderson-MIT Sea Grant College ProgramKenneth Raposa-URI-USGS, Chris Rilling- CT DEP, Greg Shriver-SUNY College/Env. Sci., Jan Smith-MA Bays Program, Geoff Wilson-Northeast Wetlands Restoration, Ray Whittemore-Ducks Unlimited

Rationale

Birds are highly visible organisms that are popular with the general public, therefore they are an obvious group to include in a monitoring program. In cases where increasing the bird use of salt marsh habitat is a major rationale of a restoration project, monitoring birds is essential for measuring success. In addition, there are a number of nonprofessional birders who are excellent at identifying birds and are likely to be competent and enthusiastic volunteers.

On the other hand, a difficulty in monitoring birds on restored marshes relates to the question of scale. Most birds, particularly those charismatic species that are usually of most interest (e.g. herons, shorebirds, waterfowl, raptors), have home ranges much larger than the size of typical salt marsh restoration projects in the Gulf of Maine. Thus it is difficult to get a large enough number of observations of individuals to draw conclusions about habitat use in a restored marsh compared with that of a suitable control. In addition, wetlands birds in particular have specific habitat preferences (such as a large percentage of open water or pannes) that may or may not be present in a particular restoration site.

Abundance by species and number of species (richness) provide information on overall value of the habitat to birds in a simple, direct way. Behavioral observations provide an even better indicator of the value of the habitat to birds, but the information is more difficult and time-consuming to collect. More detailed studies of individual species, such as salt marsh sharp-tailed sparrows and other small passerines, may be important depending on the particular goals of the restoration, but are beyond the scope of routine monitoring of individual restoration sites.

Core Variables

- **Abundance:** # of birds per ha, by species
- **Species richness:** # of species
- **Feeding and breeding behavior:** type of feeding behaviors per 20 minute observation interval by species; type of breeding behaviors per 20 minute observation interval, by species

Sampling Method

Observations of birds will be made from vantage points that provide an uninterrupted view of at least a portion of the salt marsh. The exact location and number of vantage points will be site specific. An observer will remain at each vantage point for 20 minutes, recording the number of birds of each species within view in the restored and control marsh. Flying birds that are foraging over the marsh, such as swallows, are to be included in the survey, but those simply in transit are not. The data sheet will include space to record behavioral observations, such as whether the birds are feeding, involved in nesting, loafing, roosting, etc. Sampling will be carried out only in the morning. Information will be collected on stage of tide, time of day, and weather during each observation period. General information on the site will be collected, including dominant plant species and estimated cover of each, number of pannes, area of pannes, and area of unvegetated surface.

Pannes on the high marsh

Sampling Design

Conduct sampling two times during the breeding season (May and June), once per week during migration of waterfowl (late March through the end of April and again in October and November) and shorebirds (late July through early September). Such sampling would also incorporate waders. Sampling should encompass both high and low tides. Sampling should begin at least one full season before the restoration is initiated.

Skill Level

Part of the attraction of monitoring birds is that there is a cadre of skilled amateur birders who could participate in a project as volunteers. This would hopefully enable the relatively frequent sampling suggested above. A professional is likely to be needed for data analysis, particularly when comparing marshes that differ in area.

Cost

Two weeks of direct professional involvement is required to set up the sampling design, train volunteers, and analyze results. Equipment costs are negligible, since the assumption is that the volunteers would provide their own optical equipment.

Additional Variables

Small passerines and other cryptic birds of the salt marsh

Small passerines, rails, and bitterns will likely be under-represented in observations taken from a high point above the marsh. They can be measured by setting up 50-m radius counting circles in the salt marsh. An observer enters the circle and records all birds seen or heard within a 20 minute time period. If possible, the observer will use a tape recorder to broadcast songs of several species of most interest.

Birds in the Buffer

Counting circles, as described above, can be set up in the buffer habitat adjacent to the salt marsh. This will enable evaluation of the importance of the buffer zone to birds of both the salt marsh and the upland.

Waterfowl in winter

The marsh will be sampled throughout the winter as long as it is ice free. This will provide information about the use of the restored marsh by wintering waterfowl.

Key References

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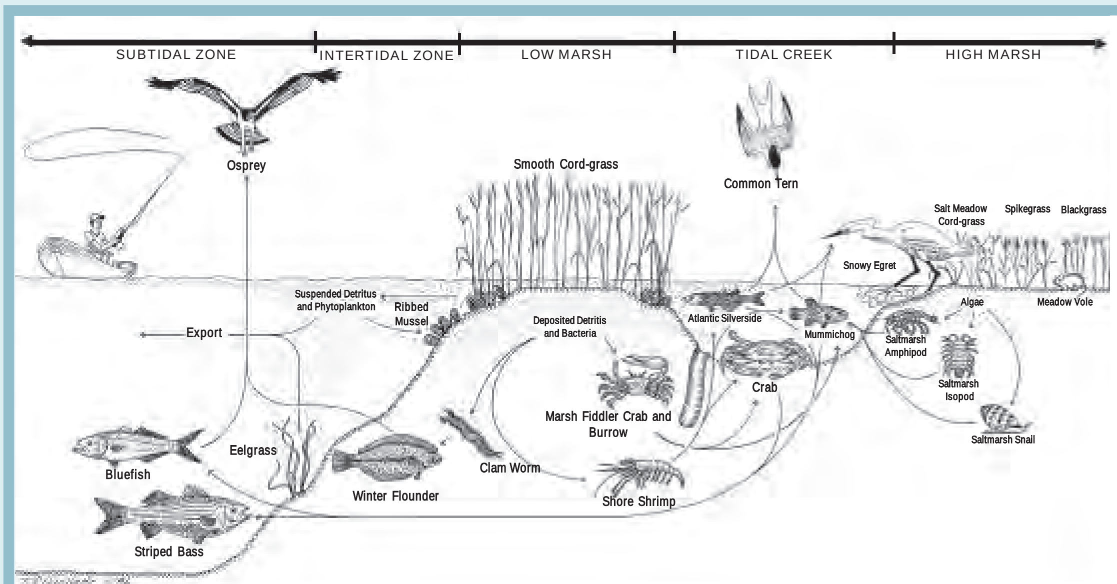
Habitats, inhabitants, and food web linkages in a typical New England estuarine ecosystem. This figure was originally designed to illustrate a southern New England salt marsh. In the Gulf of Maine, the blue crab is replaced by the non-native green crab.



Thomas R. Ouellette

Workshop Summary:
Tools for Region-wide Site Selectionand Monitoring

Our goal at the workshop was to develop standardized and realistic methods for 1) identifying Gulf of Maine tidal marshes suitable as reference or restoration sites, and 2) assessing the response of Gulf of Maine salt marsh ecosystems to restoration efforts. The models and protocols presented in this report were the outcome of discussion fueled by the combined experience of nearly fifty tidal marsh scientists and resource managers. This group worked diligently to achieve consensus regarding the specific parameters, core variables and methods that would form an acceptable minimum set of data and information with which to achieve the workshop goals. The details of these protocols will undoubtedly be modified as they are put into practice and reviewed, in order to fine-tune their ability to quantify regional gains and losses in the functions and values of tidal marshes. Although the workshop focused specifically on the Gulf of Maine coastline, there is no obvious reason to restrict the use of the inventory and monitoring protocols to this region.

The group charged with developing the template for the restoration and reference site inventory (Inventory workgroup) began with several local inventories and a long list of candidate parameters. They worked their way through the list to select 14 identifiers and descriptors to create the minimum necessary information base. The template contains six parameters that identify the name, location and ownership of the site; three that describe disturbances and impacts to the system; four parameters that outline the size, type, cost and nature of potential or actual marsh restoration; and a final entry to identify points of contact.

The remaining work groups (Hydrology and Soils, Vegetation and Mapping, and Animals) focused on identifying those ecosystem indicators sufficient for monitoring the success of tidal marsh restoration projects. At the outset, we agreed the general goal of restoration is to produce a self-sustaining ecosystem that closely resembles the natural system in structure, function and value. The Hydrology and Soils group identified the elements of hydroperiod, consisting of tidal signal and marsh cross-sectional elevations, as core hydrologic variables. For soils and sediments they identified pore water salinity as the key indicator. The Vegetation group discussed the creation of baseline habitat maps and vegetation monitoring. The baseline map they propose includes cover types, adjacent land use, impacts and sampling locations. Core variables for vegetation monitoring are the % cover of plants by species, and plant height and density for species of special concern. The Animal group identified core variables for both birds and nekton. For nekton (captured with traps), these variables are species densities and wet weights, species richness, and individual fish length. For birds (observed at a distance), the core variables are abundance by species, species richness, and feeding and breeding behavior.

The template for the restoration and reference site inventory can be used to develop a regional database from existing maps and inventories. This database will be extremely useful as salt marsh restoration continues to become a more common element of Gulf of Maine coastal resource management. The database will also serve to identify information gaps on a regional scale. The design of the restoration success monitoring program is based on the comparison of indicator variables among restoration and reference sites both before (when possible) and during/after restoration. Some marsh functions and values may recover more quickly than others, and the rate of change for any given variable may not be uniform. Once the proposed monitoring protocols are implemented across a representative range of marsh types and locations throughout the Gulf of Maine, it will be possible to determine the appropriate frequency and duration of monitoring (i.e. number of years sampled, and interval between samples). It may also be possible with sufficient data to develop a range of reference values characterizing natural tidal wetland systems across the region.

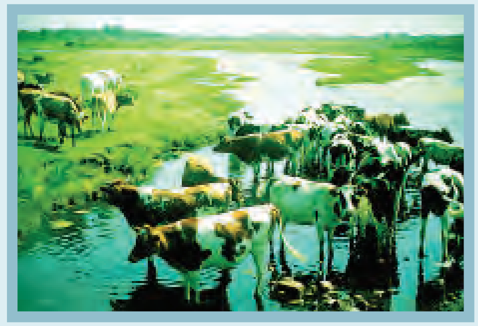
Next Steps

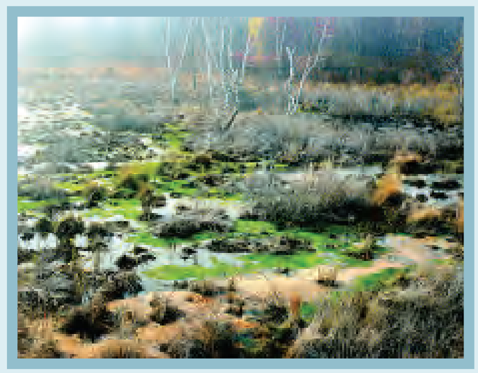
The workshop products presented here provide the foundation for developing a Gulf of Maine inventory of salt marsh restoration opportunities and a monitoring network of restored and reference salt marshes. Implementation of regional inventory and monitoring programs is expected to occur through partnerships between estuarine professionals and volunteer members of community based organizations. Broad participation by all individuals working in Gulf of Maine tidal marshes is invited.

The standard inventory model will be used to populate a regional database of potential tidal marsh restoration sites throughout the Gulf of Maine. Federal, state, and provincial agencies charged with tidal marsh protection and restoration have agreed to use the regional inventory model for describing and cataloging restoration opportunities within their jurisdictions, and community organizations are also urged to use this format for local projects. Site-specific inventory data from all sources can then be submitted to a regional database, which will be maintained by the U.S. Fish and Wildlife Service Gulf of Maine Program. Regional inventory coordinator contact information is included in Appendix D. The resulting comprehensive inventory of restorable sites will provide a basis for prioritizing among potential restoration sites and identifying those most appropriate for restoration projects. This inventory will offer consistent baseline information for gauging overall restoration progress in the region.

Organizations are also urged to use the standard protocols presented here for monitoring tidal marsh restoration projects throughout the Gulf of Maine. Additional funding is being sought to apply the protocol to 30 pairs of restored and reference marshes throughout the region. Professionals will guide data collection efforts, compile data from the site network, and synthesize resulting information. On site data collection will involve members of community based organizations and be facilitated by volunteer coordinators with access to state and provincial repositories of scientific equipment. Ultimately, comparisons of standard monitoring variables between a large number of restored and reference sites can be used to identify reliable indicators of restored marsh functions and to suggest regionally applicable success criteria for restoration projects. Such information will be valuable for evaluating the effectiveness of tidal marsh restoration in the Gulf of Maine to date and for guiding future restoration efforts.

Inquiries regarding these salt marsh monitoring protocols can be directed to the contacts denoted with an "*" in Appendix B.





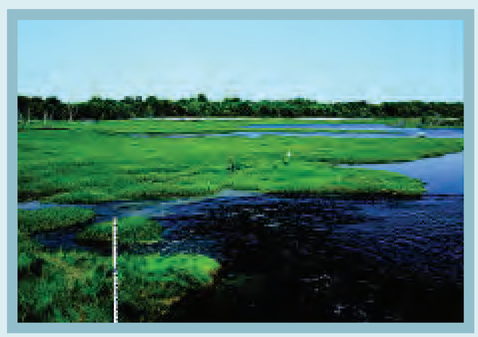


Photo series to the right shows restoration of impounded salt marsh on Webhannet River in Wells, Maine. Sequence from top to bottom: Cows in drained marsh, 1950's; colonization by Spartina alterniflora (short form) and Salicornia europea in 1991, 3 years after partial restoration of tidal flow; close up showing salt-killed plants and filamentous green algae in 1991; S. alterniflora short form covers much of the area in 1994; S. alterniflora increases in density and Spartina patens becoming more abundant by 1999.

APPENDIX A: Workshop Agenda

WORKSHOP ON RESTORATION OF COASTAL WETLAND ECOSYSTEMS IN THE GULF OF MAINE

June 2-3, 1999
Wells National Estuarine Research Reserve
Sponsored by the Global Programme of Action Coalition for the Gulf of Maine
AGENDA

Wednesday, June 2

8:30 COFFEE

9:00 WELCOME TO WORKSHOP
Hilary Neckles, USGS Patuxent Wildlife Research Center - Augusta, ME

9:05 WELCOME TO WELLS RESERVE
Kent Kirkpatrick, Director, Wells National Estuarine Research Reserve

9:15 INTRODUCTION TO GPAC
Katie Ries, Deputy Director, International Programs Office, National Ocean Service, NOAA

9:30 WORKSHOP PURPOSE: BACKGROUND, GOALS, AND OBJECTIVES
Michele Dionne, Research Director**,** Wells National Estuarine Research Reserve

10:15 BREAK

10:30 WORKGROUP BREAKOUT SESSIONS

1. Inventory Development
2. Monitoring protocol development: Plants
3. Monitoring protocol development: Animals
4. Monitoring protocol development: Physical components

12:00 LUNCH

1:00 WORKGROUP BREAKOUT SESSIONS (CONTINUED)

3:00 BREAK

3:30 WORKGROUP REPORTS AND PLENARY DISCUSSION

5:30 SOCIAL HOUR AND FIELD TOUR

7:00 BANQUET

WELCOME**: Kathryn S.B. Davis**, President, Laudholm Trust

INTRODUCTION: **Kent Kirkpatrick,** Director, Wells National Estuarine Research Reserve

GUEST SPEAKER: **Jeffrey R. Benoit**, Director, Office of Ocean and Coastal Resource Mgmt., NOAA

Thursday, June 3

8:00 COFFEE

8:30 PLENARY SESSION: REVIEW AND FOCUS
Kim Hughes, NB Department of the Environment, New Brunswick, Canada

9:00 WORKGROUP BREAKOUT SESSIONS (CONTINUED)

11:00 PLENARY SESSION: SYNTHESIS
Michele Dionne, Research Director, Wells National Estuarine Research Reserve

12:00 WORKSHOP ENDS

1:30 NOAA – MEETING FOR THE REGIONAL HABITAT RESTORATION PROGRAM
John Catena, National Marine fisheries Service, Gloucester, MA

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**** Denotes contacts to whom you may forward inquiries regarding monitoring protocol.***

APPENDIX C: Existing Inventory Models and Monitoring Protocols

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APPENDIX D: Regional Inventory Coordinators

The following individuals will coordinate the regional inventory of potential tidal marsh restoration opportunities in specific Gulf of Maine jurisdictions. Please contact a local coordinator to contribute tidal marsh inventory data or for more information. Inventory coordinators will compile data within their jurisdictions and submit to the regional database.

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APPENDIX D: Regional Tidal Marsh Inventory Data Sheet

Site ID: __ __ __ __ __
(leave blank)

Date: ___/___/___
(fill in)

Regional Tidal Marsh Inventory Data Sheet

Please fill out the form as completely as possible. Your responses will help populate a searchable database, located at http://gulfofmaine.fws.gov, of potential and existing tidal marsh restoration projects in the Gulf of Maine watershed. Lines for additional notes are optional but will help clarify your responses, especially when "other" is chosen. If your project can be broken down into phases, please submit one form per phase. Thank you for your participation.

PROJECT NAME *(subjective; fill in one letter/punctuation per box including blank boxes for space; e.g. Conomo Point-Phase1)*

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

CITY OR TOWN (e.g. Manchester-By-The-Sea)

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

STATE OR PROVINCE *(circle one):*
MA ME NH NB NS

AREA IMPROVED: __________ *m*^{2} (practicable area of enhancement/restoration not just the area worked on e.g. a dam removal area would be large, but the area restored could be small)

WATER BODY (closest waterbody identified from a 1:24,000, 7.5 minute quadrangle map produced by the US geological Survey or a 1:50,000 map produced by Energy, Mines, and Resources, Canada; e.g. Saratoga Creek)

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

COORDINATES (of a point near the center of the restoration site; e.g. 40°E 18' 30" N, 70°E 34' 45" W)

LATITUDE ___ degrees ______minutes ______ seconds _____

LONGITUDE ____ degrees ______minutes ______ seconds _____

OWNER(S) check all that apply
and list owner acronym or abbreviation if known

❑private ______________________________
❑non-profit organization __________________
❑public ________________________________

ESTIMATED COST (circle one) ***<$10K*** ***$10K-100K*** ***>$100K***

IS THE PROJECT FUNDED? (circle one) ***YES*** ***NO*** ***PARTIALLY***

Revised 4/10/2000 Regional Tidal Marsh Inventory Page 1 of 2

Cut along dotted line to remove Tidal Marsh Inventory Data Sheet for copies, completion and submission.

HISTORIC CONDITION (pre-impact National Wetlands Inventory Classification (US) or Canadian Wetlands Atlas Classification (Can) or specific species (scientific); e.g. E2EM/S. patens)

note:

NATURE OF ALTERATION (check all that apply)

❑ *tidal restriction* ❑ *bulkhead* ❑ *stormwater* ❑ *ditch* ❑ *fill* ❑ *salt hay*

❑ *other*

note:

IMPACTS (consequence of alteration, check all that apply)

❑ *drained marsh* ❑ *impounded* ❑ *flooded* ❑ *invasive vegetation*

❑ *other*

note:

RESTORATION ACTION *(check all that apply)*

❑ *stormwater treatment* ❑ *culvert enlargement* ❑ *ditch plugging* ❑ *fill removal*

❑ *other*

note:

ACTIONS (check all that have been completed including the current status)

❑ *none* ❑ *pre-monitoring* ❑ *permitted* ❑ *implementation* ❑ *post-monitoring*

❑ *other*

note:

FURTHER INFORMATION (up to 2 contacts)

Name:	***Name:***
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Address:	***Address:***
City:	***City:***
State/Province:	***State/Province:***
Zip Code:	***Zip Code:***
Phone:	***Phone:***
E-mail:	***E-mail:***

RETURN TO: (Regional Inventory Coordinator contact information goes here)

APPENDIX E: Gulf of Maine Marsh-Estuarine Fish Species

Fish Species Known to Occur in Salt Marsh Estuarine Ecosystems in the Gulf of Maine

- *Alosa aestivalis* (blueback herring)
- *Alosa mediocris* (hickory shad)
- *Alosa pseudoharengus* (alewife)
- *Alosa sapidissima* (American shad)
- *Brevoortia tyrannus* (Atlantic menhaden)
- *Clupea harengus* (Atlantic herring)
- *Ammodytes americanus* (American sand lance)
- *Anguilla rostrata* (American eel)
- *Apeltes quadracus* (fourspine stickleback)
- *Gasterosteus aculeatus* (threespine stickleback)
- *Gasterosteus wheatlandi* (blackspotted stickleback)
- *Pungitius pungitius* (ninespine stickleback)
- *Cyclopterus lumpus* (lumpfish)
- *Liparis atlanticus* (seasnail)
- *Decapterus macarellus* (mackerel scad)
- *Fundulus heteroclitus* (mummichog)
- *Fundulus majalis* (striped killifish)
- *Gadus morhua* (Atlantic cod)
- *Microgadus tomcod* (Atlantic tomcod)
- *Pollachius virens* (pollock)
- *Urophycis chuss* (red hake)
- *Urophycis tenuis* (white hake)
- *Pholis gunnellus* (rock gunnel)
- *Menidia beryllina* (inland silverside)
- *Menidia menidia* (Atlantic silverside)
- *Menidia peninsulae* (tidewater silverside)
- *Morone americana* (white perch)
- *Morone saxatilis* (striped bass)
- *Mugil cephalus* (striped mullet)
- *Hemitriperus americanus* (sea raven)
- *Myoxocephalus aeneus* (grubby)
- *Myoxocephalus oxtodecimspinosus* (longhorn sculpin)
- *Myoxocephalus scorpius* (shorthorn sculpin)
- *Cryptacanthodes maculatus* (wrymouth)
- *Osmerus mordax* (rainbow smelt)
- *Peprilus tricanthus* (butterfish)
- *Petromyzon marinus* (sea lamprey)
- *Pleuronectes ferrugineus* (yellowtail flounder)
- *Pseudopleuronectes americanus* (winter flounder)
- *Scopthalmus aquosus* (windowpane flounder)
- *Pomatomus saltatrix* (bluefish)
- *Salmo salar* (Atlantic salmon)
- *Salmo trutta* (brown trout)
- *Salvelinus fontinalis* (brook trout)
- *Scomber scombrus* (Atlantic mackerel)
- *Sphyraena borealis* (northern sennet)
- *Syngnathus fuscus* (northern pipefish)
- *Tautogolabrus adspersus* (cunner)

Key References

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Map courtesy of R.Signell and E. Roworth
U.S. Geological Survey

Tidal Marsh Restoration and Enhancement in the Gulf of Maine

Restoration projects in salt marsh ecosystems in the Gulf of Maine. The majority of projects are characterized by tidal flow restoration in tidally restricted marshes. Numbers within parentheses indicate multiple projects at a given site. Asterisks indicate the number of projects characterized by panne construction or ditching plugging (to create or replace open water habitat on the high marsh), or perimeter ditches (occasionally used to control invasive plants). For example, in Ipswich, MA, of the 6 projects, 5 were panne/ditch projects, and 1 was a tidal restoration.

Appendix C – Channel Geomorphology SOPs

Stream Barrier Removal Monitoring Guide (Collins *et al* 2007) available at:
http://www.habitat.noaa.gov/pdf/Stream-Barrier-Removal-Monitoring-Guide-12-19-07.pdf

The Reference Reach Spreadsheet (Mecklenburg 2006) is available at:
http://www.agri.ohio.gov/divs/SWC/docs/Reference_Reach_Survey_4_3_L.xlsm

Stadia rod specifications: Crain SVR-25-Tenths, Model #98010

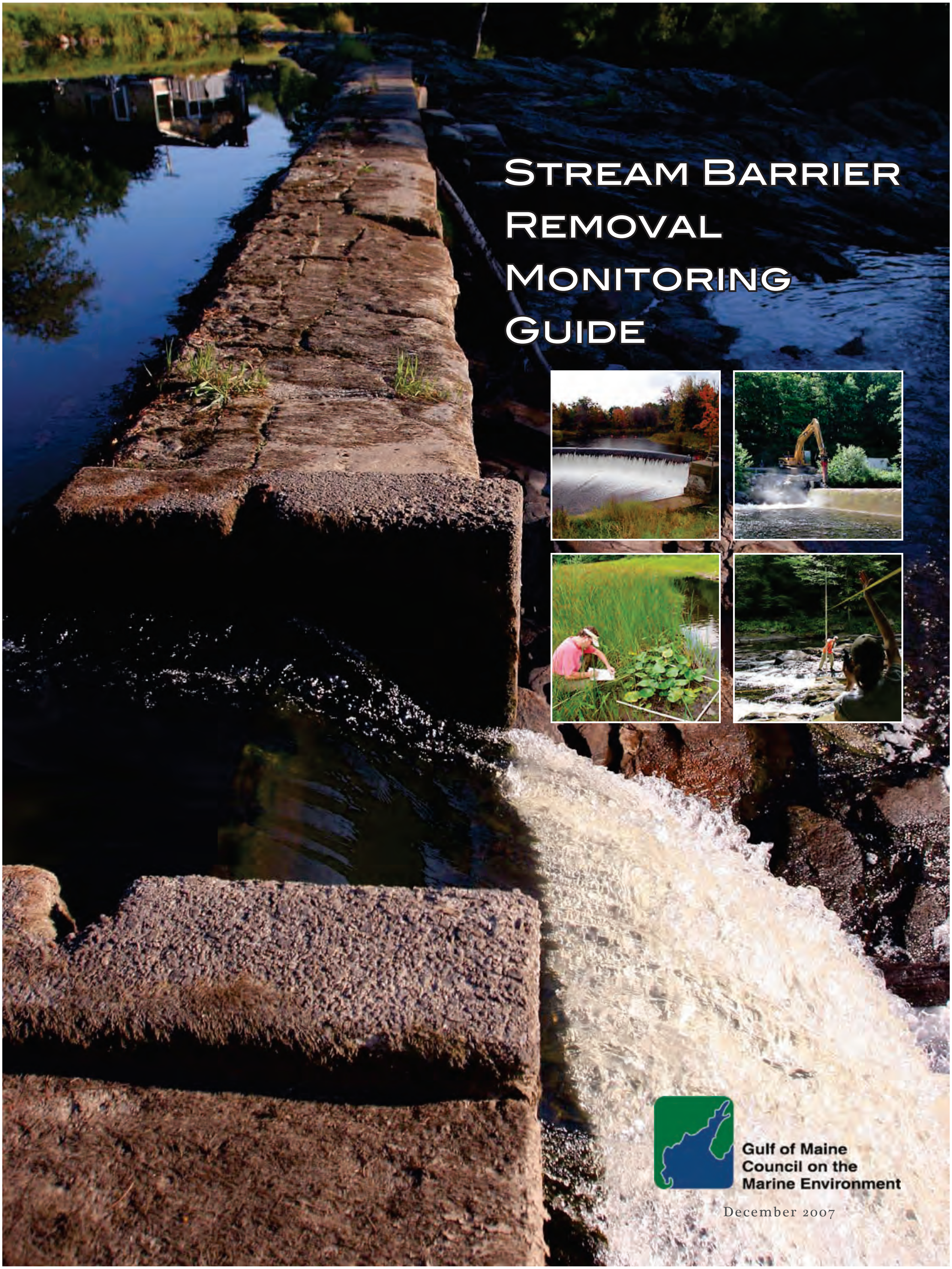
- 25 feet long, fully extended
- Measurements to the hundredth of a foot
- Six extendable sections

Automatic level specifications: Topcon AT-B3 Automatic Level

- 28x magnification
- Accuracy 1 km
- Double level run: +/- 1.5 mm
- Coarse sighting: Peep sight
- Weight: 3.75 lbs.
- Other Specifications: http://www.forestry-suppliers.com/Documents/1206_msds.pdf

Tape reel specifications: Keson English/Metric Open Reel Fiberglass Tape

- Graduated both sides meter/cm/2 mm; feet/tenths/hundredths other side



Stream Barrier Removal Monitoring Guide

Gulf of Maine Council on the Marine Environment

December 2007

Stream Barrier Removal Monitoring Guide

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The Gulf of Maine Council's mission:
"To maintain and enhance environmental quality in the Gulf of Maine and to allow for sustainable resource use by existing and future generations."

Gulf of Maine Council on the Marine Environment

December 2007

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Cover photo: Dam on the Royal River in Yarmouth, Maine. *© Peter H. Taylor / Waterview Consulting*
Cover inset photos (clockwise from top left):
Dam removal in progress. *NOAA*
A low-head dam in the Gulf of Maine watershed. *NOAA*
Collecting data along a monumented cross-section. *Karla Garcia / NOAA Restoration Center*
Sampling the riparian plant community. *James Turek / NOAA*

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Stream Barrier Removal Monitoring Workshop Participants

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A stream flowing from a culvert under a road.

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Dam and fish ladder.

Karla Garcia / NOAA Restoration Center

Low-head dam spillway on a stream in the Gulf of Maine watershed.

I. ABSTRACT

Across the Gulf of Maine watershed, agencies, non-governmental organizations, and private parties are removing dams and replacing culverts to restore stream processes and fish passage. Significant resources are invested in these stream barrier removal projects, but monitoring the outcomes of the projects usually has not been a priority. The lack of standardized monitoring information for stream barrier removal projects in the Gulf of Maine watershed mirrors a lack of river restoration monitoring nationwide and limits both the ability to document project success and learn from past experiences. The Gulf of Maine Council on the Marine Environment (GOMC) River Restoration Monitoring Steering Committee (Steering Committee) is addressing the need for consistent stream barrier removal monitoring. It has developed a framework of monitoring parameters that can be used for stream barrier removal projects throughout the Gulf of Maine watershed. The watershed covers approximately 70,000 square miles encompassing all of the state of Maine and portions of New Hampshire, Massachusetts, Nova Scotia, New Brunswick, and Quebec.

In June 2006, the Steering Committee convened a Stream Barrier Removal Monitoring Workshop to gather input on stream barrier removal monitoring from more than 70 natural resource scientists, resource managers, and watershed restoration practitioners. Structured breakout and plenary sessions generated priority lists of monitoring parameters specific to stream barrier removal in the Gulf of Maine watershed. From the prioritized lists, the Steering Committee selected eight parameters that, when analyzed collectively, are expected to provide valuable data that will characterize adequately the physical, chemical, and biological response of a given stream to a barrier removal project. These eight parameters, referred to in this document as *critical monitoring parameters*, include monumented cross-sections; longitudinal stream profile; stream bed sediment grain size distribution; photo stations; water quality; riparian plant community structure; macroinvertebrates; and fish passage assessment.

This Stream Barrier Removal Monitoring Guide (Monitoring Guide) presents detailed methods for each of the critical monitoring parameters except for macroinvertebrate and fish passage assessment. Because of the considerable variability associated with assessing these biological parameters, only general guidance is given here. The Monitoring Guide also presents important additional monitoring parameters that practitioners may choose to use on a case-by-case basis.

Mill building and river below a dam.
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II. INTRODUCTION

A. CONTEXT

Aging dams and improperly sized culverts are significant natural resource management issues in the Gulf of Maine watershed. Dams and culverts may create impassable barriers for migrating fish, degrade water quality, and negatively alter ecosystem conditions. Many of the thousands of stream barriers in the Gulf of Maine watershed are nearing the end of their design life, and some are being considered for removal or replacement. The socioeconomic costs and ecological impacts posed by aging dams and undersized and impassable culverts have led private entities, natural resource professionals, non-profit organizations, and municipalities to seek dam removal and culvert upgrades as viable options for stream restoration.

Common goals for these stream barrier removal projects include

- reconnecting artificially fragmented stream and riparian systems;
- restoring instream habitat for migratory and resident fishes;
- restoring natural flow regimes and stream processes; and
- improving water quality.

Understanding the effectiveness of barrier removal with respect to these goals requires systematic project monitoring and data reporting. To our knowledge, a systematic approach to stream barrier removal monitoring has not been developed in the United States. Consequently, systematic monitoring data are not available and thus our understanding of barrier removal project effectiveness is limited. The Gulf of Maine Council on the Marine Environment (GOMC) River Restoration Monitoring Steering Committee (Steering Committee) developed this Stream Barrier Removal Monitoring Guide (Monitoring Guide) to improve the ability to

- evaluate the performance of individual restoration projects;
- assess the long-term ecological response of regional restoration efforts;
- advance our understanding of restoration ecology and improve restoration techniques;
- better anticipate the effects of future stream barrier removal projects; and
- communicate project results to stakeholders and the public.

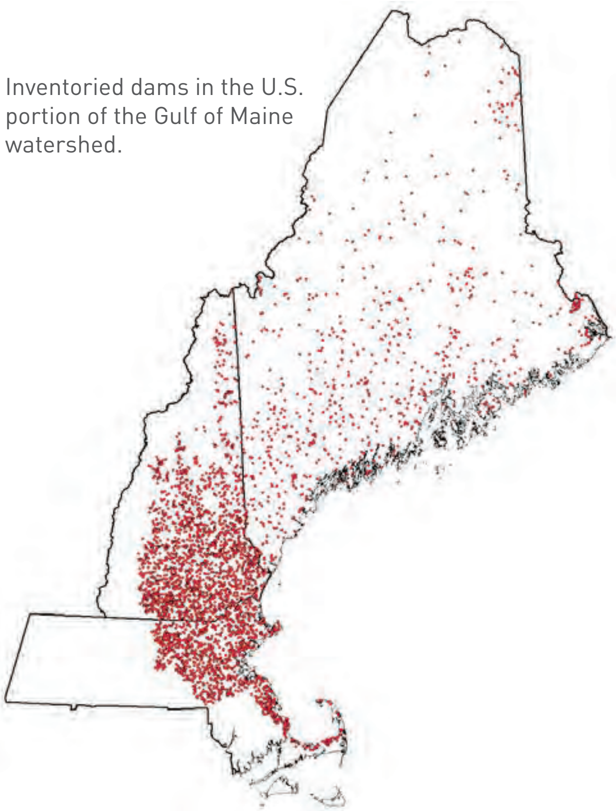
Dams in the Gulf of Maine

The Gulf of Maine watershed is an approximately 69,000-square-mile (179,000-square-kilometer) region encompassing all of the state of Maine and portions of New Hampshire, Massachusetts, Nova Scotia, New Brunswick, and Quebec. On the U.S. side, there are 4,867 inventoried dams: 2,506 in New Hampshire, 782 in Maine, and 1,579 in Massachusetts (Gulf of Maine Council, 2004). Because inventory methods and reporting standards differ from state to state, the completeness of the inventories varies widely. For instance, New Hampshire has a robust inventory method that registers any dam greater than 4 feet (1.2 meters) tall or that impounds more than 2 acre-feet of water. In contrast, Maine relies on a voluntary registry that closed in 1993; undoubtedly, Maine has many more dams that have not been registered (Gulf of Maine Council, 2004). Regardless of the exact figures, habitat fragmentation caused by dams in the Gulf of Maine watershed significantly affects diadromous fish passage.

Most dams in the northeastern United States are run-of-river structures less than 20 feet (6 meters) in height. These low-head dams have relatively small, shallow impoundments. Sediments can accumulate behind the dam, with some impoundments on high-bedload streams filling in rapidly. Small, narrow impoundments located on high-gradient reaches often retain limited sediments because fines, sand, and even gravel can be scoured from the impoundment by storm flows.

NOAA

Removing a dam using an excavator with a hydraulic hammer attachment.



Inventoried dams in the U.S. portion of the Gulf of Maine watershed.

Large, high-head dams associated with storage impoundments are typically constructed for flood control, hydroelectric power, water supply, and/or recreational needs. These larger dams generally are associated with larger rivers, and they may create extensive, deepwater impoundments (Petts, 1984). Large dams are a relatively small proportion of all dams in the Gulf of Maine watershed. For example, only 5% of dams in New Hampshire are used for hydropower (Lindloff, 2002).

Controlled, yet variable, flow releases are characteristic of high-head hydropower or flood-control dams. Stream discharges downstream of certain hydroelectric dams can fluctuate substantially over hours on a daily basis. During certain hours of the day, these facilities minimize releases from the dam to increase head, which is released rapidly to drive turbines to meet peak power demands. At flood-control dams, substantial impoundment drawdowns may be planned to offset snowmelt runoff or large storm events, and larger releases may occur during certain seasonal periods.

Dam Removal

Approximately 600 dams have been removed throughout the United States over the past several decades, the majority of which were less than 20 feet (6.1 meters) tall (ICF, 2005). Ecology, economics, and public safety were the most frequently stated reasons for removal (ICF, 2005). On the U.S. side of the Gulf of Maine, approximately 20 dams have been removed since 1995, and another 20 dams are currently being evaluated for removal.

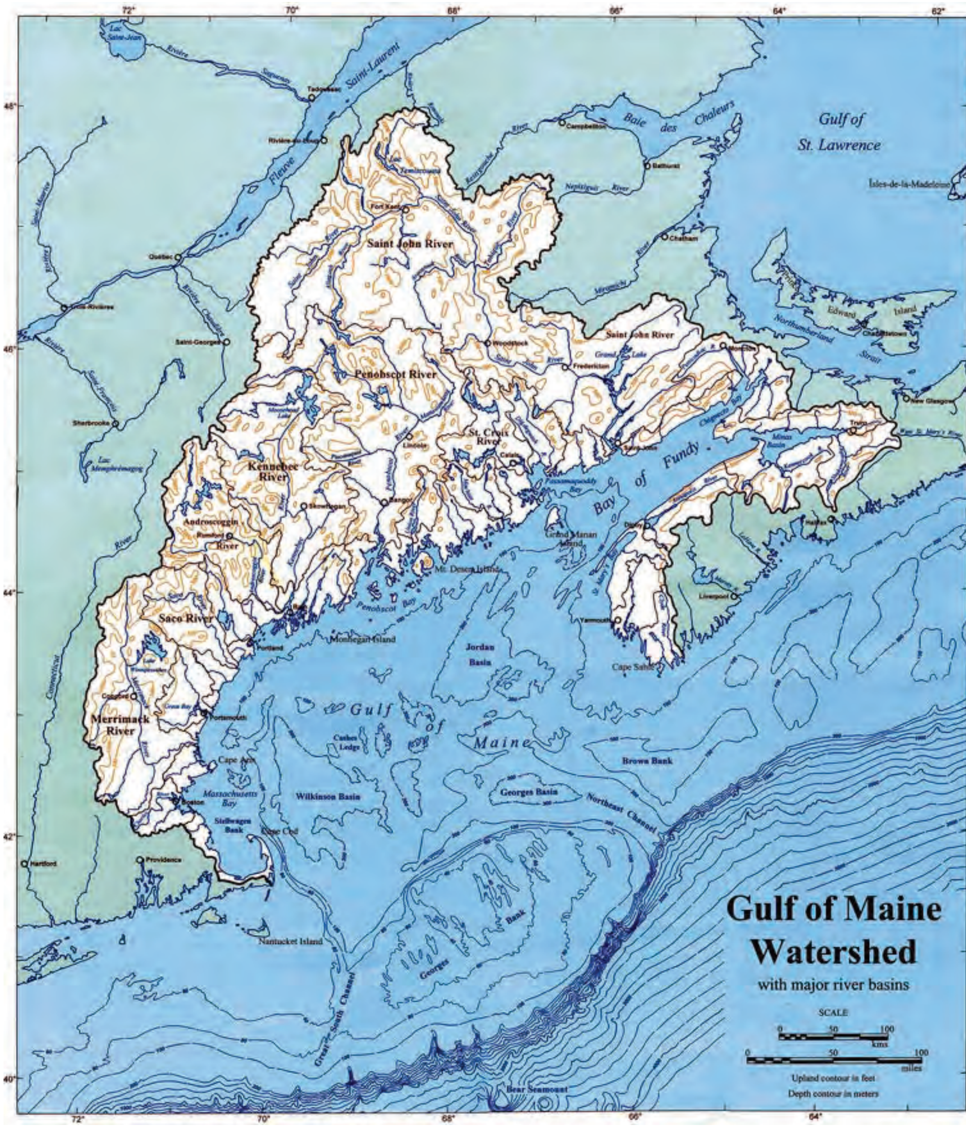
Over the last decade, there has been a resounding call for increased stream monitoring to evaluate the effectiveness of dam removals (Babbitt, 2002; Aspen Institute, 2002; Graf, 2003). Hart et al. (2002) reported that fewer than 5% of dam removals in the United States in the twentieth century were accompanied by published ecological studies. Defining goals at the outset of a barrier removal project is essential to understand the effects of barrier removal projects and to communicate information to stakeholders.

Culverts in the Gulf of Maine

When culverts are perched or undersized, they may impede fish passage. Perched culverts have outlets elevated high above the natural streambed, making it impossible for fish to swim through (Flosi et al., 2003). Undersized culverts restrict the width of the channel, which may cause the water to flow too fast for fish attempting to move upstream through the culvert, particularly during storm flows. These situations are referred to as velocity barriers. Undersized culverts also may cause water to impound on the upstream side during floods.

Effective stream crossings span the width of the stream, have natural streambeds, and do not affect water velocities. Bridges, open-bottomed culverts, and appropriately designed and installed culverts recessed into the streambed are the best available options for stream crossing replacements (Singler and Graber, 2005).

Resource managers in the Gulf of Maine watershed have only recently begun to strategically assess culverts from an ecological improvement perspective. Replacing undersized or perched culverts has proven to be an effective means to increase available habitat to migratory and resident native fishes, and to improve water quality. With proper assessment, engineering design, and installation, replacing stream crossings that have negative ecological impacts can have multiple benefits, including improving public safety by reducing flood risk.



Gulf of Maine Council on the Marine Environment

The white area on this map indicates land that drains into the Gulf of Maine.

B. WORKSHOP PROCESS

On June 20 and 21, 2006, the Steering Committee convened a workshop to discuss stream monitoring with respect to barrier removal projects in the Gulf of Maine watershed. The Steering Committee sought broad representation from state, provincial, and federal resource management agencies, academia, non-governmental organizations, and the private sector. More than 70 attendees with expertise in physical and/or biological stream and floodplain processes were organized into teams on the following topics for structured breakout sessions:

- Hydrology, hydraulics, and sediment
- Wetland and riparian habitat
- Instream habitat
- Fish passage and habitat utilization

The workshop was designed to produce a list of key monitoring parameters and reporting standards from which the Steering Committee subsequently could choose a set to recommend for this Monitoring Guide. The parameters sought for this list ideally would provide fundamental data useful for a broad range of analyses and be relatively inexpensive and straightforward to collect. Cross-cutting parameters, those recommended by more than one topic team, were sought specifically for their value in developing minimum monitoring recommendations.

The following structure and process guided the topic teams to produce the list of parameters:

- Breakout Session I: Topic teams reviewed four barrier removal scenarios designed to capture the range of physical, biological, and management conditions found at Gulf of Maine barrier removal

Table 1.
Critical monitoring parameters identified as priorities by topic teams at the June 2006 workshop. An asterisk indicates that the parameter is to be monitored at monumented cross-sections.

Critical Monitoring Parameters	Topic Teams			
	Hydrology Hydraulics Sediment	Instream Habitat	Wetland Riparian Habitat	Fish Passage
Monumented Cross-sections	✓	✓	✓	
Longitudinal Profiles*	✓	✓		
Grain Size Distribution*	✓	✓		
Photo Stations*	✓	✓	✓	
Water Quality*		✓		✓
Riparian Plant Community Structure*			✓	
Macroinvertebrates		✓		
Fish Passage				✓

sites (Appendix C). After review and discussion in small groups, each topic team developed a prioritized list of monitoring parameters to report back to the entire workshop.

- Plenary Session: Each topic team presented its prioritized parameter lists to the workshop. A facilitated group discussion identified cross-cutting parameters.
- Breakout Session II: Topic teams reconvened to identify important data elements and reporting standards for their prioritized lists of monitoring parameters.

An earlier effort to develop regional monitoring protocols for salt marsh habitat in the Gulf of Maine served as a model for convening this workshop on monitoring protocols for river barrier removals. Information about the Gulf of Maine Salt Marsh Monitoring Protocol is available at www.gulfofmaine.org/habitatmonitoring and in Taylor (2008).

C. SELECTION CRITERIA

By analyzing the lists of prioritized monitoring parameters produced by the workshop's topic teams, the Steering Committee developed the critical monitoring parameters described in this Monitoring Guide.

The *critical monitoring parameters* are common monitoring parameters that, when analyzed collectively, are expected to provide valuable data to characterize adequately the physical, chemical, and biological response of a stream to a barrier removal project.

The Steering Committee selected critical monitoring parameters based on the following selection criteria:

- *Relevance to a range of topic areas*. The Steering Committee focused specifically on monitoring parameters identified as high priorities for more than one of the topic areas. These are referred to as cross-cutting parameters.
- *Usefulness across a range of physical settings and management contexts*. The critical monitoring parameters are intended to be useful for a range of barrier removal projects in the Gulf of Maine watershed.
- *Cost effectiveness*. Recognizing that funding and personnel typically constrain monitoring programs and projects, the Steering Committee targeted monitoring parameters that require relatively modest expenditures.
- *Ability to answer questions relevant to common restoration goals*. Stream restoration and barrier removal projects typically have shared ecological goals. The critical monitoring parameters were selected to provide data useful for answering common questions related to expected restoration goals.

* Indicates critical monitoring parameter

D. THE CRITICAL MONITORING PARAMETERS

Eight critical monitoring parameters emerged from the workshop process and subsequent review by the Steering Committee. These parameters provide fundamental pre- and post-project data for analyses to characterize the physical, chemical, and biological changes at barrier removal sites. Most of the critical parameters are to be monitored at monumented cross-sections (Table 1).

E. INTENDED USE

With this Monitoring Guide, the Steering Committee hopes to encourage systematic monitoring and data reporting for stream barrier removal projects. The Monitoring Guide is specific to stream barrier removal projects in the Gulf of Maine watershed. However, the methods may also be adapted for projects in other regions. We anticipate that this Monitoring Guide will be useful throughout the Gulf of Maine watershed and can be adapted to provincial or state-specific circumstances. In certain instances, we refer users to relevant state or provincial protocols and advocate close coordination with existing government programs.

F. NAVIGATING THIS DOCUMENT

Section III. Scientific Context of Stream Barrier Removal

This section provides scientific discussion of stream barrier removal, focusing on the following topic areas:

A. Hydrology, hydraulics, and sediment
B. Wetland and riparian habitat
C. Instream habitat
D. Fish passage

The subsections summarize the effects of stream barriers with respect to the given topic and the anticipated responses to barrier removal. The subsections also provide the rationale for the critical monitoring parameters, as well as discussions of other parameters identified as priorities at the workshop. While not retained as critical monitoring parameters for the Monitoring Guide, these additional parameters support more detailed investigations and may be necessary on a site-specific basis to answer particular questions.

Section IV. Methods for the Critical Monitoring Parameters

This section provides detailed monitoring methods for the six critical monitoring parameters:

- Monumented cross-sections
- Longitudinal profile
- Grain size distribution
- Photo stations
- Water quality
- Riparian plant community structure

The methods include information about equipment, monitoring design, sampling frequency, and site-specific considerations. Section IV.A, Study Design, provides general guidance on how to implement a monitoring program and describes how the critical monitoring parameters are related to one another.

Fisheries and macroinvertebrate experts in our region agreed that a single method for either fish passage or macroinvertebrates would not be applicable to the variety of expected barrier removal projects. For that reason, we include in this section only a recommendation that users consult with experts in their state or province to identify appropriate methods for macroinvertebrates and quantitative fish passage assessment. We also provide summary tables that describe, in general terms, common monitoring methods for these parameters.

Section V. Data Management

This section describes the importance of common data elements, reporting standards, and metadata. The intention is to ensure that data collection, reporting, and management are systematic and coordinated. This is also the reason we developed detailed data sheets (see Appendix E) for the six critical monitoring parameters for which detailed monitoring methods are provided.

Section VII. Appendices

The appendices provide information about field safety, workshop products, and macroinvertebrate monitoring, along with a glossary. Data sheets are contained in Appendix E and are available for downloading from www.gulfofmaine.org/streambarrierremoval.

Dam in the Gulf of Maine watershed.
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III. SCIENTIFIC CONTEXT OF STREAM BARRIER REMOVAL

A. HYDROLOGY, HYDRAULICS, AND SEDIMENT

Introduction

Water flow and sediment transport govern the physical characteristics of alluvial rivers and therefore influence the quantity and quality of their aquatic and floodplain/riparian habitats. River barriers such as dams and culverts can change water flow and sediment transport, and thus the river's form and function. A number of studies have described how barriers impact stream processes and/or forms (Andrews, 1986; Graf, 2006; Magilligan and Nislow, 2001; Magilligan et al., 2003; Perry, 1994; Petts, 1979; Williams, 1978; Williams and Wolman, 1984). However, the magnitude, timing, and range of physical changes resulting from barrier removal have not been as well documented (Hart et al., 2002).

This section briefly summarizes 1) how barriers can influence stream form and process; 2) observed and expected stream response to barrier removal; and 3) relevant hydrologic, hydraulic, and sediment transport monitoring parameters for answering questions of interest at proposed barrier removal sites. For the purposes of this document, hydrologic impacts are changes to the quantity and timing of stream flow and hydraulic impacts are changes to the physical properties and behavior of flow as it is influenced by floodplain geometry and instream structures.

Barrier Effects on Stream Process and Form

The primary effects of barriers are changes in stream flow timing (i.e., the hydrograph) and sediment transport processes. These changes cause a variety of secondary effects such as changes in bed slope, channel width, bed forms, and roughness. The magnitude and direction of primary and secondary effects can vary considerably from site to site with barrier type and watershed characteristics (e.g., lithology, tributary sediment loads, vegetation cover).

The upstream effects of barriers tend to be more predictable than the downstream effects. Upstream of the barrier, the reach may become lacustrine in character, or it may remain riverine. In either case, habitats are altered considerably from those farther upstream and downstream. In the case of dams, water often ponds on the upstream side, and the impoundment extends upstream until it intersects the stream water surface elevation approximately equal to the elevation of the dam crest, spillway, or other controlling outlet. The impoundment may cause increased groundwater elevations in the floodplain/riparian zone upstream of the barrier. For run-of-river dams, which operate without flood storage, flood stages for a limited distance upstream of the dam are frequently higher than they would be without the impoundment. Culverts may have much the same effect as dams, particularly during small to moderate flood events when a substantial amount of water may impound behind them. However, during large events their influence may diminish if the roadway is overtopped.

The sediment trapping efficiencies of impoundments vary widely depending on the dam type and operation and on the sediment characteristics. Much of the sediment delivered to the impoundment from upstream reaches is often deposited there as the stream loses energy. For culverts, upstream impacts may be more transient in nature and include impoundment during flood events and debris accumulation on the upstream face.

The downstream effects of barriers vary from site to site. Many primary and secondary effects have been reported in the literature (Collier et al., 1996; Petts, 1979, 1980, 1984; Williams and Wolman, 1984). The type of barrier, its operation, and the watershed's physical characteristics largely govern the variability of downstream changes in river form and process. The following is a brief characterization of some commonly observed stream barrier impacts downstream of barriers.

Hydrology Impacts

- Dams with significant flood storage can decrease the downstream magnitude of flood discharges up to 70% (Andrews, 1986; Graf, 2006; Magilligan and Nislow, 2001; Magilligan et al., 2003; Perry, 1994; Williams and Wolman, 1984).
- Stored flood volumes that are released slowly over time produce a common phenomenon downstream of dams: higher discharges during low flow periods when compared to pre-dam conditions (Andrews, 1986; Hirsch et al., 1990).
- The decreased natural variability of flow in downstream reaches can also be manifest as a decreased range of daily discharges (Graf, 2006; Poff, 1997; Richter and Powell, 1996; Richter et al., 1996).
- Storage dams alter the timing of annual maximum and minimum flows, in some cases by as much as 6 months (Graf, 2006), and alter the duration of flows of a given magnitude (Magilligan and Nislow, 2001).

Hydraulic and Sediment Transport Impacts

- As a consequence of reduced flood discharges below storage dams, flood velocities and shear stresses are also reduced. This is a reduction in flow competence, the ability to entrain and transport sediment of larger size fractions.
- Dams trap upstream sediment loads, thereby reducing sediment loads downstream, sometimes considerably (Williams and Wolman, 1984). Channel degradation, a frequent phenomenon downstream of dams, can result. For rivers in a quasi-equilibrium state, sediment delivery to a reach approximately equals delivery out of the reach such that the river neither aggrades nor degrades (Mackin, 1948). The sharp decrease in sediment supply to a downstream reach subsequent to reservoir construction creates a situation in which sediments eroded in that reach are no longer replaced. Stream incision results and can continue until a reduction in slope, or an increase in roughness (see next bullet), decreases the velocity to accommodate the new, reduced sediment load. Channel degradation is common below culverts as well.
- Increased roughness, or armor development, commonly accompanies channel degradation. Though reduced sediment loads can cause bed erosion in the reaches immediately downstream of a dam, primarily finer sediments are eroded from the channel bed and banks by the reduced flood peaks and under average discharge conditions. These reduced flood peaks lack the competence to transport larger clast sizes, a situation that results in the winnowing of fines and the development of an armor on the bed of coarse materials, which prevents further degradation (Petts, 1979).
- Channel aggradation can result downstream of dams, often from the combination of reduced flow competence and a downstream tributary contribution of sediment (Andrews, 1986). Some proportion of the aggraded sediment may come from upstream scour (Collier et al., 1996).
- Channel narrowing downstream of dams has been reported widely in the literature (Benn and Erskine, 1994; Graf, 2006; Gregory and Park, 1974; Kellerhals, 1982; Williams, 1978; Williams and Wolman, 1984). It is often linked to decreases in flood discharges, especially the channel-forming discharges that have 1- to 2-year recurrence

frequencies (Magilligan et al., 2003).
- Sediment deposition, frequently in the form of gravel bars, often occurs immediately upstream of culverts. The coarse materials are deposited when floodwaters are impounded behind the culvert.

Stream Response to Barrier Removal

Just as construction of river barriers affects stream processes and forms, removal of barriers also affects them. Changes in process and form after barrier removal vary in magnitude, direction, and timing, according to barrier type and operation as well as stream and watershed physical characteristics. The magnitude and frequency of storm events after barrier removal also play an important role. Stream responses to barrier removal may continue for years to decades (Pizzuto, 2002).

- *Stream gradient and longitudinal profile.* One of the most widely seen changes after barrier removal is a shift in patterns of sediment movement and sediment deposition (Hart et al., 2002). As the channel adjusts, the streambed may develop a new slope. This may occur through channel incision in the impounded sediments, manifested initially in a headcut, and progressing upstream through the deposit in a process called headcut or nickpoint migration. This process may happen rapidly, or it may occur gradually with annual (or less frequent) peak flows. As knickpoint migration takes place, the longitudinal profile of the river changes progressively in the incised reach (see Pizzuto, 2002) and likely changes in the downstream reach. Formerly impounded sediments may be deposited in the reaches below and cause bed aggradation. Changes in longitudinal profile will likely result in the redistribution of pools, riffles, and bars.
- *Channel geometry.* Changes in sediment transport will be manifest in stream cross-section geometry changes, and over time the reintroduction of the natural flood regime will influence cross-section shape. The channel upstream of the barrier may narrow and develop a floodplain through incision and/or deposition (Pizzuto, 2002).
- *Stream bed particle size distribution* may change in response to changes in sediment transport regime. Bed sediment size distributions in the upstream reach may show greater proportions of coarse material as fines are transported downstream with increased flow competence; coarsening or fining may take place downstream (Hart et al., 2002).
- *Groundwater levels* proximal to the former impoundment will typically be lowered when the dam is removed.

Monitoring Parameters for Hydrology, Hydraulics, and Sediment

The members of the Hydrology, Hydraulics, and Sediment Topic Team at the June 2006 workshop considered dam and culvert removal. They identified the following monitoring parameters as the most critical for understanding stream response to dam removal:

- Monumented cross-sections*
- Longitudinal profile*
- Grain size distribution*
- Stage/discharge
- Contaminated sediments

Channel cross-sections, longitudinal profile, and grain size distribution were deemed within the technical and budgetary reach of most project proponents and were retained and recommended as critical monitoring parameters. These parameters are used to monitor changes in stream form over time, from which changes in process can be inferred.

Sediment contaminant testing is not recommended in this Guide as a critical monitoring parameter because it is not necessary for every site and it is more relevant to project design, engineering, and implementation monitoring than for long-term ecological monitoring. Stage/discharge gaging, while very valuable, is also not recommended because it is too costly.

Monumented cross-sections:* Repeated cross-section surveys will document vertical and horizontal channel adjustments (i.e., degradation, aggradation, widening, narrowing) in response to the new flow and sediment transport regimes following barrier removal. The cross-section data also are useful for hydraulic models, which can provide a wide variety of quantitative information, including water surface profiles, competence to carry sediment, hydraulic conveyance capacity, flow regime, and water speed. See monumented cross-sections method (Section IV.B.1).

Longitudinal profiles:* Repeated longitudinal surveys will show how the channel slope is adjusting to changes in stream processes. They will document any creation, destruction, and/or movement of pools and riffles. See longitudinal profile method (Section IV.B.2).

* Indicates critical monitoring parameter

Grain size distribution:* Resampling grain size distribution during cross-section re-surveys documents changes in the composition of the bed material over time. The data reveal local changes in the stream's hydraulic characteristics, such as roughness and flow competence. Grain size distribution data can be coupled with hydraulic modeling results to compare the stream's competence to carry sediment with the size of the sediment available on the bed. Both pieces of information are critical to understand the likelihood of actual sediment transport. See grain size distribution method (Section IV.B.3).

B. WETLAND AND RIPARIAN HABITAT

Introduction

Riparian zones are defined as the stream channel between the low- and high-water marks, bordering lands where vegetation may be influenced by elevated groundwater tables or flooding, and soils having the ability to retain water (Naiman et al., 1993). Riparian zones are unique lands with distinct geomorphologic and biological attributes regulating energy and material flows within relatively narrow distances between streams and upland ecosystems (Crow et al., 2000). These systems have physical, chemical, and biological effects on surface water, groundwater, instream conditions, and the biota that use the stream and riparian zone as habitat or as corridors for wildlife movement. See Naiman and Decamps (1997) for a good summary of riparian zone functions.

Vascular plants that border streams and rivers contribute important riparian zone structural components and riverine functions. The setting, structure, and composition of a plant community influence the type and level of functions and services (Haberstock et al., 2000). These functions and services include the following:

- Release of leaf litter, mast, and woody debris that provide cover and a food source for animals, fuel instream detrital food webs, and contribute to instream habitat structure/cover for macroinvertebrates and other biota.
- Alteration of suspended/particulate matter and uptake or transformation of dissolved nutrients and other materials transported in stream flows or groundwater discharge.
- Canopy cover that provides shade and minimizes daily fluctuations of temperature in the stream and riparian zone.

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- Development of ground micro-topography and wildlife habitat.
- Protection of streambanks from erosion.
- Decrease in flood velocities attributable to overhanging and stream-edge vegetation and woody debris.
- Reduction in peak discharge by storing overbank flows in floodplain depressions and former stream-channel features.

Many riparian zones are classified as wetlands. Even where riparian zones do not meet the wetland definition, these zones are saturated by groundwater for at least brief periods during the growing season, within the normal rooting depth of plants, and thus are linked hydrologically to streams (Verry, 2000). Floodplains provide important functions including overbank flow storage and velocity reduction, and they serve as sites for stream-channel meandering or secondary flow channels. Field reconnaissance of a project area will help identify floodplain indicators, such as alluvial soil deposits; debris wrack or wash lines; water marks; debris lodged in trees and shrubs; and floodplain vegetation with flood-adapted features (e.g., buttressed tree trunks; adventitious or suckering roots).

Vegetation response to barrier removal is strongly influenced by changes in the physical environment (Shafroth et al., 2002). Because barrier removals may result in drastic changes in physical conditions, the characterization of riparian plant community structure and composition is an important component of a monitoring regime for barrier removals. This section summarizes 1) how stream barriers influence riparian zone structure and functioning; 2) expected responses of riparian vegetation communities when a stream barrier is removed; and 3) important parameters used to monitor riparian zone communities at barrier removal sites.

Barrier Effects on Riparian Zone Structure and Function

A number of authors (Petts, 1984; Ligon et al., 1995; Collier et al., 1996; Nilsson and Berggren, 2000) discuss the impacts associated with dams and culverts on riparian zones. The following is a brief summary of the physical effects of barriers on riparian zone plant communities.

Low-head dams often convert streams to ponds and forest/shrub-dominated riparian habitat to emergent/floating emergent-dominated habitat. Many impoundments created by low-head dams accumulate organic, fine-grained sediments. These impoundments may become covered by emergent (e.g., reed canary grass, *Phalaris aruninacea*), woody (e.g., water willow, *Decodon verticillatus*), or floating emergent (e.g., pond lilies, *Nuphar* spp.) wetland plants. Organic soils flooded by impoundments may release excess phosphorus and nitrogen that may increase aquatic plant productivity (Nilsson and Berggren, 2000).

Scrub-shrub species (e.g., buttonbush, *Cephalanthus occidentalis*) often colonize shallow waters along the perimeter of an impoundment. In the absence of these impoundments and other disturbances, streams are typically bordered by forested and shrub-dominated riparian habitats.

Dams that regulate flows may disrupt natural disturbance regimes of downstream reaches. Flow disruptions reduce variability and alter the frequency, magnitude, and duration of riparian flooding, and they truncate the pulse of sediments, nutrients, and wood debris to and from the floodplain (Sparks, 1995). With lesser flow and flooding frequency, the riparian zone narrows. Storage impoundment dams may change a downstream reach from a multi-channel river and broad floodplain system with mid-channel bars and islands to a single channel. Loss of these features results from reduced peak flows that historically flooded the riparian zone and cut new channels, receiving sediments from upstream riverbanks and terraces (Ligon et al., 1995).

Reduced peak flows and trapped sediments may cause a loss of fertile floodplain soils and pulse-stimulated riparian vegetation responses. Without flood or soil deposition stimulation, some riparian plants may not successfully reproduce, leading to displacement by more generalist native upland and exotic plant species. Plant seeds with poor floating capacity may have decreased potential for dispersal downstream of dams, affecting the abundance of these species in downstream riparian zones (Jansson et al., 2000).

Riparian Zone Response to Barrier Removal

The degree of riparian zone change after removal of a stream barrier depends on

- size of the stream, barrier, and impoundment;
- stream discharge;
- dewatered sediment grain size and composition; and
- geomorphic characteristics of the stream channel and valley.

Effects on the riparian zone can be distinguished into two primary categories: upstream and downstream effects. Removal of low-head dams and culverts result in plant community structural changes primarily upstream of the barrier, while removal of storage impoundment dams may result in significant plant community changes both upstream and downstream of the project site. A planned staging of a dam breach/removal may also affect how plant species colonize and community succession occurs in the riparian zone.

Upstream Effects

With dam removal, the dewatering of an impoundment may be rapid, resulting in the loss of open water habitat and changes in the hydraulic gradient. Groundwater levels may be lowered by dam removal and dewatering. A new hydraulic gradient will develop with impoundment loss or lowering, and the gradient will be affected by the topography and stage-discharge relationships (ICF, 2005). A broad, flat topography would be expected to result in more homogeneous plant cover types. The tolerance of flooding and soil saturation by each plant species influences the zonation and patterns of plant community development following dam removal and impoundment loss. Besides the loss of deepwater habitats, the vegetation response generally includes plant dieback with decreased cover by nonpersistent emergent plants (e.g., *Pontederia cordata*, *Sagittaria* spp.) and loss of submerged aquatic vegetation (e.g., *Vallisneria*, *Potamogeton* spp).

Exposed sediments resulting from impoundment loss may be colonized rapidly if a seedbank of wetland plants exists within the wetland soils and/or adjacent communities provide wind-blown seed sources. Plant colonization period depends on the timing of the dam removal, as well as the grain size composition and water content of the soils. Nutrient levels in the former impoundment sediments may also affect plant species colonization and plant community composition in riparian zone succession. Persistent and non-persistent hydrophytes may colonize areas that continue to have prolonged inundation. Persistent emergent (e.g., *Scir-*

pus spp.) and non-persistent emergent plants will dominate the semi-permanently saturated soil zone, while scrub-shrub (e.g., *Alnus*, *Cornus* spp.) and tree (e.g., *Acer* spp., *Nyssa sylvatica*) species will dominate the riparian zone underlain by permeable soils with temporarily to seasonally flooded or saturated soil conditions.

A primary concern of stream restoration practitioners is the fate of the impoundment area after dam removal and potential invasion of non-native plants. See Orr and Koenig (2006) for a case study of non-native and native plant establishment after removal of two low-head dams. In places with nutrient-rich soils, weedy plants are typically the early colonizers, produce seeds at high rates, have effective dispersal mechanisms, and are invasive, non-native species.

Soils with high levels of micronutrients or metals may support only nuisance plant species tolerant of these contaminants. Non-native species may out-compete native riparian vegetation by rapidly colonizing exposed sediments, if the exotic species already existed in the impoundment. Other modes of dispersal include seeds transported by stream flows from upstream parent stock, carried in by animals (e.g, *Lythrum salicaria*, *Elaeagnus angustifolia*), or dispersed by wind (e.g., *Phragmites australis*).

Riparian plant diversity is expected to be lower with a well-established and dominant invasive plant cover. Hydrologic conditions at the site and the species' flood tolerance will dictate the limits and vigor of the invasive species cover in the riparian zone. Once established, a healthy invasive plant cover may modify microhabitat conditions in ways that are likely to inhibit or prevent natural plant community succession in riparian zones. To combat potential invasions with planned dam removals, restoration practitioners often prepare plans including seeding and/or planting of native species and other practices such as use of geo-fabrics to help expedite growth of a desired riparian zone vegetation cover.

Downstream Effects

Removal of storage reservoir dams results in an increase in downstream flooding and sediment transport. Sediment transport is also often increased after removing low-head, run-of-river dams. Downstream floodplain communities may be altered as floods remove or bury vegetation in downstream habitats lacking regular flooding. Subsequently, riparian habitats dominated by flood-tolerant species will re-establish on the newly deposited barren soils. Restoring sediment transport processes to downstream reaches may result in sediment deposits and increases in transient bed elevation and lateral stream channel migration within the floodplain (Healy et al., 2003). A greater frequency of depositional bars and other landforms that could support pioneer plant species (e.g., *Salix*, *Populus* spp.) would also be expected to form (Shafroth et al., 2002).

Following dam removal, seed dispersal via stream flow may help to restore native plants in the downstream riparian zone (Jansson et al., 2000). For dams that increase groundwater elevations, wetlands that form locally both downstream and along impoundment margins by lateral seepage around a dam may be affected by lowering of the groundwater table. A lowering of the water table may result in the loss or conversion of wetlands that had been sustained by seasonally to permanently saturated soils (ICF, 2005), but any conversions would be expected to be localized, and are frequently offset by new wetland formation elsewhere (i.e., along the new stream margin upstream of the removed barrier).

Monitoring Parameters for Wetland Riparian Habitat

The Wetland and Riparian Habitat Topic Team at the June 2006 workshop identified the following monitoring parameters as most important to assess the response of vegetation to stream barrier removal:

- Riparian plant community structure*
- Invasive plant species monitoring
- Restoration planting survival
- Plant condition assessment
- Groundwater elevations

Riparian plant community structure:* Of the parameters discussed by the Wetland and Riparian Habitat Topic Team, plant community structure was the only one recommended as a critical monitoring parameter. Repeated plant community assessments at permanent stream/riparian cross-sections at both the barrier removal site and upstream or nearby reference reaches will reveal changes in species percent cover, plant composition, and community succession attributed to the barrier removal. Riparian plant community monitoring will help explain changes in ecological functions associated with restoring the riparian zone, such as wildlife habitat quality and plant material export to the stream. See riparian plant community structure method (Section IV.B.6).

* Indicates critical monitoring parameter

James Turek / NOAA

Invasive plant species monitoring: Although invasive species monitoring was not recommended as a critical monitoring parameter, the Wetland and Riparian Habitat Topic Team identified invasive plants as a significant management concern at barrier removal sites. Depending on the objectives, budget, number of monitoring staff, and study period associated with the project, monitoring methods may be considered to document the extent of any non-native, invasive species. While monitoring of sampling plots may provide adequate information about the relative percent cover and frequency of invasive plants, it may be desirable also to record stem density per unit area at a site. This is particularly true in dense patches or near monotypic stands of plants. Delineation and mapping of the spatial limits of exotic plants (e.g., common reed, *Phragmites australis*; purple loosestrife, *Lythrum salicaria*; reed canary grass, *Phalaris arundinacea*; Japanese knotweed, *Fallopia japonica*) can show the extent of the invasion of the project area over time.

Physical disturbance in riparian areas can result in increased proportions of invasive species. For this reason, special attention should be paid to all disturbed areas including the dewatered impoundment area, bordering vegetation, and construction areas. The limits of the invasive plant cover should be recorded via GPS and depicted on a site map or aerial photo. For broad project sites or long stream reaches, an alternative method—using a scaled series of annual color or infrared aerial photographs complemented by limited field groundtruthing—should be considered for mapping invasive plants.

Restoration planting survival: Some barrier removal projects may include installing plantings, cuttings, and seeds of native plants to expedite the restoration of bare riparian soils. For barrier removal restoration sites that have been planted (e.g., plugs, containerized stock, or bare root), annual monitoring should include the percentage of dead, stressed, or surviving plants out of the total number of plantings of each species. Woody plantings should be mapped/tagged or depicted on the restoration-planting plan because often many plantings do not survive and might be difficult to locate. Dormant material such as livestakes or wattles (typically willows, *Salix* spp.) should be monitored for at least the first full growing season (e.g., percent survival for stakes or posts; percent cover for wattles). Natural regeneration of trees and shrubs also will occur, potentially leading to artificially high estimates of survival if plantings are not mapped/tagged (Pollack et al., 2005). If an entire planted area is not assessed, care should be taken to document the location and area of the monitored sub-area. This information may be used in recommending plant species to be replaced or other native species as substitutes in the replanting, especially if a warranty has been secured with a landscaper/plant nursery supplier contract for the restoration project.

Plant condition assessment: Plant condition, particularly of exotic plants, can be described by measuring plant height of a representative number of plants (e.g., 10) within each sample plot, as well as recording whether each randomly selected plant is flowering or has fruit as an indicator of successful seed production. Documenting the amount of grazing by herbivores (e.g., beaver, deer) and impacts of insect pests is another suggested practice.

Groundwater elevation monitoring: Barrier removal often results in dewatering or lowering of surface water impoundments and will influence riparian groundwater elevations. If time and budget allow, groundwater monitoring may be conducted to help define changes in sub-surface hydrology influencing riparian community development at barrier removal sites. This monitoring requires installation of multiple monitoring wells at both barrier removal and reference sites, and effort to monitor groundwater elevations over multiple seasons.

C. INSTREAM HABITAT

Introduction

Removing river barriers results in changes to chemical, physical, and biological processes that, in turn, influence instream habitat conditions (Hart et al., 2002). These changes can cascade throughout all components of instream habitat, influencing habitat structure, water quality, and biotic assemblages. This section briefly summarizes 1) how stream barriers influence instream habitat; 2) how instream habitat responds when a stream barrier is removed; and 3) important parameters to monitor to document changes in instream habitat as a result of barrier removal.


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Dam removal site in New Hampshire showing remaining left-bank abutment.

Effects of Barriers on Instream Habitat

Habitat Structure

Barriers impound water and may result in a shift from a riverine habitat to a lacustrine, or lake-like, habitat. The alteration of hydrologic regime and the changes in sediment transport caused by river barriers may change the quality and distribution of instream habitat types such as riffles, runs, and pools. Riffles are composed of cobbles and gravel, and typically they are free from finer-grained material. These shallow, high-velocity environments are well aerated, provide important habitat for spawning, and serve as critical nurseries for fish eggs. Pools are found between riffles, and they are characterized by smoother bottoms, deeper water, and lower flow velocities than riffles.

Pools provide important refugia and rearing habitat for multiple age classes of fish species during high-water events and low-flow conditions. Riffle and pool complexes also incorporate runs of swift-moving water between each complex, which provide habitat for fish and other biota. These habitats, and the organisms that depend on them, may be eliminated by a stream barrier's impoundment.

Stream barriers also reduce large woody debris recruitment from upstream sources. Large woody debris is an important contributor to instream habitat complexity and diversity, including the formation of mid-channel bars and islands (Abbe and Montgomery, 1996). Large woody debris enhances microhabitat diversity and surface roughness in floodplains and riparian zones, thereby encouraging flow dissipation versus concentrated flow patterns. This debris also enhances plant and wildlife habitat diversity.

Some stream barriers create tidal restrictions, which may exclude the daily tidal exchange or allow a muted tide to progress past the barrier. In both instances, the impacts of tidal barriers are complex and often result in a shift from estuarine habitats to freshwater habitats with a corresponding shift in species composition.

Water Chemistry

Barriers influence water chemistry by trapping nutrients and sediment and by changing water temperature and dissolved oxygen concentrations. Impoundments in urban, suburban, or agricultural areas may develop high nutrient concentrations as a consequence of receiving nutrient-rich runoff. These nutrients may result in increased macrophyte and algae growth, potentially at nuisance levels.

Because the microorganisms that decompose dying macrophytes and algae consume dissolved oxygen, elevated nutrient concentrations can lead to low dissolved oxygen concentrations in impoundments, particularly at depth. Also, impoundments may have higher temperatures than free-flowing river reaches upstream and downstream. Elevated temperature may further reduce dissolved oxygen concentrations. Increased water temperatures and decreased oxygen concentrations can prevent sensitive species such as trout and many invertebrates from using the pond habitat.

Sediment and sediment-bound toxic contaminants carried by rivers may settle in impoundments as water velocities slow. Modern and legacy industrial pollution have contributed persistent contaminants (i.e., contaminants that do not break down easily) to surface and ground waters, and the contaminants may bioaccumulate in intermediate to higher trophic organisms (Hart et al., 2002). These bioaccumulative contaminants include but are not limited to DDT, PCBs, mercury, and dioxins. Contaminated sediments may adversely impact aquatic ecological resources or humans who consume these resources.

Benthic Communities

Changes in habitat structure and water chemistry may result in a shift in macroinvertebrate communities (e.g., aquatic insects, clams, mussels, worms, snails). Communities of macroinvertebrates upstream of a barrier may resemble those of lake-like environments. Macroinvertebrates are important components of most freshwater riverine ecosystems, functioning as a link between primary producers (algae), nutrient inputs such as leaves and woody debris, and tertiary consumers (fish) (Resh, 1995). Mussels are among the least mobile macroinvertebrates in stream systems and therefore may be affected most strongly by habitat changes.

The physical changes caused by a stream barrier, particularly when an impoundment is created, provides a change in habitat conditions that sometimes favors freshwater mussels. Upon dam removal, however, freshwater mussels are vulnerable, particularly during the dewatering period. Furthermore, if any impounded sediments are released downstream when a dam is removed, the sediments may affect downstream habitats of mussels and other macroinvertebrates.

Response of Instream Habitat to Barrier Removal

Small barriers are the chief focus of removal efforts in the Gulf of Maine watershed. Little information exists on the ecological impacts of these smaller and/or partial removals. The primary goal of most barrier removal projects is to increase fish passage. The rapid achievement of this goal has been documented in high-profile scientific studies and confirmed by many anecdotal reports (O'Donnell et al., 2001). However, less is known about the responses of other instream habitat components to barrier removal projects and the implications for other aquatic organisms.

Barrier removal is expected to result in reestablishment of riverine habitats upstream of the barrier. Upstream and downstream impacts of barrier removal on the physical stream structure are further described in Section III.A.

Stream barrier removal effects on water chemistry vary from site to site depending on geomorphic and hydrologic factors (e.g. Doyle et al., 2003; Gergel et al., 2005). Barrier removal may increase dissolved oxygen in the formerly impounded reach, reduce water temperature, release stored nutrients from the impoundment, and/or release fine sediments to downstream reaches. Prior to barrier removal, the nutrients in an impounded reach are stored in the sediments (Ahearn et al., 2005).

After the barrier is removed, and the upstream sediments are available for transport, the nutrients may be mobilized. The extent to which nutrients are mobilized and transported may depend on geomorphic changes at the site. For example, Ahearn et al. (2005) found that removing a small dam on Murphy Creek in California resulted in increases in sediment and nitrogen export from the recovering reach. In contrast, Velinsky et al. (2006) found that removing a small dam in southeastern Pennsylvania had no significant effects on upstream or downstream water chemistry, including nutrients and dissolved oxygen concentrations.

Stream barrier removal projects can affect water chemistry through the mobilization of accumulated sediments and sediment-bound contaminants to downstream aquatic environments. Post-dam removal sediment mobilization can increase the downstream occurrence of fine-grained sediments, which can smother important spawning grounds, fill pools, and decrease water clarity. Before dam removal occurs, it is common to conduct a grain size analysis to determine sediment size and sediment mobility. Testing for the presence of pollutants is also common. This Monitoring Guide does not specifically recommend monitoring the toxicity of impounded sediments. However, sediment toxicity testing may fall under regulatory requirements for projects that occur in some jurisdictions. The project manager should contact federal, provincial/state, and municipal regulatory authorities for advice on how to proceed.

Barrier removal may affect benthic organisms that in turn provide food for other organisms. Macroinvertebrates are used frequently by researchers and managers to document changes in community composition and habitat type (Casper et al., 2001; Collier and Quinn, 2003; Doyle et al., 2005; Kanehl et al., 1997). The ability of many aquatic macroinvertebrate taxa to opportunistically recolonize areas of previously unavailable habitat is made possible by short life cycles (~1 year) coupled with mobile terrestrial adult phases. Macroinvertebrate populations are expected to shift from lake or pond species to riverine species over time frames of days to years upstream of the barrier removal (Bushaw-Newton et al, 2002). Benthic communities downstream of the barrier removal site may be affected as well. Thomson et al. (2005) found that macroinvertebrate density and algal biomass declined downstream of a dam during 12 months of sampling after removal. This was attributed to increased fine sediment transport from the restored reach. The authors hypothesized that over time the downstream benthic communities would recover to resemble upstream communities. In general, recovery processes should be expected to vary in length of time and magnitude of community change.

Freshwater bivalves may be particularly affected by barrier removal. A study of a dam removal project on the Koshkonong Creek in Wisconsin documented upstream and downstream impacts to freshwater bivalves (Sethi et al., 2004). The study documented 95% mortality of mussels in the former impoundment due to desiccation and exposure (Sethi et al., 2004, cited in Nedeau, 2006). The study also reported that a downstream increase of silt and sand from the former impoundment resulted in decline of mussel densities and extirpation of rare mussel species. Efforts to relocate mussels during the Edwards Dam removal in 1999 successfully rescued 607 tidewater muckets and 16 yellow lampmussels, both of which are listed by every New England state as threatened or endangered (Nedeau, 2006).

Monitoring Parameters for Instream Habitat

Techniques to assess instream habitat either 1) quantify specific physical instream habitat components (e.g., stream bed cross-sections or grain size distribution) or 2) use indicators to assess overall instream habitat quality (e.g., macroinvertebrates). This Monitoring Guide recommends using both quantitative measurements and ecosystem indicators to assess instream habitat.

The following parameters were identified by the Instream Habitat Topic Team at the June 2006 workshop as most important for assessing the response of instream habitat to stream barrier removal:

- Macroinvertebrates*
- Water quality*
- Photo stations*
- Longitudinal profiles*
- Monumented cross-sections*
- Grain size distribution*

Macroinvertebrates:* Surveys of macroinvertebrates are used by many organizations to indicate the health of freshwater riverine ecosystems. In 1995, the U.S. EPA reported that 41 out of 50 states had biological assessment programs in place and that macroinvertebrates were the most commonly utilized assemblage (U.S. EPA, 2002). Each state and province bordering the Gulf of Maine has its own specific macroinvertebrate assessment protocol. Therefore, this Monitoring Guide does not recommend a particular methodology but rather advocates using the protocol that is recommended by the project's regulatory authority.

Water quality:* Water quality is an important component of instream habitat that should be considered when removing stream barriers. Depending on project specifics, the following water quality parameters may be important for barrier removal projects: temperature, dissolved oxygen, total suspended solids, pH, salinity, conductivity, nutrients, chlorophyll a, carbon, pathogens, and contaminants. Of these parameters, temperature, dissolved oxygen, and conductivity are the recommended critical monitoring parameters. See water quality method (Section IV.B.5).

Photo stations:* A properly executed and documented photo record can be an invaluable resource for project proponents, regulatory authorities, and outreach and education. The monumented cross-section-based monitoring framework of this Monitoring Guide will provide the spatial and temporal basis for a detailed and robust photo record. An accurate photo record should, at a minimum, start the year preceding implementation and continue through years 1, 2, and 5 after the project has been completed. See photo stations method (Section IV.B.4).

The cross-sections, longitudinal profile, and grain size distribution can provide quantitative information on habitat types, including pool depth, habitat unit length, and critical grade control points (see Section III.A for further discussion of these three critical monitoring parameters). Qualitative habitat information can also be gleaned from certain quantitative monitoring parameters. For example, cross-section survey notes should include qualitative descriptions of bank conditions, bed substrate, large woody debris occurrences, and vegetation type.

* Indicates critical monitoring parameter

D. FISH PASSAGE

Introduction

Since European settlement, dams have contributed to the decline of diadromous fish species in the Gulf of Maine region. To protect annual harvests, colonial laws were enacted to counter the detrimental effects of blocking fish from spawning habitat (Trefts, 2006). Many of the earliest dams still remain, some having been rebuilt multiple times for different purposes. The long history of industrial, commercial, and residential development in the region has meant that road and rail stream crossings are also ubiquitous. Massachusetts alone has an estimated 3,000 dams, along with an estimated 30,000 culverts and bridges associated with road and rail crossings, according to the state's Geographic Information System database.


New Hampshire Coastal Program

It is not known what percentage of existing road and rail crossings create barriers to fish movement. It is known that many of these bridges and culverts do not fully span the stream's full width, have perched outlets, are constructed with high longitudinal slopes, and otherwise present velocity or elevation barriers to fish migrating upstream. As barrier removal becomes a prevalent practice for fishery enhancement, there is a greater need to quantify the impacts of these efforts. Measuring the success of these restoration projects has been challenging in part because of a lack of established, systematic monitoring protocols.

This section briefly summarizes: 1) how stream barriers affect fish passage; 2) fish passage response when a stream barrier is removed; and 3) important monitoring parameters to assess fish passage.

Effects of Barriers on Fish Passage

Dams, dikes, perched culverts, and other stream barriers have the potential to limit or completely restrict access to spawning habitat and other habitats for various life stages of native resident species and anadromous species. Many watersheds in the Gulf of Maine no longer sustain runs of anadromous fish. Atlantic salmon (*Salmon salar*) were extirpated from most of the U.S. east coast by the early 1800s. Other anadromous fish including alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*), American and hickory shad (*Alosa sapidissima* and *A. mediocris*), Atlantic sturgeon (*Acipenser oxyrhynchus*), sea lamprey (*Petromyzon marinus*), and rainbow smelt (*Osmerus mordax*) have suffered dramatic population declines. Also in decline is the once-abundant American eel (*Anguilla rostrata*), a catadromous species. Inability of fish to reach historic spawning habitat may contribute to these declines.

Complete barriers to passage have obvious implications for fish migration, but partial passage barriers and poorly constructed or failing fish ladders also can have deleterious effects. Fish ladders that are poorly designed, in disrepair, or not managed properly can be significant barriers to passage. In some cases, fish ladders may be temporal barriers for weak-swimming fish or for different age classes of fish at certain flows or tides. Dams with fish ladders that do not have adequate provision for juvenile out-migration can reduce population viability. Dams that are partially breached can allow strong-swimming fish to pass but not allow weaker fish, or fish of different age classes, to pass. Perched culverts and undersized culverts, although considered hydraulically adequate under certain flows, can be as problematic to upstream fish migration as dams.

Fish Passage Response After Barrier Removal

Fish monitoring has been an integral part of some Gulf of Maine barrier removal projects. The removal of the Edwards Dam in Maine and the Billington Street Dam in Massachusetts both included fish monitoring. Fish movement response to barrier removal has been researched, and findings show that improvement is immediate and significant. If a dam or barrier is properly and fully removed, and natural stream hydraulic and geomorphic conditions are restored, natural fish migration patterns are likely to return during the subsequent migratory period. Removal of a small dam at Town Brook in Plymouth, Massachusetts, resulted in more than 95% passage efficiency of alewife through the restored river reach with concomitant median transit times of less than 20 minutes (Haro, personal communication 2007).

Improved fish movement has been observed in the Gulf of Maine region for non-anadromous fish species following barrier removal. Migrations of native species, such as brook trout and white sucker, typically are restored following barrier removal.

Monitoring Parameters for Fish Passage

Many different fish sampling or monitoring techniques have been developed for streams, and state and provincial agencies have adopted a variety of them. Monitoring methods to assess fish passage through a reach where a barrier has been removed are of two general types: measurement of physical stream characteristics or measurement of fish movement.

Measurement of physical stream characteristics: This approach uses physical stream characteristics such as water depth, water velocity, and the presence or absence of any abrupt changes in bed elevation as a surrogate for fish passage and assumes that if physical stream characteristics fall within a predetermined range, then fish will be able to pass. If a culvert has been replaced, then additional assessment components may include culvert length, height of any inlet or outlet drops, and pitch of the culvert.

An example of this approach is FishXing, a U.S. Forest Service software product used by engineers, hydrologists, and fish biologists to evaluate and design culverts for fish passage. FishXing compares known fish swimming abilities with culvert measurements and physical stream characteristics to model hydraulic properties of a crossing to evaluate fish passage (USFWS, 2005). The community of expert fisheries scientists in our region indicated that the swimming abilities of Gulf of Maine diadromous fish are not well understood and that because of our lack of understanding of fish capabilities, this approach would not confirm whether fish passage had been restored at a barrier removal site. Consequently, it was not selected as a critical monitoring parameter.

Direct fish measurement:* Our recommended approach is the direct measurement of fish movement to determine whether the barrier removal project has been successful at restoring fish passage. This approach assumes that a project has been effective if fish, previously known to be restricted below the barrier, are documented above the barrier removal site.

There are, however, several difficulties in recommending the direct measurement of fish movement at a barrier removal site:

- *High diversity of diadromous fish in the Gulf of Maine:* The 10 species of diadromous fish within the Gulf of Maine each have specific life history strategies, migration periods, and habitat utilization preferences.
- *Diadromous fish populations may be small or not yet restored* making presence or absence determinations difficult.
- *Stream barrier removal projects present unique site-specific conditions:* The scope of this Monitoring Guide includes all types of stream barriers in the Gulf of Maine watershed, which occur in many habitat types.
- *Required expertise:* Measurement of fish movement requires advanced expertise, specific equipment, and substantial personnel and financial resources.

Given the variability of fish species affected by stream barriers, the variability of site-specific conditions, reduced population size of some target species, and the expertise required to conduct fish assessments, recommending one fish passage method for all sites is not possible. We recommend that project proponents work with jurisdictional authorities to develop direct fish assessment methods that are appropriate for their barrier removal project.

* Indicates critical monitoring parameter

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A stream swollen by a recent rainstorm.
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Grace Levergood / NHDES

Measuring elevation and distance on a transect.

IV. METHODS FOR THE CRITICAL MONITORING PARAMETERS

A. STUDY DESIGN

The eight critical monitoring parameters are designed to be used together as a monitoring framework. Monumented cross-sections, the skeleton of this framework, are permanently established and georeferenced. Several of the critical monitoring parameters—grain size distribution, photo stations, water quality, and riparian plant community structure—should be evaluated at the monumented cross-sections (Table 1). This study design allows for spatial and temporal consistency for long-term monitoring. Adequate consideration must be given to choosing the cross-section locations because, once set, they should not be changed.

Before cross-sections are established, the monitoring reach must be determined. The monitoring reach is delineated into three segments: reference reach (upstream), impoundment, and downstream reach. Once the monitoring reach is defined, we recommend that the longitudinal profile be conducted to facilitate monumented cross-section placement. General site reconnaissance and review of remote sensing data are also very useful for choosing cross-section locations.

In addition to the cross-section-based spatial and temporal monitoring framework, this Monitoring Guide employs a Before-After (BA) study design that requires an assessment of pre-project and post-project conditions (Kocher and Harris, 2005). A BA design can be improved by including a control site so that environmental conditions (natural and otherwise) affecting both sites can be accounted for when evaluating the restoration. Such a design is called a Before-After-Control-Impact (BACI) design. Where practical, the Steering Committee encourages the use of a control site. However, this Monitoring Guide does not require it for two reasons: (1) project evaluation will be twice as costly, and (2) the uppermost monumented cross-section should be upstream of the project's zone of influence, hence serving as a de facto control site, though not an entire control reach.

A written monitoring plan, a summary of accomplished work, and a schedule of anticipated work are recommended to provide project partners and data users with a clear account and detailed description of

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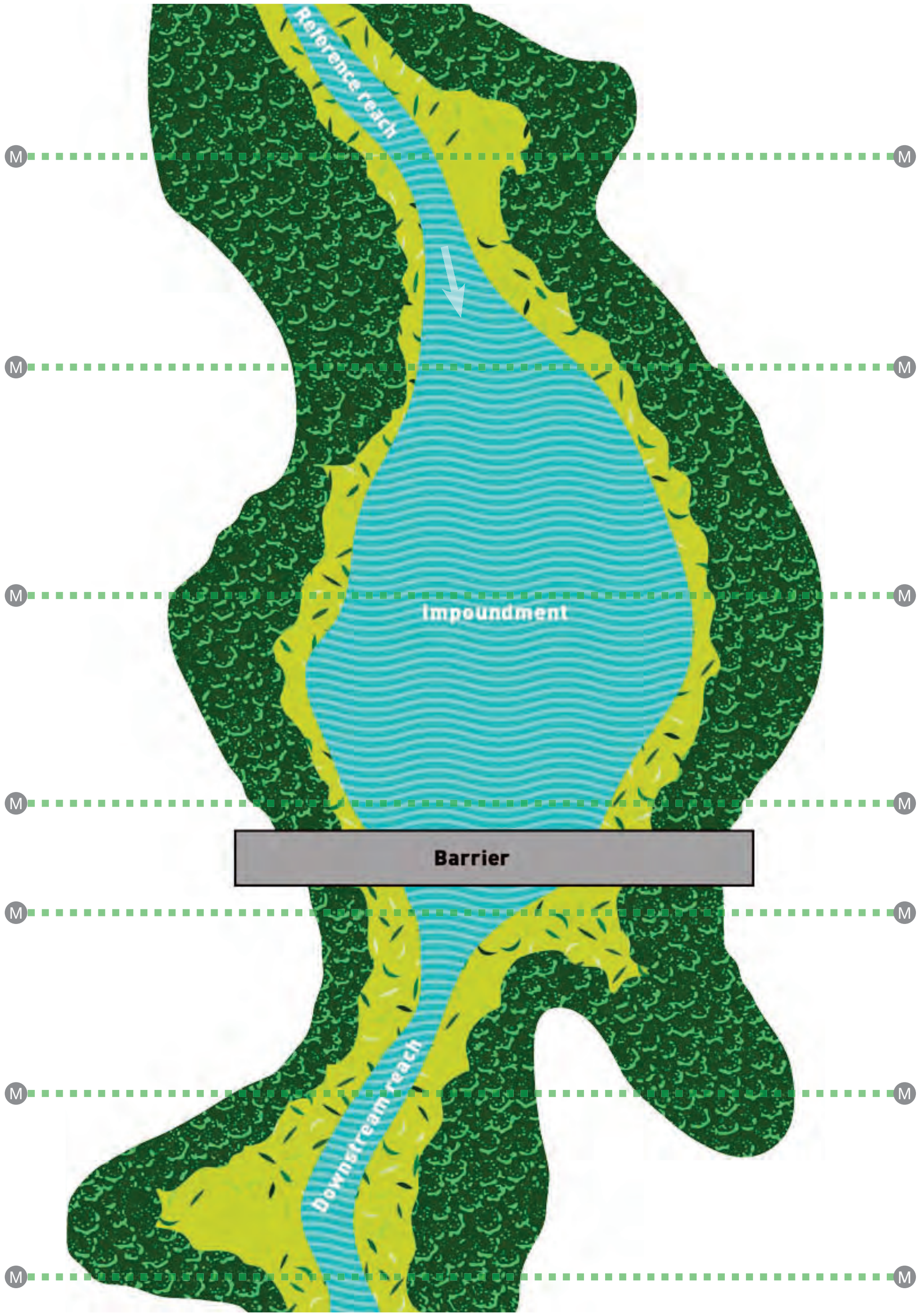
Conducting monitoring for a stream barrier removal project.

monitoring that has taken place and the direction of future efforts. We recommend that practitioners leverage field opportunities to optimize the effort and resources employed. For instance, certain parameters can be assessed on the same field day, such as water quality and macroinvertebrates, or photo stations and riparian plant community structure.

Two or more persons should be dedicated to each monitoring team to help complete the data collection expeditiously and facilitate quality assurance. If possible, at least one person should be involved throughout the monitoring period to ensure consistency and uniformity in implementing the monitoring methods. The monitoring team also should designate someone who will be responsible for compiling and retaining the field data.



Monumented cross-sections are a key element of the standardized methods recommended in this Monitoring Guide. This figure shows some possible locations of monumented cross-sections at a hypothetical barrier removal site. Figure not to scale.

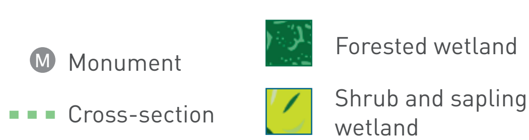


Table 2. Summary of the critical monitoring parameters.

Parameter	Variables	Description	Monitoring Design	Sampling Frequency
Monumented cross-sections	Elevations and distances	Cross-section geometry measured at permanently monumented transects. Horizontal distances recorded to tenths of feet (0.1 ft) and elevations to hundredths of feet (0.01 ft).	The number and location of cross-sections will depend on site-specific conditions. At a minimum, cross-sections should be established immediately upstream and downstream of the barrier, at bridges, in the impoundment, and upstream of the impoundment influence. Permanent geo-referenced monuments must be established at cross-section endpoints.	Monitoring should be conducted in the year preceding barrier removal. In the case of impoundments, pre-removal assessments should be coordinated with drawdown. Resurveys should occur annually or every other year for at least five years.
Longitudinal profile	Elevations and distances	Longitudinal profile measured in conjunction with monumented cross-sections. Horizontal distances recorded to the tenths of feet (0.1 ft) and elevations to hundredths of feet (0.01 ft).	Take elevation readings along the thalweg at important bed features, measuring distances using the baseline. In addition to distances and elevations, note details of features being measured and water-surface elevations at each bed-elevation measurement.	Longitudinal profiles should be resurveyed at the same frequency as the cross-section surveys.
Grain size distribution	Distributions of sediment size classes	Streambed surface grain size distributions characterized by collecting and analyzing sediment samples at monumented cross-sections.	In cross-sections dominated by fine sediments, each sample point should contain 1 liter of surface sediments for laboratory analysis. In cross-sections dominated by gravel, a pebble count should be performed.	Grain size sampling should be conducted at the same frequency as the cross-section surveys, during wading-depth stream conditions.
Photo stations	N/A	Repeat photographs capture a variety of ecosystem conditions and visually document stream response.	Photo stations should be described as distances or bearings from other known points such as cross-section endpoints or other permanent landmarks.	Photo-monitoring should include both leaf out and full vegetation in the year preceding restoration. Post-restoration photo monitoring is recommended for years 1, 2, and 5.
Water quality	Temperature	Precision: +/- 0.2°C. Accuracy: +/- 0.2°C	Select a minimum of three monumented cross-sections to evaluate water quality: upstream of the impoundment influence; deepest part of impoundment; and immediately downstream of the barrier. Properly record site information, including GPS coordinates, for purposes of resurveying. Prepare, test, and calibrate equipment. Collect and record water-quality data and site information.	Monitoring should occur one year prior to removal and annually thereafter for five years. All data should be collected weekly for eight weeks during August and September. If macroinvertebrate data are not being collected, water-quality data should be collected weekly from June through October or through continuous monitoring.
	Dissolved oxygen	Precision: +/- 2% or 0.2 mg/L, whichever is greater. Accuracy: +/- 2% of initial calibration saturation or 0.2 mg/L, whichever is greater		
	Conductivity	Precision: +/- 5%. Accuracy: +/- 5% against a standard solution		
Riparian plant community structure	Herbaceous layer	Using 1-m^2 (10.8 ft^2) quadrat, identify each species, record species percent cover and number of stems for all non-woody and all emergent species less than 3 ft (0.9 m) tall. Identify floating or submerged plants.	Monitor plant community at permanent sampling plots established within the restoration site and within an unaltered upstream reference site. Select three transects at each site, perpendicular to the streambank. Establish three permanent sampling plots along each transect according to vegetation types: herbaceous layer, shrub/sapling layer, and tree layer.	Vegetation monitoring is conducted best during the peak of the vascular plant growing season. In the northeastern U.S., this period is generally between July 15 and August 31. Vegetation monitoring should include a minimum of one year of pre-restoration and three years of post-restoration sampling. Preferably, post-restoration monitoring is conducted over a longer period, such as once every 3 to 5 years.
	Shrub and sapling layer	Within a 5-m (16.4 ft) radius, identify species and record percent cover of all woody stemmed plants with height 3–20 ft (0.9–6.1 m) and DBH 0.4–5.0 inches (1–12.7 cm). Note number of dead standing shrubs.		
	Tree layer	Within a 9-m (29.5 ft) radius, identify species and calculate basal area of each woody plant with height greater than 20 ft (6.1 m) and DBH greater than 5 inches (12.7 cm). Note number of dead standing trees.		
Macro-invertebrates	Recommend that project proponents work with regulatory jurisdictional authorities to develop a monitoring plan for macroinvertebrates. Please see Section IV.B.7 for additional guidance.			
Fish passage	Recommend that project proponents work with regulatory jurisdictional authorities to develop a monitoring plan for fish passage. Please see Section IV.B.8 for guidance.			

B. MONITORING METHODS

1. Monumented Cross-sections

Purpose

This section describes how to establish and survey permanent (i.e., monumented) stream cross-sections for long-term monitoring. It identifies the equipment needed, describes the basic protocol, discusses the frequency with which the cross-sections should be re-surveyed, and presents some site-specific considerations. This section does not provide detailed instruction on basic surveying techniques, such as conducting a level survey. For a more complete treatment of stream surveying techniques, see Harrelson et al. (1994).

Monitoring Design

Sampling Protocol

1. Define the monitoring reach.

Defining the length of the stream monitoring reach is the first step in conducting cross-section surveys. Upstream of the barrier, the monitoring reach should, at a minimum, include the length of the impoundment and a representative portion of undisturbed reach upstream of the barrier (e.g., a reach length of approximately 10 channel widths). The downstream monitoring reach is less easily defined because the length of reach physically impacted by the barrier, and/or its removal, is not generally known precisely beforehand.

Minimum Equipment

- ❑ Automatic level (surveyor's level) or laser level
- ❑ Leveling rod in English (to tenths and hundredths) or metric units, preferably 25-foot length
- ❑ Measuring tape in same units (300 ft or 100 m)
- ❑ Field book with waterproof paper
- ❑ Data sheets (see Appendix E)
- ❑ Pencil
- ❑ Permanent marker
- ❑ Two-way radios
- ❑ Topographic maps and/or aerial photographs
- ❑ Chaining pins
- ❑ Flagging tape
- ❑ Machete
- ❑ Wood survey stakes
- ❑ 4 ft (1.2 m) steel rebar stakes
- ❑ Hacksaw
- ❑ Small sledge or mallet
- ❑ Spring clamps
- ❑ GPS
- ❑ Compass

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Installing a monument.

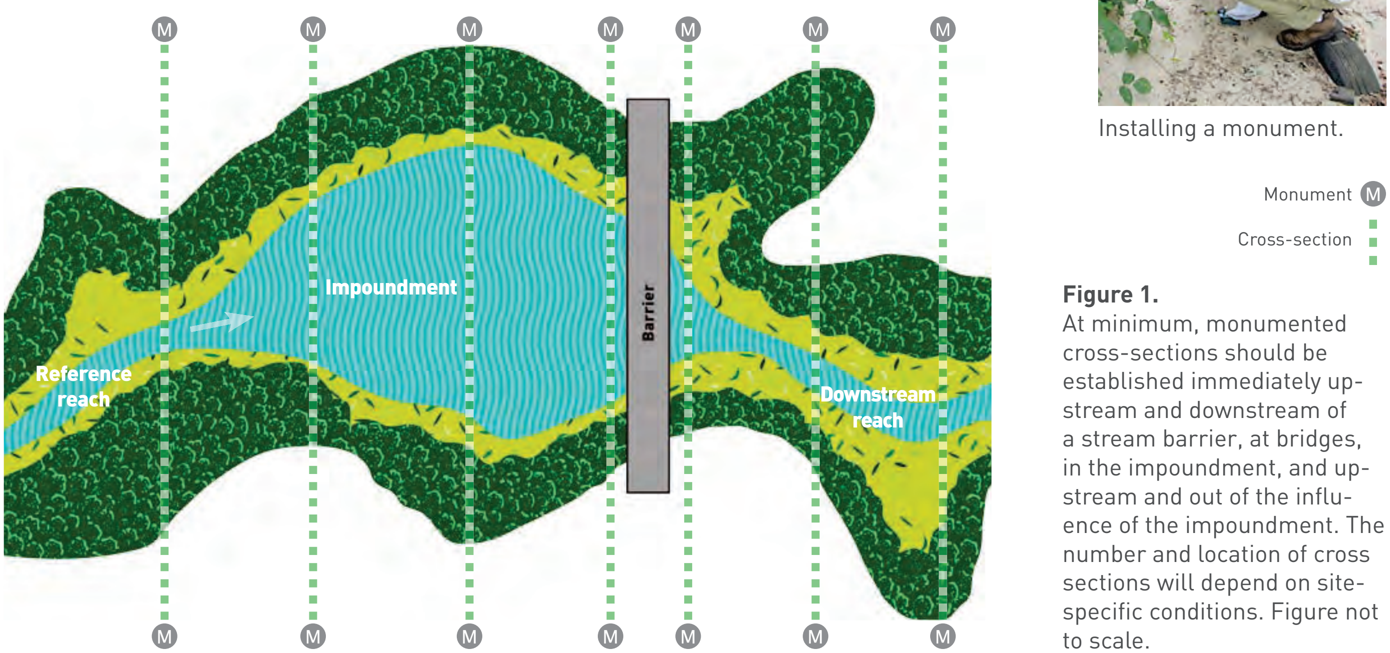

Figure 1.
At minimum, monumented cross-sections should be established immediately upstream and downstream of a stream barrier, at bridges, in the impoundment, and upstream and out of the influence of the impoundment. The number and location of cross sections will depend on site-specific conditions. Figure not to scale.

This length can be estimated, or the downstream limits can be identified based on other project considerations such as downstream habitats of concern, infrastructure, or locations of hydraulic or geomorphic controls such as bridges, outcrops, or knickpoints.

2. Determine number and location of cross-sections.
Once the length of the monitoring reach has been identified, the monitoring team must determine the number of cross-sections needed to adequately represent that reach. The most easily identifiable locations are those areas where infrastructure in the floodplain is likely to be impacted by the project. For example, cross-sections should be established immediately upstream and downstream of the barrier and at bridges within the identified project reach. There also should be cross-sections representing the impoundment (see Site Specific Considerations below), at least one in the undisturbed reach upstream of the impoundment, and at any locations judged to be sensitive to disturbance or of high habitat value. The engineering and geomorphic analyses used to plan the barrier removal should be consulted to identify critical locations. If present in the monitoring reach, cross-sections should be established at existing, monumented cross-sections and/or stream gage locations (Figure 1).

The choice of other cross-section locations should be based on the number of physically homogeneous stream reaches within the monitoring reach—those with similar slopes, bed and bank material, floodplain/terrace sequences, riparian vegetation, and channel-forming processes (Simon and Castro, 2003). For example, the number of cross-sections representing pools, riffles, meander bends, straight reaches, and flow divergence should closely approximate their proportion in the entire monitoring reach. Identification of these sub-reaches or cross-section types should begin with a pre-field inspection of available topographic maps, aerial photographs, surficial/bedrock geology maps, soil surveys, and other relevant information. In addition to subsequent field inspection, you may want to perform and plot a longitudinal profile to use in selecting cross-section locations (see section IV.B.2). Reviewing these data will be valuable for identifying reaches with similar physical characteristics and dominant processes.

3. Locate and establish the cross-section monuments.
At each cross section, establish the permanent markers for both endpoints by driving a ½-inch-diameter, 4-foot rebar stake either flush with the ground or ½ inch above the surface. You may want to cover the tops of the stakes with colored plastic caps available from survey suppliers and use different colors to distinguish different cross-sections (Harrelson et al., 1994). Be sure to note the color associations in the field book. The cross-sections should be straight and perpendicular to the bankfull flow direction, and they should extend across the floodplain/riparian zone to the first terrace or as far as practicable.

To facilitate locating each cross-section for future surveys, establish the horizontal position of the monuments via GPS and one other method. You can fix the position of monuments by taking a bearing and measured distance to the benchmark (see step 4 below), or by triangulating between the monument, benchmark, and another permanent feature on site (e.g., large, healthy tree or bedrock outcrop) (Harrelson et al., 1994; Miller and Leopold, 1961). If the benchmark is not visible from a given cross-section, triangulate with two permanent features. The GPS coordinates of each monument will facilitate mapping the cross-section locations in GIS. Once located, depict the cross-sections on a scaled map or aerial photograph of the project area.

4. Locate or establish the benchmark.
Once the cross-sections have been established, you must either locate, or establish, a local benchmark for the site. This is a permanent marker of known, or assumed, elevation that functions as survey control and the survey starting point. The U.S. Geological Survey (USGS) and other entities historically involved in developing geodetic control networks have benchmarks throughout the country. If one is available at your site, use it. They are typically found on stable site features such as bedrock outcrops; the tops of large, embedded boulders; and bridges.

In the event that a USGS or other geodetic control benchmark is not present in reasonable proximity to the project area, you will need to create a local, or project, benchmark. This offers the opportunity to establish it in a location that is advantageous for the survey; that is, locate it at a point relatively high on the site and visible from most, or at least many, of the permanent cross-sections. You can do so by driving a rebar stake 3 or 4 feet into the ground, chiseling a mark in an outcrop feature or stable boulder, or other means described by Harrelson et al. (1994). Be sure to describe its location in the field book and establish its coordinates with GPS. Always record the horizontal datum employed by the GPS (e.g., NAD 83). If you establish a benchmark, it is conventional to assign it an arbitrary elevation of 100 feet. Alternatively, the benchmark can be tied into an established vertical datum (e.g., NAVD

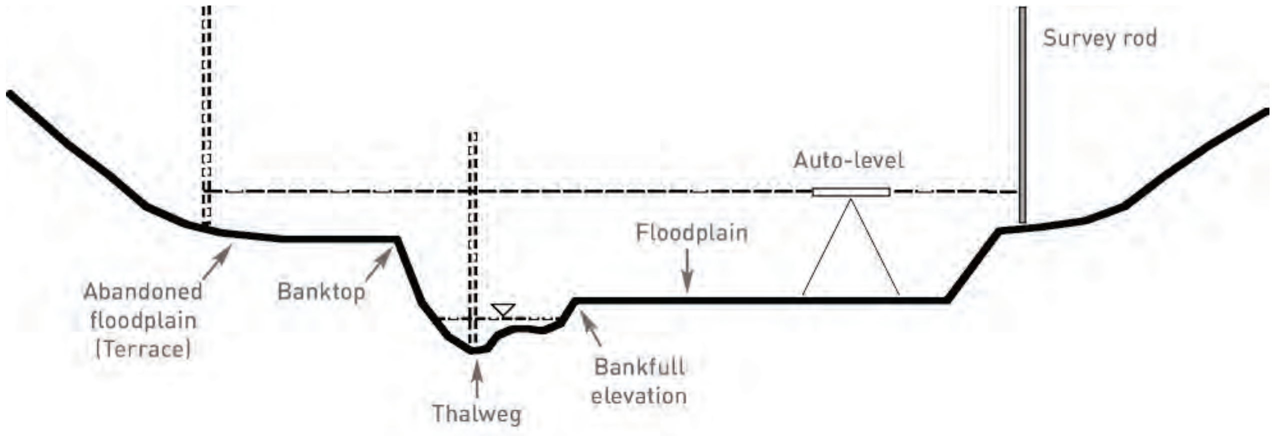

Figure 2. Basic channel and valley features of an unimpacted (reference) stream reach. Note that some features, such as the bankfull elevation, will not be identifiable in the impacted project reach or in all reference reaches.

88) or referenced to mean sea level for projects in areas subject to tidal influence. The horizontal and vertical datums used for the cross-sections should be used also for the longitudinal profile.

5. Set-up the survey instrument and tape.
If possible, set up the survey level in a location from which the local benchmark and all points of one or more cross-sections are visible. Though one or more cross-sections might be shot from one instrument station, to complete all cross-sections for your site you may need to set up two or more instrument stations. From each new instrument station you will need to take backsights on the benchmark (see below), if it is visible, or from turning points if it is not (Harrelson et al., 1994). A machete can be useful to trim low-hanging branches or other vegetation and decrease the number of times you need to move the instrument, but you should avoid cutting large amounts of vegetation for this purpose to minimize property and habitat impacts. At each cross-section, stretch a tape as taut as possible between the monuments. It can be attached to the monument itself with spring clamps, to a shorter rebar stake driven next to the monument with 6 inches exposed for easier attachment, or with chaining pins (Harrelson et al., 1994).

If you are using an optical surveyor's level (auto-level), the person operating the level will make and record the rod readings while the rod person will choose the survey points and call out the lateral distances to the level operator. Lateral distances are referenced to the left bank monument, which is the cross-section zero (left bank is referenced as the left bank looking in the downstream direction). A third person dedicated to recording all readings and descriptions in the field book is recommended and will be necessary for surveying the impoundment with a boat (see Site Specific Considerations below). One advantage of using a laser level is that one person can execute the cross-section survey (or two for impoundment surveys).

6. Survey the cross-section.
Begin with a rod reading on the benchmark. This "backsight" will be added to the elevation of the benchmark to establish the "height of instrument" (HI). All "foresights" on cross-section locations will be subtracted from the HI to obtain the elevation of those points (Harrelson et al., 1994). The first foresight will be taken at the left bank monument. From there, take readings at all breaks in slope and especially at significant geomorphic features as you make your way across the valley (e.g., bankfull, bank top, bank toe, bar tops, edge of water, thalweg), describing each feature in the notes for the respective reading (Figure 2). Capture features such as woody debris and bank-failure deposits, and record in the notes important changes in substrate type.

Also make notes about the nature of the vegetation, especially its structure (e.g., trees, shrub, herbaceous; see Section II.B.7 for the riparian plant community structure method), and be sure to record the locations where discrete changes occur. Adequately characterizing the complexity of the cross-section will typically require a minimum of 30 to 40 rod readings. Larger floodplains and more complex geometry can require many more. Record the horizontal distances to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Cross-section elevations are also recorded to hundredths of feet.

Bear in mind that identifying a bankfull channel will be most applicable to the cross-section(s) upstream of the hydraulic influence of the impoundment that represent the un-impacted channel reach. The bankfull channel is adjusted to an approximately 1.5- to 2-year recurrence interval discharge and the prevailing sediment transport conditions (Leopold et al., 1964). Because water flow and sediment discharge conditions will, in most cases, be changing at a barrier removal site, a persistent bankfull channel likely will not be identifiable in the monitoring reach. This may also be true of the reference reach, especially in watersheds with changing land use. See Harrelson et al. (1994) for a good discussion about field identification of the bankfull channel. The USDA Forest Service Stream Systems Technology Center (2003) also produces a video specifically geared towards field identification of the bankfull channel in the eastern United States (www.stream.fs.fed.us/publications/videos.html).

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Monument at a cross-section.

Sampling Frequency

Pre-removal surveys are essential for comparison with post-removal data to assess channel and floodplain response. Pre-removal surveys may be most easily accomplished if the impoundment can be drawn down before removal (see Site Specific Considerations below), such as during project feasibility studies. In any case, for efficiency purposes, selection of the long-term monitoring cross-sections and pre-removal data collection should be integrated with any planned feasibility work. As a general guideline, post-removal re-surveys should occur annually, or every other year, for at least 5 years. However, sampling frequency and duration should reflect project objectives and site conditions. For example, sites with great amounts of loose sediment may require more frequent sampling over a longer period than sites with bedrock channels or beds dominated by coarse materials. At a minimum, the frequency should conform to any regulatory requirements. The monuments should be recoverable for much longer so that longer-term studies of channel evolution are possible.

Site-specific Considerations

Some of the pre-removal cross-sections will need to traverse the impoundment. The determination of whether cross-section data in an impoundment can be acquired by wading or using watercraft must consider the depth of the impoundment and suitability of sediment for wading. Impounded sediments may be unconsolidated, fine-grained material with saturated interstitial spaces, making them very soft and incapable of supporting a wader. In such conditions, it will be necessary to obtain the data from a boat. Depending on the nature and depth of the impoundment, surveying cross-sections within it can be accomplished either by employing the methods described in the previous section and taking rod readings at fixed intervals from a small boat, or by using a fathometer from a boat navigated along the transect and integrating the readings with the rod readings on shore via GPS positioning. If you are taking rod readings from a small boat, you will need to take care in positioning the rod and try to make sure the rod rests on top of the sediments and does not sink into soft substrate. At least two people are needed for boat work—one to work the survey rod and the other to station the boat.

Analysis and Calculations

The data from a cross-section survey are elevations and distances. Horizontal distances are recorded to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Cross-section elevations are recorded to hundredths of feet. These data should be recorded in standard level-survey notation (see Cross-Section Survey Data Sheet in Appendix E). Harrelson et al. (1994) also provide a nice graphic example of proper field book notation for level surveys. The horizontal and vertical datums of the survey must always be recorded (see Site Information Data Sheet in Appendix E). The distances and elevations can be plotted manually on graph paper as 'x' and 'y' coordinates, respectively, or brought into a spreadsheet program for plotting and analyses.

Additional Information

Harrelson et al. (1994) provide an excellent reference for basic survey techniques and for specific information on conducting cross-section and longitudinal profile re-surveys. We strongly recommend that readers with minimal experience consult this reference. It also is a useful review for those with more experience.

2. Longitudinal Profile

Purpose
This section describes how to survey the longitudinal profile of the channel thalweg at your monitoring reach. It identifies the equipment needed, outlines the basic protocol, discusses the frequency with which the profile should be re-surveyed, and presents any site-specific considerations. As with the monumented cross-section method (see Section IV.B.1), this section does not provide detailed instruction on basic surveying techniques. See Harrelson et al. (1994) for a more complete treatment of this subject.

Monitoring Design
Sampling Protocol

1. Define the monitoring reach.
This must be accomplished before surveying the longitudinal profile and the cross-sections. See Section IV.B.1 for general guidelines. Your longitudinal profile should extend the length of the monitoring reach, beginning at a stable channel feature (e.g., riffle) upstream of the impoundment. Your profile should always begin upstream of the uppermost cross-section and should continue to the lowermost cross-section and include survey shots at the thalweg of all monumented cross-sections.

Minimum Equipment
- ❑ Automatic level (surveyor's level), laser level, or total station
- ❑ Leveling rod in English (to tenths and hundredths) or metric units, preferably 25-foot length
- ❑ Measuring tape in same units (300 ft or 100 m)
- ❑ Field book with waterproof paper
- ❑ Data sheets (see Appendix E)
- ❑ Pencil
- ❑ Permanent marker
- ❑ Two-way radios
- ❑ Topographic maps and/or aerial photographs
- ❑ Chaining pins
- ❑ Flagging tape
- ❑ Machete
- ❑ Wood survey stakes
- ❑ Small sledge or mallet
- ❑ Spring clamps
- ❑ Compass

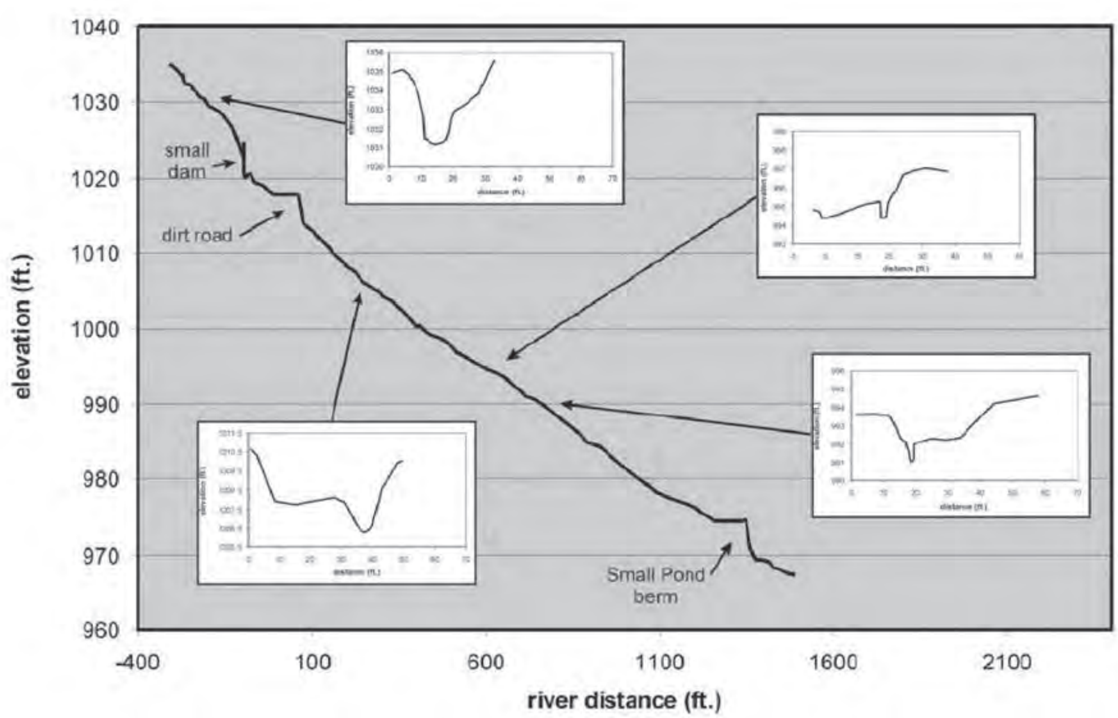


Figure 3. A longitudinal profile surveyed pre-project at Kamrath Creek, Wisconsin. The survey points for a channel bed longitudinal profile are taken at the deepest point in the channel, i.e., the thalweg (see Figure 2). Profile plot courtesy of Brian Graber.

2. Set up the survey instrument.
If possible, set up the level in a location from which the benchmark, and as much of the monitoring reach as possible, is visible (See Section IV.B.1, step 4, for information on benchmarks). You may want to consider setting up the instrument in the channel, if the flow and bed conditions permit (Harrelson et al., 1994). Choose instrument locations carefully to minimize the number of times you need to reposition.

3. Establish the stationing:
Downstream distance should be measured along the channel thalweg. A straightforward method is to station the channel with a baseline along one bank. The downstream distance of each survey shot is measured as the right-angle projection from that location to the baseline on the bank.

The baseline can be established by two people measuring along the stream thalweg with a tape, while someone on shore drives, and clearly marks, wooden survey stakes at regular intervals (commonly a channel width). The purpose of the stationing stakes is to make estimating distances easier. They do not necessarily mark the locations of actual survey shots. See Harrelson et al. (1994) for further information on stationing. Using a total station with a GPS interface, if available, can make stationing unnecessary and considerably simplify profile completion. These units can "fix" the horizontal position of survey shots in known datums such as NAD 83 for subsequent plotting in GIS and calculating distances. Total stations and laser levels are also advantageous for profile surveys because of the long distances over which they can obtain shots (Simon and Castro, 2003).

4. Survey the profile.
Begin with a rod reading on the benchmark to determine the height of the instrument (HI) (see Section IV.B). Then take readings along the thalweg (i.e., deepest part of the channel) at important bed features (e.g., pools, riffles, bedrock sills, woody debris), measuring downstream distance using the baseline. Include enough shots to well define each feature (Simon and Castro, 2003). It is particularly important to determine the highest elevation at pool-riffle (and/or run) transitions.

Along with distances and elevations, record in the field book details about the feature being measured and the locations of important changes in substrate type. Also, take elevations of the water surface at each bed elevation measurement. This can be done easily by taking the elevation of the water's edge closest to the thalweg along the projection to the baseline. Move the instrument as needed to complete the profile.

Sampling Frequency
As with the cross-section surveys, a pre-removal longitudinal profile may be accomplished most easily during an impoundment draw-down and should be integrated with any planned feasibility work (see Site Specific Considerations below). As a general guideline, post-removal re-surveys should occur annually, or every other year, for at least 5 years. However, sampling frequency and duration should reflect project objectives and site conditions. At a minimum, the frequency should conform to regulatory requirements. Note that follow-up surveys should trace the post-barrier removal thalweg, which may not be in the same horizontal position as the pre-removal thalweg.

Site-specific Considerations
A portion of the pre-removal longitudinal profile will run through the impoundment. As with the cross-sections, this may require a boat and should be done with great care. See Site Specific Considerations under Section IV.B.1 for general guidelines and considerations.

Analysis and Calculations
The data from a longitudinal profile survey are elevations and distances. Horizontal distances are recorded to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Profile elevations are recorded to hundredths of feet as well. These data should be recorded in standard, level survey notation (see Longitudinal Profile Survey Data Sheet in Appendix E). Harrelson et al. (1994) also provide a nice graphic example of proper field book notation for level surveys. The horizontal and vertical datums of the survey must always be recorded (see Site Information Data Sheet in Appendix E). The distances and elevations can be plotted manually on graph paper as 'x' and 'y' coordinates, respectively, or brought into a spreadsheet program for plotting and analyses (Figure 3).

Additional Information
Harrelson et al. (1994) is an excellent reference for basic survey techniques and for specific information on conducting cross-section and longitudinal profile re-surveys. We strongly recommend that readers with minimal experience consult this reference. It also provides a useful review for those with more experience.

3. Grain Size Distribution

Purpose

This section presents methods for characterizing streambed surface grain size distributions by collecting and analyzing sediment samples at a stream channel cross-section. It identifies the equipment needed, outlines the basic protocol, discusses the sampling frequency, and presents site-specific considerations.

Monitoring Design

As with any sampling effort, surface sediment sampling aims to characterize a larger population of bed materials for which a complete census is impractical. To do so, a sample must be random, comprise enough grains for an adequate sample size, and be drawn from a homogenous streambed area. For streams with beds dominated by sand size sediments and finer, it is relatively easy to obtain a large enough sample that can be analyzed in the lab. There, sandy sediments are dried and passed through progressively finer sieves and the weights of materials retained on sieves of particular size classes are recorded. Finer fractions must be separated by sedimentation (e.g., hydrometer or pipette), elutriation, or centrifuge separation (Kondolf et al., 2003). With the weights obtained of the various size fractions, the grain size distribution is then presented as cumulative percent finer by weight.

For gravel-bed streams, however, the requisite sample sizes are too large to be transported off-site and are impractical to sieve in the field. To address this problem, geomorphologists have developed field-sampling techniques that require no lab analyses. The most enduring protocol was developed by Wolman (1954) and is referred to as a Wolman Pebble Count. Put simply, this method prescribes randomly collecting and measuring at least 100 particles from a homogeneous area of the streambed. From these data, a grain size distribution is developed as the cumulative frequency of numbers of stones of different size classes. If the sampled stones are of the same density, which will be true if sampling one lithology, the results obtained will be comparable to a distribution by weight (Kondolf et al., 2003). [If the bed of your cross-section is composed of heterogeneous composition of bed material sizes, or facies (determined by eye), the sample can be improved by collecting 100 particles from each facies and calculating a weighted average grain size distribution with estimated proportions of the bed occupied by each facies. See Kondolf et al. (2003) for a more complete treatment of how to handle a cross-section with mixed populations of bed materials.]

Minimum Equipment

- ❑ Measuring tape in same units as rod (300 ft or 100 m)
- ❑ Ruler marked in millimeters
- ❑ Gravel template (optional)
- ❑ Field book with waterproof paper
- ❑ Pencil
- ❑ Chaining pins
- ❑ Data sheets (see Appendix E)

There are differing standards in the literature regarding the proper sample size for Wolman Pebble Counts, sources of error in conducting them, and ways to improve sampling technique to reduce those errors (see Brush, 1961; Hey and Thorne, 1983; and Fripp and Diplas, 1993 for more discussion). We do not present varying standards here but have adopted some recent modifications to the Wolman Pebble Count that are designed to address observed deficiencies. We also prescribe collecting a minimum of 100 particles, recognizing that collecting larger sample sizes—up to 300 or 400—could improve results (Olsen et al., 2005, Rice and Church, 1996). Within the context of this Monitoring Guide, we do not feel the precision gained merits the extra effort required, although we do encourage collecting a larger sample size if project resources permit.

Sampling Protocol

Because the bed sediment characteristics of a given barrier removal stream reach are not typically known beforehand, nor is the variability between cross-sections, the following protocols address sampling of beds dominated by 1) sand-size and finer sediments or 2) gravel. Note that both methods may be relevant to a given project, particularly for pre-project monitoring of proposed dam removal sites (see Site-specific Considerations below).

At a minimum, collect a bed material sample for at least one of each cross-section type representing physically distinct stream reaches in the monitoring reach and at cross-sections where important infrastructure or habitat zones are located. In all likelihood, this means you will collect bed material samples for only a subset of the cross-sections you re-survey.

At all sampled cross-sections, samples should be collected from within the normal low flow channel unless particular study objectives require characterizing the bed of the larger bankfull channel. In these situations, sample between the toe of bank on each side of the stream (some of which may be dry at sampling time).

Cross-sections Dominated by Fine Sediments (Sand Size and Finer)
At these cross-sections, each sample point should be composed of approximately one liter of surface sediments for laboratory evaluations (i.e., a bulk sample). On exposed beds or bars samples can be obtained with a trowel or shovel. A variety of bed material samplers (e.g., grab samplers) can be used for sample acquisition under water. The number and location of samples required to characterize the cross-section will depend on how heterogeneous the bed material is in that stream reach (Kondolf et al., 2003). If multiple samples are required to characterize a heterogeneous cross-section, compositing those samples for laboratory analyses may be appropriate.

Cross-sections Dominated by Gravel
1. Perform a pebble count at each selected cross-section after a cross-section survey is performed to make use of the tape already stretched across the channel.

2. Assign a sampler to collect and measure the particles and a reader to record the results. The sampler calls out the measurements to the reader. The reader repeats back each measurement as a quality control check.

3. The sampler will walk back and forth along the transect, and perhaps 2 to 4 others closely paralleling the transect, reaching down at regular intervals to pick up a particle near the tip of their boot. The intervals should be scaled to the length of the transect(s) such that 100 particles will be collected. For example, if the transect length is 10 meters and the sampler's stride is a half meter, approximately 20 samples will be collected with each bank-to-bank sampling pass, and at least 5 passes will be required to obtain a minimum of 100 samples.

4. As the sampler's finger falls to the bed to pick up the particle, the sampler should not look at the stream bottom to avoid bias toward selecting larger particles. The sampler should pick up the first particle encountered. Do not count organics such as wood fragments or other detritus. If the sampler touches fine material that is clearly less that 4 mm, the sampler should simply call out "fines" to the reader who will record the occurrence in the < 4 mm size class (see Table 3 in Analysis and Calculations below). For larger particles, the sampler measures the particle's "b-axis" in millimeters (mm) and calls out the measurement to the reader.

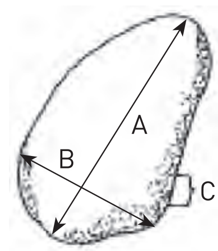


Figure 4. Particle axes (from Potyondy and Bunte, 2002).
A = Longest axis (length)
B = Intermediate axis (width)
C = Shortest axis (thickness)

The b-axis can be identified by first finding the long axis (A), then the short axis (C), and finally the intermediate axis (B) that is perpendicular to both the A and C axes (see Figure 4). The b-axis is the axis that governs whether a particle will fit through a sieve mesh of a given size, so measuring it gives results most comparable to a standard sieve test. The particle can also be measured using a particle size template or "gravelometer" (Potyondy and Bunte, 2002). Doing so can reduce observer error in measuring the b-axis. Whichever measurement method is employed, either ruler or gravel template, be sure to consistently use that method from year to year throughout the monitoring period so that results are directly comparable.

5. Repeat this procedure until at least 100 particles have been collected.

Sampling Frequency
Sampling should be conducted at the same frequency as the cross-section surveys (see Section IV.B.1) and performed during wading-depth stream conditions.

Site-specific Considerations
For dam removal sites, bed material samples should be collected from at least two cross-sections in the impoundment: one representing the upper impoundment and another representing the lower impoundment. Impounded sediments will frequently be sand-size and finer deposits that need to be collected as bulk samples from a boat with a grab sampler or other similar device (see above). As with other cross-section sampling locations, the number and location of samples at a cross-section will depend on the heterogeneity of the bed material there. If the general location of the post-removal channel is also known, this information should influence the choice of sampling locations.

For many dam removal projects, feasibility studies will include contaminant sampling of sediments in the impounded area. For efficiency purposes, the long-term bed sediment monitoring program should be coordinated with any such investigations so that some of the contaminant sampling locations are coincident with at least one long-term monitoring transect and to ensure that the samples are analyzed in the laboratory for grain size.

Analysis and Calculations

The data from a pebble count are simply counts of particles in different size classes. For example, a particle with a b-axis measuring 100 mm will be recorded in the row marked “<128” on Table 3 and a particle measuring 65 mm will be marked in the “<90” row. In the office, hash marks can be tallied and the percent frequency and cumulative percent finer can be calculated with a spreadsheet program. The cumulative percent finer can be plotted as shown in Figure 5. The results of fine sediment bulk samples sent to the lab should be reported in a similar manner.

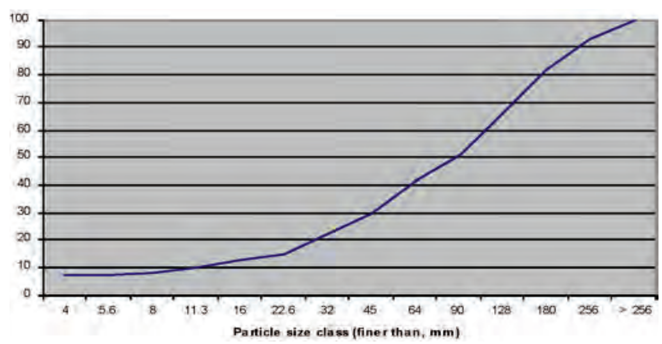
Additional Information

Kondolf and others (2003) provide a good overview of bed sediment sampling in general. Bunte and Abt (2001) and Kondolf (1997) should be reviewed for a more thorough treatment of sampling coarse-grained bed sediments.

Table 3. Example spreadsheet developed from field notes. Note that the first and second columns are the only columns needed in the field book. Note also that recording counts as hashes in the second column builds a histogram in the field.

Size Class (mm)	Count	Count	Frequency (%)	Cumulative % Finer
>=256	𝍸 ||	7	7	100
<256	𝍸 𝍸 |	11	11	93
<180	𝍸 𝍸 𝍸 |	16	16	82
<128	𝍸 𝍸 𝍸	15	15	66
<90	𝍸 𝍸	10	10	51
<64	𝍸 𝍸 |	11	11	41
<45	𝍸 |||	8	8	30
<32	𝍸 ||	7	7	22
<22.6	||	2	2	15
<16	|||	3	3	13
<11.3	||	2	2	10
<8	|	1	1	8
<5.6		0	0	7
<4	𝍸 ||	7	7	7
	Totals:	100	100	

Figure 5. Cumulative frequency curve generated from pebble counts.



Karla Garcia / NOAA Restoration Center

Bed sediments downstream of a dam in New Hampshire.

4. Photo Stations

Purpose

Maintaining a standardized photo/video monitoring record of stream barrier removal projects can serve multiple purposes, from tracking the visual changes of a site over time to satisfying grant and regulatory requirements. Photographs used for stream restoration monitoring can capture various physical and biological conditions such as changes in riparian vegetation or changes in channel features. Photographic images of pre-and post-restoration conditions can showcase project successes and can be used to promote future restoration projects. This section describes how to conduct standardized photo monitoring specific to stream barrier removal projects in the Gulf of Maine watershed.

Minimum Equipment

- ❑ Digital camera (preferred specifications: optical zoom, video function, >3 megapixel resolution)
- ❑ Extra batteries (digital-camera grade)
- ❑ Compass with degrees
- ❑ Site plans, topo maps, aerial photos
- ❑ Timepiece
- ❑ Field notebook or sketch pad
- ❑ Pencils and pens
- ❑ Data sheets (see Appendix E)
- ❑ Tape measure
- ❑ GPS unit (optional)
- ❑ Monumenting material: stakes, rebar, hammer, flagging (optional)
- ❑ Stadia rod (optional)
- ❑ Chalk board/white board (optional)

Monitoring Design

A critical component of photo monitoring is ensuring that key landscape features are represented at a scale and resolution that is legible and reproducible. Another critical component and perhaps the most complicated aspect of this relatively simple monitoring procedure is being able to locate each photo station over multiple years and reproduce the same vantage point. Detailed documentation is essential to capturing adequate information for resurveying each photo station.

Sampling Protocol

The length of time required to complete photo monitoring will depend upon the size of the site and the scale of monitoring efforts. For quality assurance, photo monitoring is best accomplished with two people. A field partner, equipped with a stadia rod and whiteboard can provide scale to a photograph and convey critical site information. Prior to establishing photo stations in the field, you should chart out potential stations on a site plan, topographic plan, or aerial photo. Ideally this plan should include cross-sections and physical features of your site. Before permanent photo

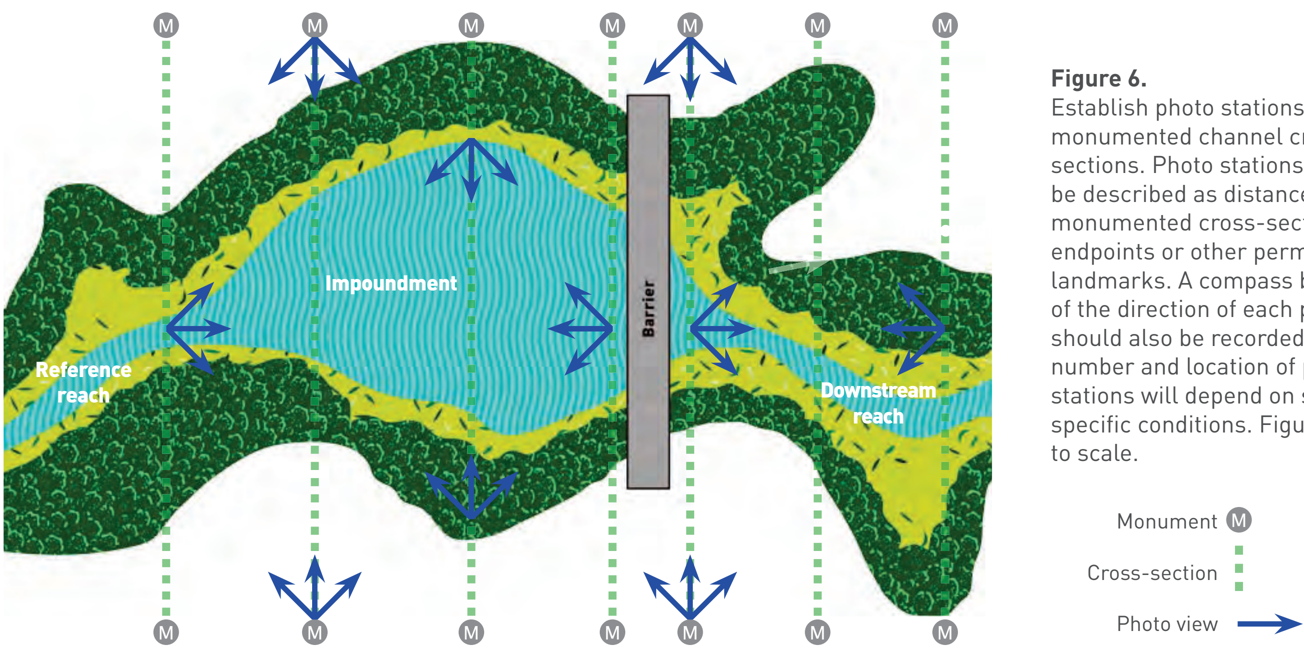


Figure 6.
Establish photo stations along monumented channel cross sections. Photo stations should be described as distances from monumented cross-section endpoints or other permanent landmarks. A compass bearing of the direction of each photo should also be recorded. The number and location of photo stations will depend on site-specific conditions. Figure not to scale.

stations are established, a brief reconnaissance of the site should be conducted to confirm the suitability of predetermined sites.

Locations of photo stations should be described as distances and/or bearings from other known points such as cross-section endpoints or other permanent landmarks. Geographic context of each photo should, at minimum, include: left bank, right bank, upstream, downstream (left and right bank determinations are made facing downstream). Photo station locations should be selected to take advantage of complimentary light, include long-term reference points (buildings or permanent landscape features), and be easily accessible for post-restoration monitoring. Once permanent stations are decided upon, these locations should be monumented with staking, if possible. Flagging can also be used but should be considered a temporary means to mark a photo station. Date-stamping digital photographs can be helpful, but it can be problematic if the date stamp obscures important parts of the image.

The following views are recommended:

- Upstream and downstream view of the barrier.
- Upstream and downstream view from the barrier.
- Across the barrier from left bank to right bank and vice versa.
- Across and along monumented cross-sections from both cross-sectional end points, including floodplain and riparian wetlands.
- Along the longitudinal profile.

Special emphasis should be paid to the following:

- Ecosystem features such as wetland plant communities, floodplains, riparian vegetation, streambanks, meanders, depositional/erosional features, flow-diverting structures, riffles, pools, and large woody debris.
- Events such as barrier removal, high-water conditions, low-flow conditions, and any other noteworthy natural or anthropogenic events.

Sampling Frequency

At a minimum, pre-and post-project photo monitoring is needed to create a valuable image record. The best time to take pre-restoration photos or videos is during leaf-out so landscape features and physical structures are clearly visible, unless the goal of the photo and video record is to document vegetation changes. In that case, specific emphasis should be on the flowering periods of signature riparian plants. We recommend that pre-restoration photo monitoring include both leaf out and full vegetation in the year preceding restoration. Post-restoration photo monitoring is recommended for 1, 2, and 5 years after the restoration project (Table 4). Photo monitoring during construction is equally important as pre-and post-restoration monitoring and can be used to capture short-term changes in ecosystem conditions; inform the efficacy of implementation techniques; confirm implementation success; and support as-built design plans.

Site-specific Considerations

The scale of the project will dictate how photo monitoring is done. For example, it may be difficult to portray adequately a large impoundment with normal photography, in which case aerial photography should be considered. Aerial photography can be used to determine landscape feature changes such as large-scale changes in impoundment area, stream-course narrowing, thalweg configuration, and large-scale vegetation changes. Historical aerial photographs can illuminate important landscape changes, which is particularly useful for informing pre-restoration decisions.

Analysis and Calculations

Appropriate documentation and organization is necessary to store and properly manage digital photos. The photo log form should be filled out if any photos are taken (see Appendix E). Each photo station should be marked on a plan or sketch with arrows indicating direction or compass bearing of the photo (Figure 6). Once uploaded, picture files should be properly labeled and stored in appropriate folders labeled by site name and date. Metadata should be stored with pictures.

Additional Information

These methods for photo monitoring of stream barrier removal monitoring projects were informed by Collins (2003), Landry (2002), and Hall (2002).

Table 4. Recommended photo-monitoring timeline for stream barrier removal projects.

Project phase	Pre-restoration		Restoration	Post-restoration					
Year	–1		0	1		2		5	
Timing of photo monitoring	Full vegetation	Leaf out	Multiple times throughout	Full vegetation	Leaf out	Full vegetation	Leaf out	Full vegetation	Leaf out

5. Water Quality

Purpose

Aquatic organisms such as fish and macroinvertebrates have varying tolerances to dissolved oxygen, temperature, conductivity, salinity, and pollution. Measuring water quality parameters at a barrier removal site offers insight regarding the quality of habitat available and the species that can be supported at that site. Conductivity data can show evidence of pollution and groundwater sources of surface water. Salinity, when measured at an intertidal barrier, may be used predict the aquatic species as well as vegetation that may colonize an area after the barrier is removed.

This section describes how to measure temperature, dissolved oxygen (DO), conductivity, and salinity at a barrier removal site. We recommend that the user monitor these parameters at least once per week for eight weeks during August and September (see Sampling Frequency below for further discussion). Monitoring should be done as close to dawn as possible. This monitoring design will allow the user to describe how a barrier is impacting water quality at a site and how conditions change with barrier removal. This design is intended as a minimum, and the user may choose to conduct more monitoring to answer questions specific to a particular barrier removal project.

Minimum Equipment

- ❑ Pencils
- ❑ Clipboard
- ❑ Multi-parameter probe
- ❑ Equipment calibration solutions
- ❑ Data sheets (see Appendix E)
- ❑ Bucket (if necessary)
- ❑ Watch
- ❑ Air thermometer
- ❑ Chest waders
- ❑ Boat

Equipment Considerations

Water temperature, conductivity, and salinity are most commonly measured using electrometric equipment. Temperature, conductivity, and salinity probes and meters are available from a number of vendors. Conductivity is often reported in terms of specific conductance (i.e., conductivity results that have been adjusted to what it would be at 25°C). Most conductivity probes have a feature that can automatically convert conductivity readings at any temperature to specific conductance values. Probes and meters are available that measure all three of those parameters—temperature,

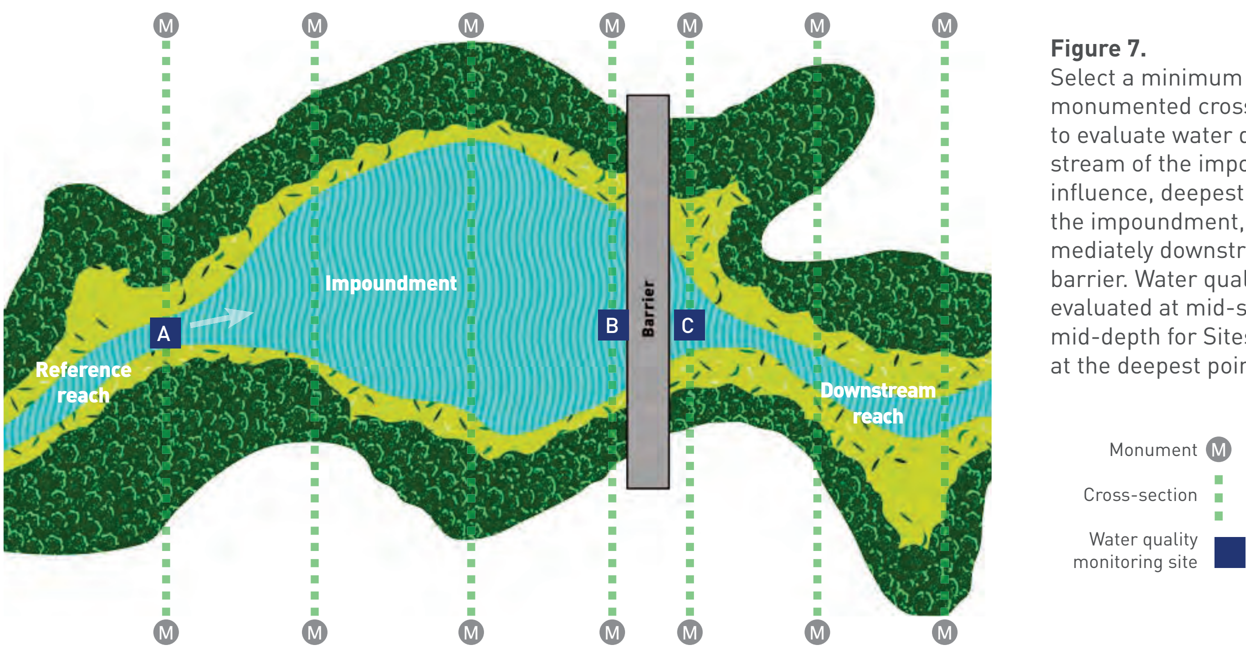


Figure 7.
Select a minimum of three monumented cross-sections to evaluate water quality: upstream of the impoundment influence, deepest point within the impoundment, and immediately downstream of the barrier. Water quality should be evaluated at mid-stream and mid-depth for Sites A and C and at the deepest point for Site B.

conductivity, and salinity—plus dissolved oxygen (DO) (see below). Calibration, use, and maintenance will vary among equipment and between manufacturers. Careful treatment and regular equipment maintenance are essential for accurate data collection. Salinity need only be measured if barrier removal is occurring in an intertidal area and the removal is expected to restore tidal flow. If it is necessary to collect data along a vertical profile, be sure to purchase or secure the use of a probe with a long cord so that the data can be collected at the appropriate depth.

Two methods are commonly used for measuring dissolved oxygen: the Winkler method and the electrometric method. Each requires different equipment. The choice of method depends on the desired accuracy, convenience, staff training level, and available equipment. In general, the Winkler method is held to be more precise and accurate than a meter and probe. However, the results can be influenced in the field by such factors as nitrite, organic matter, iron, and the capabilities of the person collecting the data. A comparison of the two methods is beyond the scope of this document; refer to sources such as Standard Methods for the Treatment of Water and Wastewater (APHA, 2006) and the National Environmental Methods Index (www.nemi.gov) for detailed information about both methods.

The Winkler method is a titration procedure based on the oxidizing property of dissolved oxygen (USEPA, 1983). Samples analyzed with the Winkler method can be analyzed on site or fixed (stabilized), refrigerated, and analyzed in the lab up to six hours after collection. Several vendors sell kits that include the necessary equipment, chemicals, and detailed instructions for analyzing water samples. The user must read Material Safety Data Sheets (MSDS) for all chemicals and take safety precautions.

The electrometric method relies on the diffusion of oxygen across a membrane located in a probe-based sensor. Measurements must be taken either in the stream or impoundment itself or immediately after collection in a bucket. DO instruments are available from a number of commercial vendors. The instructions for calibration, use, and maintenance may differ from instrument to instrument and among manufacturers. Therefore, the user is encouraged to read the instructions carefully and follow them closely. DO probes in particular are extremely sensitive. Careful treatment and equipment maintenance are essential for accurate data collection. The U.S. Geological Survey offers a thorough discussion of dissolved oxygen equipment calibration in its National Field Manual for the Collection of Water-Quality Data (Wilde, 2005). Note that if DO is being measured in a saline environment, a correction factor must be applied after the data are collected.

Monitoring Design

This monitoring design is based on the cross-section design described in section IV.B.1. The sampling design will describe water quality conditions upstream of the zone of influence of the barrier, just upstream of the barrier, and downstream of the barrier. These data will reveal how the barrier is affecting water quality before barrier removal. After the barrier is removed, returning to the previously monitored sites will show how barrier removal has affected water quality at the site.

Sampling Protocol

1. Identify three water quality data collection sites.
Site A should be upstream of the area influenced by the barrier, preferably along the furthest upstream cross-section (Figure 7). Water-quality data should be collected mid-stream and at mid-depth.

Site B should be along a cross-section that traverses the deepest part of the impoundment, and water-quality data should be collected at the deepest point. If there is no impoundment, Site B should be located along the cross-section immediately upstream of the barrier.

Site C should be located along the cross-section just downstream of the barrier. Water-quality data should be collected mid-stream and at mid-depth (Figure 7).

2. Document location of each water-quality monitoring site so user may return to sites in the future.
Describe the location of each monitoring site in relation to the cross-sections and in relation to any permanent markers or landmarks at the site, making sure to note cross-section number. Document with GPS the location of each monitoring site. Compile this information so that it can be accessed as necessary.

3. Prepare for field data collection.
Review the instruction manuals for each meter and probe being used. Make sure that probes are undamaged and are functioning properly. Inspect electrical connections and batteries. Install new batteries if necessary. Test calibration. Collect and inventory field equipment. If the Winkler titration method is being used, review the method, and make sure that the reagents have not expired. Before handling chemicals, check Material

Safety Data Sheets (MSDS) for safety precautions.

4. On the day of field data collection, calibrate the meters, being sure to follow the manufacturer's instructions.
Record all calibration data. Bring calibration solutions into the field in case recalibration is necessary.

5. Collect water quality data.
Data must be collected early in the morning, preferably close to daybreak, in order to capture the lowest dissolved oxygen readings of the diurnal cycle. The USGS National Field Manual for the Collection of Water-Quality Data (Wilde, 2005) has an excellent discussion of surface-water sampling. All data should be collected in situ. Record the time of each water-quality measurement.

Sites A and C: Collect dissolved oxygen, temperature, and specific conductance data mid-stream at mid-depth. Follow manufacturer's instructions for meters and probes. For the Winkler titration method, it will be necessary to collect a water sample in a labeled "Biological Oxygen Demand" bottle.

Site B: If this site is located in an impoundment, collect a water-quality vertical profile. Collect dissolved oxygen, temperature, and conductivity information just below the surface of the impoundment and then at foot-intervals below the surface until the probe is located just above the bottom of the impoundment.

Step 6. Maintain equipment.
After the field visit, clean equipment and conduct any necessary maintenance.

Sampling Frequency

All data should be collected weekly for eight weeks during August and September. Data should be collected early in the morning, as close to dawn as possible. This is necessary in order to collect information on dissolved oxygen when it is at its lowest point in the diurnal cycle.

Macroinvertebrate data will complement the water-quality data. If macroinvertebrate data are not being collected, however, then water-quality data should be collected weekly from June through October or through continuous monitoring. Data should be collected at least one year prior to barrier removal at a minimum, immediately after barrier removal, and annually thereafter for five years. Additional water-quality monitoring prior to barrier removal projects is preferred.

Table 5. Recommended precision and accuracy levels for water quality data.

Parameter	Precision	Accuracy
Dissolved oxygen	+/- 2% or 0.2 mg/L, whichever is greater	+/- 2% of initial calibration saturation or 0.2 mg/L, whichever is greater
Conductivity	+/- 5%	+/- 5% against a standard solution
Temperature	+/- 0.2° C	+/- 0.2° C (checked against a NIST-certified thermometer)

Site-specific Considerations

If the barrier is located in an intertidal area, salinity should be added to the monitoring protocols at all sites before and after barrier removal. Refer to Lane and Fay (1997) for guidance on safety procedures (e.g., sample collection safety, wading in streams, boating safety, chemical handling).

Analysis and Calculations

We recommend precision and accuracy levels for the data collected rather than specific pieces of equipment. Water-quality equipment varies widely in its precision and accuracy. State and provincial governments may prefer different types of equipment, and project budgets may vary. The user is encouraged to use equipment available through project partners or that fits their budget, as long as the data meet the recommended precision and accuracy guidelines (Table 5). QA/QC samples should be collected at a frequency of 1 in 10, or 10%.

6. Riparian Plant Community Structure

Purpose

This section describes the equipment, sampling protocols, sampling frequency, and site selection considerations for monitoring of the riparian zone plant community. Parameters include species abundance, composition, percent cover, stem density, and basal area. These parameters describe the riparian plant community and identify changes in the riparian zone that may occur over time.

Monitoring Design

A plant community is an association of plant species in a given place. Community structure is inclusive of all plants that occur in the tree, sapling and shrub, and ground cover (vine/liana and herbs) vegetative layers. The composition and percent areal cover of plants, as well as their general condition with respect to both native and non-native species, describes riparian plant communities. Collecting and analyzing plant community data following well-recognized methods, such as the step-by-step protocol listed below, provides the basis for documenting these communities for purposes of their protection, conservation, and/or restoration. A data sheet that is specific to the protocol outlined below is provided in Appendix E. We recommend using it for your site assessments.

Minimum Equipment

Riparian vegetation monitoring requires relatively limited equipment but should be conducted by persons trained in botany, field plant identification, and the use of systematic keys for plant identification. Field equipment should include, at a minimum:

- ❑ Laminated, scaled maps (e.g., NWI, soil survey maps) or aerial photographs, protected in clear, resealable plastic bag or folder, depicting the stream/river reach, riparian study area, and bordering uplands
- ❑ Field notebook, pencils, waterproof permanent markers, and clipboard
- ❑ Data sheets (see Appendix E)
- ❑ Tape measure (100 ft or 300 ft open-reel fiberglass tape)
- ❑ Meter stick for measuring plant heights
- ❑ Rebar or wooden survey stakes to serve as permanent monuments/markers to identify transect endpoints and plot locations
- ❑ Diameter at breast height (DBH) tape to measure trees
- ❑ Camera and photo monitoring data sheets
- ❑ Resealable plastic bags for plant specimens
- ❑ Hand lens for keying-out plants
- ❑ Plant identification keys

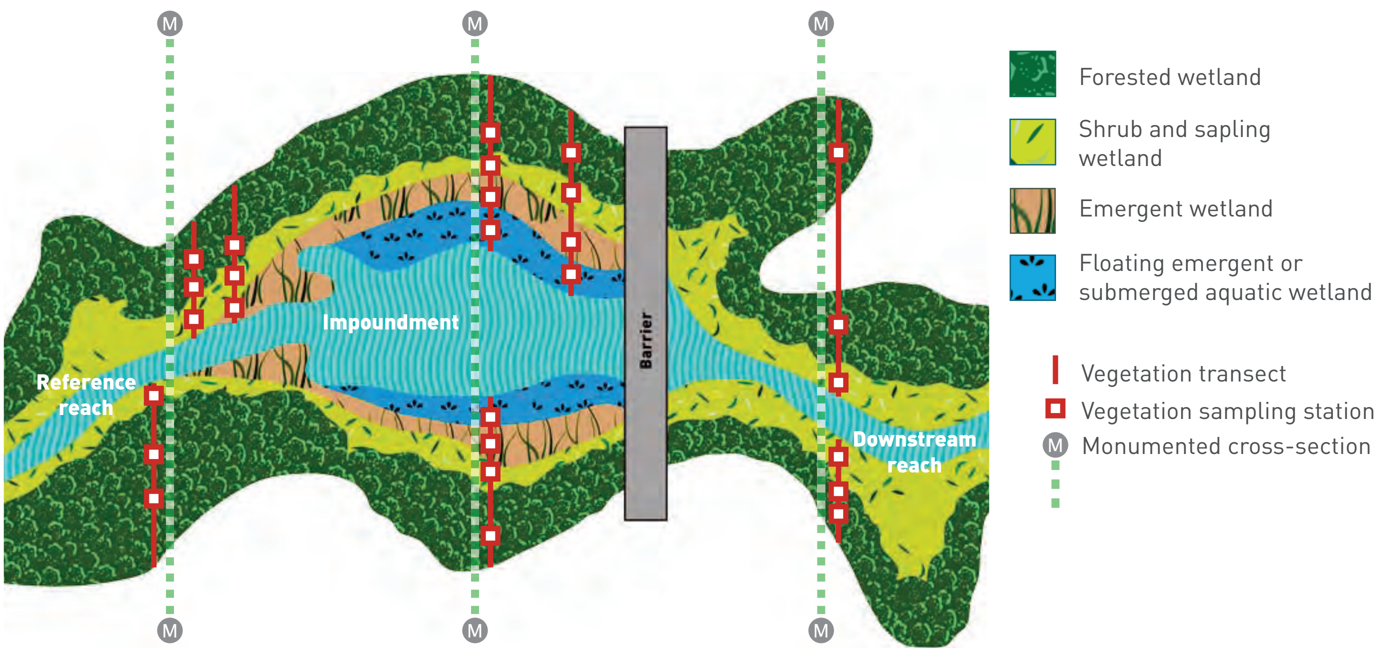


Figure 8. Establish 3 vegetation monitoring transects within the reference reach, 3 transects within the impoundment reach, and 2 transects in the downstream reach. A transect that spans the channel and both banks should be counted as 2 separate transects. At least 1 transect should coincide with, but be offset from, a monumented cross-section for each reach. The number and location of transects and vegetation sampling stations will depend on site-specific conditions. Figure not to scale.

Sampling Protocol

The goal of this protocol is to characterize riparian vegetation by sampling permanent vegetation monitoring stations along permanent transects. Transects should be established within each of the three reaches: 1) the reference reach upstream of the barrier's influence; 2) the impoundment or reach affected by the barrier; and 3) the reach downstream of the barrier. Along each transect, sampling stations are selected to characterize the vegetation within general cover types such as floating emergent and submerged aquatic vegetation; emergent wetlands; scrub/ shrub wetlands; and forested wetlands. The instructions below describe where to locate the transects and sampling stations and how to sample the vegetation at each station.

1. Identify vegetation cover types present at the barrier removal monitoring site.
Using aerial photos and field visits, identify cover types (tree, shrub, vine, liana, and herbaceous layers), wetland versus adjacent upland community types, and their condition. See Cowardin et al. (1979) for classifying wetland cover types.

2. Establish the transects.
Establish a minimum of three transects in the reference reach, three transects in the impoundment reach, and two transects in the downstream reach (Figure 8). Transects should adequately represent the plant cover types identified in step 1. Additional transects should be established if time and resources allow, particularly for extended riparian zone/stream reaches that may be affected by the barrier removal.

3. Install rebar/wooden survey stakes at each transect's start and end point.
End points should be located upgradient of the wetland-upland boundary or outside the area that is expected to change with barrier removal. Label/number each transect stake. Transects may also be referenced to monumented cross-sections or offset a known distance from the cross sections. Transects should not be co-located with the monumented cross sections because surveying will trample vegetation.

4. Mark and label the transect start and end points.
Mark them on a scaled site map or aerial photo. Record the GPS coordinates of these locations.

5. Establish at least one sampling station within each distinct vegetation cover type along each transect.
Sampling stations should be chosen to characterize each of the cover types identified in step 1. Ideally, sampling stations will be established via a systematic random approach, where the vegetation units are first identified in step 1, and station locations are then randomly selected along the transect within the identified cover types (e.g., herbaceous plants sampled every 5 meters, shrubs every 15 meters, and trees every 30 meters). Supplemental, post-restoration sampling stations may need to be established to accommodate changing cover types, particularly where deepwater impoundment drawdown results in a vegetation community (Figure 9).

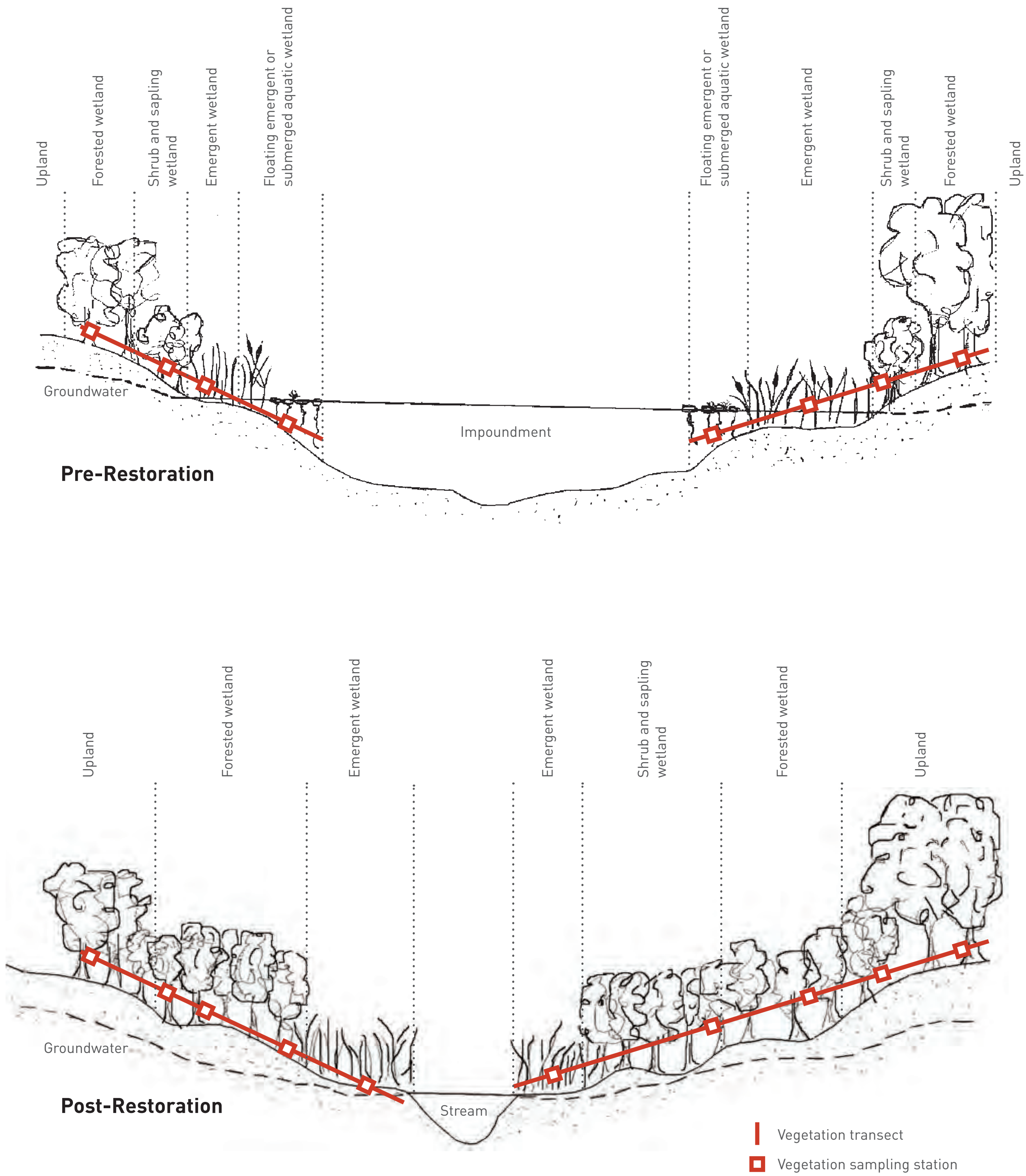
Additional Recommended Equipment

- ❑ Handheld GPS for recording the location of transects, plots, or other specific points
- ❑ Compass for laying out transects and describing photo station direction
- ❑ Plastic flagging tape for field marking monitoring plots and transects
- ❑ Hammer/mallet to install rebar or wooden stakes into the ground
- ❑ Daypack and/or field vest
- ❑ Waders, hip boots, brimmed hat, insect repellent, and sun block
- ❑ Storage cooler with ice to help preserve plant specimens and other field samples

6. Mark each station with a stake or other permanent monument.
Use GPS to determine station location, and record the distance along the transect from the starting point to the station. Document whether a station stake is the center point or a corner point for each plot, particularly if a station differs from the layout used for the remainder of the monitoring area stations.

7. At each station, estimate species cover.
Estimate cover within all of the layers that are present: herbaceous; sapling and shrub; and tree. Herbaceous vegetation is sampled using a 1 m^2 (10.8 ft^2) quadrat. The sapling/shrub layer is sampled within a 5 m (approx. 16 ft) radius of the sampling station. Trees are sampled within a 9 m (approx. 30 ft) radius of the station.

The herbaceous layer includes all non-woody, emergent species of all heights (including bryophytes) and woody-stemmed plants < 3 ft (approx. 1 m) in height. The monitoring quadrat should be 1 m^2 (10.8 ft^2) and can be defined using an increment-calibrated, 1-meter-by-1-meter frame made of PVC-pipe, or a similar meth-



Drawings by Kevin Lucey / NHDES

Figure 9. During pre-restoration monitoring (top), establish at least one vegetation monitoring station within each distinct vegetation cover type along each monumented vegetation transect. For post-restoration monitoring (above), vegetation monitoring stations may be added where vegetation has become established on the former bed of the impoundment. Within each monitoring reach, it is optimum to have three vegetation monitoring stations per cover type. Vegetation cover types should be sampled using the following plot size at each permanent monitoring station: 1 m^2 (10.8 ft^2) quadrat for the herbaceous layer, 5 m (approx. 16 ft) radius for the scrub and sapling layer, and 9 m (approx. 30 ft) radius for the tree layer. Figure not to scale.

od. Estimate cover of the vertical plant shoots' aerial projections lying only inside the plot as a percentage of the plot area. Total cover in a plot may exceed 100 percent, as plant projections often overlap one another. When the project area has high stem density of herbaceous plants but relatively low species (< 5) diversity, a 0.5 m^2 (5.4 ft^2) quadrat may be used. When monitoring prior to barrier removal with plots located inside or near the edge of the impoundment, identify floating or submerged plants that are present. Identify each species, and record each species percent cover within the plot. Also estimate and record percent of both barren ground and dead plant cover. If time allows, also count the number of stems in a 0.25 m^2 (2.7 ft^2) or 0.5 m^2 (5.4 ft^2) quadrat.

The shrub and sapling layer includes all woody stemmed plants that are more than 3 ft (approx. 1 m) but no taller than 20 ft (approx. 6 m) tall and that have a diameter at breast height (DBH) between 0.4 inch (1 cm) and 5.0 inches (approx. 13 cm). DBH is measured at 4.5 ft (approx. 1.5 m) above ground level. For the shrub and sapling layer, monitor within a 5 m (approx. 16 ft) radius of the sampling station point. Identify the species of each plant, and record species percent cover within plot. Note the number of dead standing shrubs. If time allows, randomly sub-sample the plot by counting woody stems in a 1 m^2 (10.8 ft^2) quadrat.

The tree layer includes all woody plants that are taller than 20 ft (approx. 6 m) and have a DBH greater than 5 inches (approx. 13 cm). Monitor within a 9 m (approx. 30 ft) radius of the sampling station point. Identify the species of each plant, and use a DBH measuring tape to obtain individual DBHs, which will be used later to calculate basal area [$A = \pi (d)^2/4$, where $\pi = 3.14$ and $d = \text{DBH}$] of each species within each plot. Also note the number of dead standing trees within the sample area.

When estimating percent cover, values should be recorded as whole integers that can be categorized according to a standardized, commonly used Braun-Blanquet cover class scale (Table 6) (Braun-Blanquet, 1932; Mueller-Dombois and Ellenberg, 1974). These cover class categories can be used to expedite field sampling; the mid-point values are used in place of the actual corresponding field estimate values to minimize the variability of results that can arise when multiple people estimate cover. Once field assessments are completed, cover-abundance scores can be used to calculate plant species cover for assessment sites. Refer to the Analysis and Calculations section below for database management and calculations used for generating results.

Table 6. Braun–Blanquet cover class scale and mean values to estimate cover class.

Category	Percent Cover	Mid-Point
T	<1	None
1	1-5	3
2	6-15	10.5
3	16-25	20.5
4	26-50	38
5	51-75	63
6	76-95	85.5
7	96-100	98

Sampling Frequency

It is optimal to monitor vegetation during the peak of the vascular plant growing season. For the northeastern United States, this period is generally between July 15 and August 31. Some riparian plant species flower in spring or early summer, so the monitoring team may want to consider a site assessment during spring, if time allows. Monitoring is conducted at least once annually for each monitoring year (see below), and all stations should be monitored during each monitoring period. The project and reference sites should be monitored within the same time period and as close in time to one another as possible. Vegetation monitoring should include a minimum of one year of pre-restoration and three years of post-restoration assessment, and preferably over a longer period (such as once every 3 to 5 years) for post-restoration assessment. This is particularly important for reforesting sites and if a goal of the restoration is to document ecological succession of the riparian zone.

Baseline Versus Post-Removal Monitoring: Ideally, monitoring plots are monitored at least once prior to removal of the stream barrier to define a baseline condition. When funding and time allow, it may be beneficial to monitor two or more years prior to a barrier removal because this better accounts for environmental variability. Some removals result in very little change in riparian shoreline locations, whereas others can result in substantial change. If changes in shoreline vegetation are expected with impoundment drawdown, then baseline vegetation transects should include areas of impoundment habitat where vegetation and substrate conditions are documented.

Deborah Loiselle / NHDES

Using GPS to record location of a vegetation quadrat.

Analysis and Calculations

After field assessments are completed using standardized field data sheets and handwritten data are checked for clarity and legibility, vegetation data should be entered into an Excel spreadsheet where it can be manipulated for statistical analysis. In the spreadsheet, columns should represent species, and rows should represent the sampling plots. First create columns for all species found at the project site(s). Then enter percent cover data. Alternatively, the data can be entered using the Braun-Blanquet cover scale, which uses a ranking system that facilitates similarity testing and ordination procedures (Roman et al., 2001). Note that basal area for tree plot data can be calculated as described above. Tree plot basal areas are then totaled to derive percent cover of tree species within the plot.

Non-parametric tests can be used to evaluate differences in vegetation communities between sites (e.g., project restoration reach versus reference reach) or site conditions between sampling years. Refer to Kent and Coker (1992), Elzinga et al. (1998), and Roman et al. (2001) for detailed discussions on methods for statistical analysis of vegetation data.

Additional Information

As part of the vegetation sampling process, photographs should be taken routinely during each monitoring period to document vegetation and other riparian features. Refer to the photo station methods in this document for more detailed information (Section IV.B.4).

These plant monitoring protocols and the additional monitoring methods presented in Section III.B have been adapted from the Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory, 1987), GPAC protocols for tidal wetland restoration (Neckles and Dionne, 2000), U.S. Geological Survey salt marsh protocols (Roman et al., 2001), and vegetation assessment methods of the Bureau of Land Management (Elzinga et al., 1998), U.S. Forest Service (USFS, 1987), and NOAA (Merkey and Keeland, 2005).

Elzinga et al. (1998) provides an in-depth discussion of monitoring plant populations (with a single species focus), including a step-by-step overview of developing and implementing a vegetation monitoring program, basic principles of sampling, sampling design, field techniques, data management, and statistical analysis of field data.

Many guides to plant identification are available. Some are comprehensive with user-friendly descriptive keys and accompanying drawings or photographs. Most provide specific geographic coverage, and many are targeted to a specific plant type such as woody plants, ferns and allies, bryophytes, or sedges. Guides specific to the northeastern United States include Gleason and Cronquist (1991), Magee and Ahles (1999), Conard, (1979), and Tryon and Moran (1997). Voss (1972, 1985, 1996) offers excellent keys for Michigan flora that are representative of northeastern U.S. plants; these volumes are noted for their clear, easy-to-follow keys, especially for difficult groups such as the sedges (genus *Carex*). Newcomb (1977) is another user-friendly plant guide.

7. Macroinvertebrates

We do not recommend a specific macroinvertebrate method in this Monitoring Guide because of the inherent complexity of conducting statistically valid macroinvertebrate assessments. We recommend that the user consult with professionals in their region who have the expertise necessary to design a macroinvertebrate monitoring plan appropriate for the stream barrier removal project. Appendix D provides an in-depth discussion of planning macroinvertebrate monitoring for stream barrier removal projects. Table 8 provides a summary of macroinvertebrate monitoring protocols used by different Gulf of Maine jurisdictions.

Brook floater

8. Fish Passage Assessment

We do not recommend a specific fish-monitoring method in this Monitoring Guide because fish monitoring should be managed by trained fisheries experts and must be tailored to the project site and target species. We recommend consulting with experts in the region with the necessary jurisdiction to design and implement fish monitoring for barrier removal projects.

Fish ladders sometimes are not effective at enabling fish to move past dams. After a dam is removed, monitoring can reveal if more fish are traveling up and down the river.

Table 7. Fish–monitoring methods that may be recommended by local fisheries experts.

Method	Technique	References
Visual	Human visual identification and counts of fish at specific locations.	Nelson, 2006; Stevenson et al., 1999
Simple presence/absence	Electrofishing is a commonly used and inexpensive technique to assess the presence or absence of fish species above and below a barrier.	Reynolds, 1997
Video	Pre-positioned video camera recording fish at specific locations.	Bowen, 2006
Passive Integrated Transponder (PIT tags)	Fish are captured and are inserted with a Passive Integrated Transponder (PIT tag). Fish injected with this tag can be automatically recognized by strategically located detecting/recording devices.	Bruyndoncx, 2002
Mark and recapture	Fish are captured and are fin clipped and/or have an external fish tag attached; employs nets, traps, or electrofishing.	Nielson, 1992; Parker, 1990
Telemetry	Fish are captured and tagged with electronic transmitters. Transmitters can be applied to fish internally or externally. Fish movements are subsequently determined by locating fish/transmitters using mobile and/or fixed telemetry receivers.	Amlaner and MacDonald, 1980; Baras, and Phillipart, 1996; Burnham et al., 1987; Cheeseman and Mitson, 1982; Finkenzeller, 2000; Lucas and Baras, 2001; Moore and Russell, 2000; Pincock, and Voegeli, 1990; Priede and Swift, 1992; Sibert and Neilson, 2001; Spedicato et al., 2005; Winter, 1983; Winter, 1996; Zydlewski et al., 2006

Table 8. Relevant state and provincial protocols for monitoring macroinvertebrates.

	Recommended Collection Method	Index Period	Recommended Sampling Processing Protocol	Identification Level	Recommended Assessment Approach	Protocol Reference
New Hampshire	Artificial substrates (wire mesh, rock-filled baskets); 6-8 week deployment in riffles or at base of riffles	Fall	Standardized gridded tray with sample evenly distributed across tray; 1/4 of grids randomly selected for complete sorting with 100 individual minimum subsample; additional 1/4 of grids incrementally selected for complete sorting until 100 individual subsample satisfied	Genus (if possible), except for chironomids (sub-family), ribbon worms (phylum Nemertea), nematodes (phylum Nemata), and oligochaetes (sub-class)	Multimetric index: average score of 7 metrics; index range 0 (poorest condition) to 100 (best condition); biological condition threshold established via minimally impacted reference sites	Neils, D. 2007. New Hampshire Department of Environmental Services (NHDES) Protocols for Collection, Identification and Enumeration of Aquatic Macroinvertebates for Computation of a Benthic Index of Biotic Integrity (B-IBI). Concord, NH: NHDES.
Maine	Artificial substrates (wire mesh, nylon bags, or cone-shaped containers filled with standard-sized stones); 24- to 32-day incubation; rock containing device	Fall	Full sample sort using shallow sorting pan(s) unless >500 individuals; if >500 individuals, then 100 individual subsample permissible using air-generated suspension of individuals in Imhoff-type settling cone	Genus or species for all individuals (if possible)	Multivariate linear discriminate model to predict probabilities of membership to predetermined water quality classes	Davies, S.P. and L. Tsomides. 2002. Methods for Biological Sampling and Analysis of Maine's Rivers and Streams. DEP LW0387-B2002. Augusta, ME: Department of Environmental Protection.
Massachusetts	Kick nets (500μm); 10 area delineated sampling efforts composited for a single sample within 100m reach; 2 m^2 total area; samples collected from areas with coarse substrates OR artificial substrates (rock baskets, Hester-Dendy multiplate samples in deep water or soft bottom habitats or as directed)	Fall	Standardized gridded tray with sample evenly distributed across tray; individual grids randomly selected and sorted until 100 individual subsample requirement satisfied; large and rare organisms sorted for entire sample OR full sort of entire sample for artificial substrates where quantitative sample is desired	Genus or species for all individuals (if possible)	Multimetric index following RBP II or III (Plafkin et al., 1989); index range 0 (poorest) to 54 (best) and compared to applicable reference sites	Nuzzo, R.M. 2003. Standard Operating Procedures: Water Quality Monitoring in Streams Using Aquatic Macroinvertebrates. Massachusetts Department of Environmental Protection, Division of Watershed Management.
Canada Ecological Monitoring & Assessment Network	Several noted depending on water body and habitat types; kick net (400μm) suggested as technique for wading-depth streams; multihabitat collection effort; one to many 3-minute collection efforts	Late fall or early spring	Several noted; subsampling at the 100, 200, or 300 individual target level suggested; gridded trays, flotation, or elutiation can be used to obtain representative subsample	Genus or species for all individuals (if possible)	None recommended; several options referenced	Rosenberg, D.M., I.J. Davies, D.G. Cobb, and A.P. Wiens. 1997. Protocols for Measuring Biodiversity: Benthic Macroinvertebrates in Fresh Waters. Winnipeg, Canada: Canada Department of Fisheries and Oceans, Freshwater Institute.
Canada Canadian Aquatic Biomonitoring Network	Kick net (400μm); multihabitat	None indicated	Even distribution of entire sample across gridded tray; 300 individual subsample target	Family	Multivariate discriminate model using Observed: Expected species occurrence ratios to determine similarity to a "reference" condition (1=identical; 0=no similarity)	Reynoldson, T.B., C. Logan, T. Pascoe, and S.P. Thompson. CABIN (Canadian Aquatic Biomonitoring Network): Invertebrate Biomonitoring Field and Laboratory Manual. Environment Canada, National Water Research Institute.

Cross-section established for stream barrier removal monitoring.
Mathias Collins / NOAA Restoration Center

V. DATA MANAGEMENT

A. DATA CAPTURE AND REPORTING

As noted in the Introduction, there are five primary reasons for establishing regional guidelines for barrier removal monitoring:

- evaluating the performance of individual restoration projects;
- assessing the long-term ecological benefits of regional restoration efforts;
- advancing our understanding of restoration ecology to assist in the development of more effective restoration techniques;
- better anticipating the effects of future stream barrier removal projects; and
- communicating results to stakeholders and the public.

Previous sections of this Monitoring Guide have focused on critical monitoring parameters that should be monitored at barrier removal sites and how those parameters should be measured in a consistent manner so that results are comparable across the region. Equally important to accomplishing the goals noted above are consistent data capture and reporting. This requires common data elements, reporting standards, and site metadata.

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Data elements are the specific pieces of information recorded when monitoring a given parameter. For example, the data elements for cross-sections are station (STA), backsight (BS), height of instrument (HI), foresight (FS), and elevation (ELEV). To properly perform and document a cross-section survey, these data must be collected and recorded. Each critical monitoring parameter has a set of necessary data elements.

Reporting standards specify how the data elements are recorded. Examples include what units are used and the precision to which measurements are reported. For example, for the cross-section data elements we specify that horizontal distances and elevations be reported in units of feet with precisions of tenths (0.1) and hundredths (0.01), respectively.

Metadata are "data about the data". Besides collecting and recording the data elements that are the key measurements for a parameter, it is very useful to record other quantitative and descriptive information during data collection. The metadata may be parameter-specific or general to the site. Examples of parameter-specific metadata include documenting the investigators, time/date of data collection, and notes. The latter generic category is often used to record any problems encountered in the field with equipment, weather, or extraordinary conditions. Information of this sort is particularly useful for data analyses. Metadata general to the site can include benchmark location, project datum, and watershed name.

Data elements, reporting standards, and metadata needs have been identified for each *critical monitoring parameter* for which this Monitoring Guide provides detailed methods and are defined on the data sheets provided in Appendix E. A site information datasheet to capture site metadata is also provided. Completing these data sheets will ensure that the necessary data elements and metadata are captured for each parameter, as well as for the site in general, and are reported in a consistent manner. Additionally, having field investigators transfer their data from the hard copy data sheets to the electronic versions serves as an important quality assurance mechanism.

B. DATA COLLECTION

Use of the critical monitoring parameters is encouraged to the extent practical for all barrier removal projects in the Gulf of Maine watershed. Potential recipients of funds from competitive grant programs administered by entities sponsoring this document may be requested or required to monitor some, or all, of the critical monitoring parameters as an award condition. Any prescribed monitoring would be mutually agreeable to all parties and explicitly funded through the grant. In these cases, completed field data sheets (hard copy and electronic) would be a reporting requirement for the grant. In all other cases, submitting data sheets in hard copy and electronically to the Gulf of Maine Council on the Marine Environment is strongly encouraged. For submission information, visit www.gulfofmaine.org/streambarrierremoval.

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VII. APPENDICES

APPENDIX A: FIELD SAFETY

Field crews implementing the recommended practices in this Monitoring Guide can encounter hazardous conditions. It is crucial, particularly when involving volunteers, to ensure that adequate safety precautions are taken. This section identifies the most common hazards associated with conducting ecological monitoring of riverine and riparian habitats and recommends general field safety precautions. This is not a comprehensive safety protocol, but rather a guideline to ensure safe field conditions.

General

- Develop a safety plan. Safety plans can be as simple as letting someone else know where you are, when you intend to return, and what to do if you don't come back at the appointed time.
- Always monitor with at least one partner.
- Listen to weather reports. Caution should be exercised if severe weather is forecasted.
- Have a first-aid kit accessible. Team leaders should be trained in first aid/CPR.
- If at any time you feel uncomfortable about the condition of the stream or your surroundings, monitoring efforts should be terminated.

Impoundments

- Be careful wading into the impoundment, even if it is shallow. Impounded sediments are often unconsolidated fine-grained material having interstitial spaces. This makes them very soft and dangerous because they may not support a person's weight.
- In some instances, it may be necessary to use a boat to monitor conditions in impoundments. In such cases, a personal flotation device (PFD) is needed for each person on a boat.

Stream Safety

- Do not enter the water if the stream is at flood stage.
- If you must cross the stream, use a walking stick to steady yourself and to probe for deep water and unstable terrain.
- Streambeds composed of coarse substrates and/or bedrock can be slippery and have deep pools.
- Streambeds composed of finer substrates can prove treacherous in areas where mud, silt, or sand creates unstable terrain.

Poison Ivy

- Watch for poison ivy, poison oak, sumac, and other types of vegetation in your area that can cause rashes and irritation.

Mosquitoes

Mosquito-borne illnesses in the such as West Nile virus and eastern equine encephalitis have become more prevalent. The following steps can reduce the incidence of mosquito bites.

- Apply an effective repellent to exposed skin and clothing.
- Wear long-sleeves, long pants, and socks when outdoors.
- Limit field activities during peak mosquito hours. The hours from dusk to dawn are peak biting times for many species of mosquitoes.

Ticks

Ticks, which can carry the Lyme disease bacterium (*Borrelia burgdorferi*), prefer wooded and bushy areas with high grass and abundant leaf litter. Extra precaution should be taken in May, June, and July, when ticks that transmit Lyme disease are most active.

- Use insect repellent with 20-30% DEET on adult skin and clothing to prevent tick bite. Permethrin is another type of repellent. It can be purchased at outdoor equipment stores that carry camping or hunting gear. Permethrin kills ticks on contact.
- Wear long pants, long sleeves, and long socks to keep ticks off your skin. Light-colored clothing will help you spot ticks more easily. Tucking pant legs into socks or boots and tucking shirts into pants help keep ticks on the outside of clothing.
- Perform daily tick checks after being outdoors. Inspect all parts of your body carefully, including your armpits, scalp, and groin. Remove ticks immediately using fine-tipped tweezers.

Sun/Heat

- Dress for the heat. Wear a hat and lightweight, light-colored clothing. Light colors will reflect away some of the sun's energy.
- Drink water.
- Take regular breaks when engaged in physical activity on warm days. Take time out to find a cool place. If you recognize that you or someone else is showing the signals of a heat-related illness, stop activity and find a cool place.

APPENDIX B: GLOSSARY

Aggradation
The building up of a river channel by deposition of sediment on the channel bed.

Alluvial
Pertaining to or composed of alluvium, or deposited by a stream or running water.

Anadromous
Used to describe fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn, such as salmon, river herring, and shad. Contrast with catadromous.

Avulsion
The sudden creation of a new river channel where flow leaves the existing channel during large floods and carves a new channel with a new slope and length.

Catadromous
Used to describe fish that live in fresh water but migrate into the sea to breed. Contrast with anadromous.

Critical monitoring parameters
Framework of common monitoring techniques necessary to adequately assess the physical, chemical, and biological response of stream barrier removal projects.

Degradation
The general lowering of the surface of the land by erosive processes, especially by the removal of material through erosion and transportation by flowing water.

Deposition
A natural river process in which sediment is distributed along the bed after floods recede or a change in cross-section leads to slower velocities, such as moving from a riffle to a pool. Sediment deposition is often altered in developed watersheds.

Diadromous
Used to describe fish that migrate between salt and fresh waters. See also anadromous and catadromous.

Effectiveness monitoring
Evaluation of whether or not an implemented action is having the desired effects. If the action is having undesirable effects, this should be revealed through effectiveness monitoring.

Floodplain
That portion of a river valley, adjacent to the channel, which is built of sediments deposited during the present regimen of the stream and is covered with water when the river overflows its banks at flood stages.

Grace Levergood / NHDES

Hydraulics
Related to the physical properties and behavior of stream flow as it is influenced by floodplain geometry and structures within it.

Hydrograph
A graphic representation or plot of changes in the flow of water or in the elevation of water level plotted against time.

Hydrology
The science of waters of the earth, including their occurrence, distribution, and circulation; their physical and chemical properties; and their reaction with the living and non-living environment. Also, pertaining to the quantity and timing of stream flow.

Implementation monitoring
Evaluation of whether a specific action occurred as planned. A variant called compliance monitoring evaluates whether an action meets regulatory standards. Implementation monitoring provides baseline information before and immediately after a project occurs.

Lacustrine
Pertaining to, produced by, or inhabiting a lake.

Lithology
(1) The scientific study of rocks, usually with the unaided eye or with little magnification. (2) Loosely, the structure and composition of a rock formation.

Low-head dam
A constructed barrier in a river with a hydraulic height (head water to tail water) not exceeding 25 feet. This definition encompasses run-of-river dams and other small dams. It does not include industrial dams that were designed not to create an impoundment in a river.

Riparian
Pertaining to the banks of a river, stream, waterway, or other body of water, as well as to plant and animal communities along such bodies of water.

Run-of-river dam
A constructed barrier in a river that forms an impoundment with minimal storage capacity and the inflow to the impoundment approximately equals outflow from the dam.

Stream crossing
Any human-made crossing over or through a stream channel, including bridges, culverts, paved roads, unpaved roads, railroads, trails, and paths.

Thalweg
The line connecting the lowest points along a stream bed or valley.

Wetland
Wetlands are defined and classified by the U.S. Department of Interior as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or land is covered by shallow water, and have one or more of the following attributes: (1) at least periodically the land supports hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is non-soil and is saturated with water or covered with shallow water at some time during the growing season of each year" (Cowardin et al., 1979).

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APPENDIX C: WORKSHOP PRODUCTS

Participants in the Stream Barrier Removal Monitoring Workshop, June 2006

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Stream Barrier Removal Monitoring Workshop Scenarios

	Head-of -Tide Restriction	High Head Dam with Wide Impoundment	Low Head Dam with Narrow Impoundment	Undersized Perched Culvert
Watershed Position	Near head-of-tide in large (>1000 mi^2) watershed; avg. channel width u/s 10m	Low-order stream in a large watershed (>1000 mi^2)	High order stream in a mid-sized watershed (100 mi^2<>1000 mi^2)	Second order stream
Watershed Land Use	Agriculture; light industry; forestry	Forest and rural residential.	Urban; post-industrial revolution	Suburban
Valley Geomorphic Setting	Meandering, low gradient stream; wide floodplain	Moderate gradient, low-sinuosity, riffle-run; subwatershed has areas of outwash deposits	Low gradient, slight sinuosity; channelized through town; poorly developed floodplain. Watershed dominated by till and bedrock	Steep step-pool channel
Riparian Condition	Unfenced livestock pasture adjacent to / above impoundment; wide 2nd growth forest buffer u/s.	Wide (>8xW_{bkf}) mature forested buffer; some residences	Narrow (<1xW_{bkf}) mature forested buffer; Japanese knotweed prevalent; riprap on bank	Narrow (<1xW_{bkf}) mixture of saplings, shrubs adjacent to lawns
Barrier Type	12 ft high by 300 m long earthen dyke extending across floodplain; concrete water control structure; failing fish passage structure (partial barrier)	20-foot tall concrete dam in good condition with low-level outlet for flow modification	10-foot high timber crib/rock fill spillway with concrete patching; earthen with sheetpile core, stone armoring	70-foot length; 48'' diam. double-barreled culverts; perched 3 feet; 10-foot head to unpaved road
Aquatic Species Present	Shellfish; Atlantic salmon, smelt, gaspereau, American eel, and brook trout.	Rare mussels d/s; alewife and salmon targeted for restoration	Shad, eel, herring lamprey downstream; smallmouth bass u/s	Brook trout. Salmon target for restoration
Sediment Characteristics	Fine grained potentially contaminated (domestic sewage; mild industrial)	Large quantity of coarse sand and gravel	Fine-grained; some build-up behind dam	Gravel/cobble mixed with woody debris immediately u/s of culverts; braiding of channel
Upstream Waterbody Characteristics	Shallow, wide impoundment with summer algae growth	Wide, deep, storage impoundment	Run-of-the-river; impoundment is narrow, shallow, and riverine in character	Riverine; debris, sediment, high flows blocked
Wetlands	Small wetland areas along impoundment margin; salt marsh areas between dam and causeway (d/s)	None	Oxbow wetland adjacent to channelized reach; small emergent wetland at u/s end of impoundment	None
Infrastructure and Community Concerns	Loss of u/s waterfowl habitat, hunting, trapping; loss of First Nations' traditional uses; d/s causeway / bridge; release of contaminated sediments	Concern for adjacent landowner wells; loss of water frontage u/s; potential for flooding d/s	Old / deteriorating structure. Community desire to keep dam and preserve adjacent historic structures; potential for flooding, braiding u/s;	Minimize erosion of road fill.
Restoration Issues	Full removal of barrier including all floodplain fill. Mobile sediments removed prior to breaching dam. Restore diadromous fish. Improve fish passage for traditional uses	Decommissioning of power dam; dam/ foundation removed to banks. Sediment behind dam removed. Work u/s to align channel / stabilize banks, limit fine sediment transport.	River seeded w/ shad 1 year prior to dam removal. Contaminated sediment capped; invasives control during / post dam removal. Spillway removed; earthen/ sheetpile embankment remains.	Highway improvement project. Replace with bottomless arch culvert

Gulf of Maine Council on the Marine Environment

Stream Barrier Removal Monitoring Workshop Agenda

Gulf of Maine Council River Restoration Monitoring Steering Committee
June 20-21, 2006 University of Maine, Orono

Workshop Outcomes:

1. A list of prioritized monitoring metrics / parameters by topic area, some of which are crosscutting, for barrier removal projects.
2. A refined list of monitoring questions or issues that those metrics / parameters address.

Tuesday, June 20th 2006

9:00 Welcome

1. Introduction
2. Purpose
3. History of Salt Marsh Monitoring Protocol Development

9:30 Plenary Sessions

1. Plenary A: James MacBroom, Milone and MacBroom, Inc.
2. Plenary B: Michael Kline, VT DEC River Management Program

12:00 Lunch

1:00 Instructions to Topic Teams

1:30 Breakout Groups: Topic Teams and Facilitators

A. Topic Teams review sets of typical dam removal scenarios in the context of key management issues/ monitoring questions.

B. Brainstorm appropriate monitoring parameters for each scenario.

C. Identify parameters repeatedly suggested for multiple scenarios.

D. Topic Team produces a summary parameter list highlighting those that are useful in multiple scenarios.

3:30 Break

Post Topic Team flip chart summaries; mill around; eat snacks; look at summaries.

4:00 Plenary: Integrative Metrics

A. Background

B. Topic Teams share results

C. Synthesis of results: identify crosscutting metrics, if any; identify priority metrics for each topic team; identify how this will feed into the next day's work.

8:00 Evening Presentations (optional)

Wednesday June 21st, 2006

8:00 Plenary: Ray Konisky, Ph.D., Wells National Estuarine Research Reserve

9:00 Breakout Session: Topic Teams

A. Focus on integrative metrics. Depending on the outcome of Day 1, this discussion might include arm twisting to get Topic Teams to identify possible crosscutting metrics and at the very least identify their most important 1 or 2 metrics. The goal is to refine the topic teams larger parameter list to include only their highest priorities.

B. Appropriate methods (sampling techniques, frequencies, etc.)

C. Reporting standards (common data elements, etc.)

11:00 Reporting Back and Concluding Remarks

APPENDIX D: MACROINVERTEBRATE MONITORING GUIDANCE

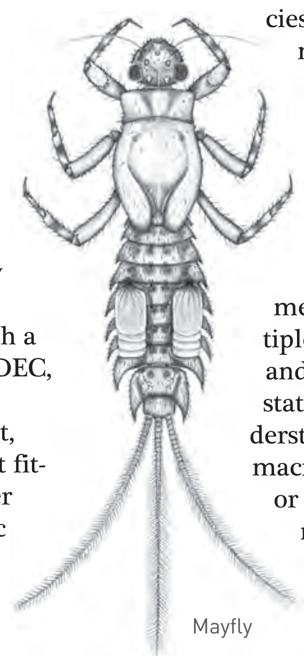
Planning Macroinvertebrate Monitoring at Stream Barrier Removal Projects

Given their utility as indicator organisms, macroinvertebrates are frequently used to document the responses of the aquatic community following barrier removal. The sections below describe the important components necessary in planning macroinvertebrate monitoring to assess aquatic community health and document shifts in community composition.

We advise that macroinvertebrate sampling be conducted in close coordination with the project's regulatory authority. Because of the inherent complexity of conducting statistically valid macroinvertebrate assessments, we encourage practitioners to use protocols recognized by state, provincial, or federal authorities.

Equipment

Several types of sampling equipment can be used to collect macroinvertebrates from wading-depth streams. Devices range from a Surber sampler to artificial substrates. While each sampling device has its benefits, the most commonly used and cost-effective sampling device currently employed is the dip net. Standard collection techniques call for the frame to be fitted with a 500µm mesh net (Lazorchak et al., 1998; VTDEC, 2006; Barbour et al., 1999) attached to a long wooden pole. Along with the rectangular net, often referred to as a kick-net, a sieve bucket fitted with 500µm mesh, and several 1- to 4-liter plastic sample containers complete the basic elements necessary to collect a representative macroinvertebrate sample.



Mayfly

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Design

As for all scientific studies, considerable time and effort should be spent prior to any fieldwork to determine what questions are to be answered through the collection of data. Once determined, careful study design must be employed so that sufficient data are collected in an accurate manner. For studies associated with barrier removal projects, documentation of the changes in macroinvertebrate community composition, abundance, or overall biomass may be of interest. In all cases, an understanding and accounting of the natural sources of variation (error) must be completed in order to draw correct conclusions. The basic sources of error that are manifested in all sampling efforts include collection techniques, laboratory processing, and spatial and temporal heterogeneity in macroinvertebrate populations. A good study design will minimize, or at least account for, each of the potential sources of error. In reality, minimizing error sources means the selection of appropriate field techniques, collection of an adequate number of samples, careful adherence to standardize operating procedures in the field and laboratory, and the use of well-developed biological indices.

With respect to biological indices, a section below focuses on regionally developed macroinverterbate indices that are widely applicable to the detection of pollution sources, including nutrient enrichment, toxic inputs, and flow modifications. In general, these indices have been developed by resource agencies and use a network of reference or minimally disturbed sites to establish acceptable conditions in overall macroinvertebrate community composition. Benefits of using regionally developed indices include the direct comparison of sample results to index thresholds, known estimates of natural variation in undisturbed macroinvertebrate community composition, use of metrics known to be most responsive to multiple pollution sources, and predetermined field and laboratory techniques. In most cases, the statistical properties of these indices are well understood and will allow for the determination of macroinvertebrate community health as above or below an established threshold and/or placement into one of many narrative categories (i.e., poor, fair, good) with a known level of certainty.

However, regional biological indices are, in most cases, not specific to barrier removal projects and have drawbacks that should be considered based on the study's questions of interest. For example, if macroinvertebrate community biomass or area of colonizable habitat is of interest, alternative measures will be required. In cases where previously developed indices are not applicable, one must decide what community measures are most representative of the questions being asked, how to obtain the necessary data, and what comparisons will best assist in determining if significant changes have occurred. In cases where established indices are not applicable, the greatest limiting factor frequently will be the establishment of thresholds for detecting change. In other words, if data collected at a site is presumed to be impacted by an existing barrier, how can that be determined if the macroinvertebrate community differs from a site where no barrier exists? While it is beyond the scope of this document to develop a detailed discussion of study designs and the limitations of data usage, the before-after-control-impact (BACI) study design provides a basic framework to begin answering such questions. Under a BACI study design, samples are collected at sites where target conditions are presumed to exist before and after a barrier removal. These are considered control sites. Concurrently, samples are collected at sites presumed to be impacted by the barrier. These are considered impact sites. Ultimately, differences between control and impacted sites are compared before and after the barrier improvement or removal event to determine if significant changes have occurred. The ability to detect significant differences is a function of the number of samples collected and the quality of data.

Other study designs are possible. All parties involved in the project should be consulted to determine how best to design the macroinvertebrate monitoring efforts. The use of regional biological indices offers the most cost effective and least labor intensive approach in determining overall changes in community condition, but may be limited in terms of the specific questions that can be answered.

Areas of Sample Collection

Macroinvertebrate samples can be collected from several macrohabitat types, such as riffles, pools, stream banks, or a combination of habitat types. Sample collection from each specific habitat type requires careful consideration of available collection techniques. Current collection techniques include two main approaches: single- or multi-habitat sampling. Single-habitat sampling is used by several states and usually includes the collection of samples at the "single, most productive" area within a selected stream reach (Barbour et al., 1999). Macroinvertebrate production generally is maximized in riffle habitats leading to the common terminology of "riffle-kick" for single-habitat samples (VTDEC, 2004). Single-habitat sampling techniques employ multiple, individual, timed sampling efforts in one or many riffles within the study reach. Individual timed sampling efforts generally range from 3 to 5 in number and are grouped together for a representative sample of the macroinvertebrate community.

More recently, some U.S. and Canadian macroinvertebrate sampling protocols have promoted the use of multi-habitat collection techniques (Lazorchak et al., 1998; Rosenberg et al., 1997) as a more complete representation of the resident community. Multi-habitat sampling techniques include the collection of macroinvertebrates from a variety of habitats in approximate proportion to the habitat types observed within the study reach. Points of collection may be randomly selected or placed along predetermined transects. Multiple, individual, timed sampling efforts are used to standardize collection techniques and are variable in number depending on the sampling protocol. As with single-habitat collection techniques, individual timed sampling efforts are grouped together to approximate the macroinvertebrate community within the study reach.

Sampling Timing and Frequency

Most macroinvertebrate collection protocols have an established index period that standardizes a window of time (weeks) during which samples should be collected. Since many aquatic macroinvertebrates have regular development and emergence patterns, the establishment of a standardized collection window minimizes the amount of observed natural variation in community composition. Based on known life cycle patterns, macroinvertebrate sampling for riverine systems in northeastern North America occurs primarily from September through November (USEPA 2002). Alternative sampling times are possible but should be considered with respect to organism developmental patterns, climatic conditions, and the protocols advocated by the applicable regulatory authority.

Site-specific Considerations

The sampling methods described herein are applicable to wading-depth sections of riverine systems. Wading-depth streams can be defined as first through fourth order streams ranging in watershed size from approximately 2 to >200 km^2 (0.77 to >77 mi^2). However, from a practical standpoint, wading-depth can be defined as any section of river where water depth is less than thigh high. Conditions prior to barrier removal often preclude wading-depth sampling techniques. In these cases, alternative macroinvertebrate sampling procedures must be employed. See Blocksom and Flotemersch (2005) for comparison of several non-wading-depth methods.

Sample Processing

Macroinvertebrate sample processing consists of two main phases: sorting and identification. In the sorting phase, organisms are separated from the sample debris. Identification generally takes place following the sorting phase and requires varying levels of expertise depending on the desired level of taxonomic specificity.

Sample Sorting

Because most whole samples contain more organisms and/or debris than can be processed, the sorting phase usually includes a sub-sampling method. Sub-sampling usually involves the homogenization of all sample contents in a single shallow pan followed by an objective process for selecting a pre-determined fraction of the sample. Currently, the most common method of sub-sampling uses the separation of a fixed-count target number of organisms from a predetermined fraction of the whole sample (Barbour et al., 1999; Lazorchak et al., 1998; Rosenberg et al., 1997). The sample fraction generally is defined by randomly selecting a minimum number of standardized areas (grids) identified by a template overlain upon the entire sample.

Debate still exists over the proportion of the whole sample that must be processed and number of organisms retained for identification and enumeration (Courtemanch, 1996; Barbour and Gerritsen, 1996; Vinson and Hawkins, 1996). A common target is the removal of organisms from enough full grids to meet a 300-individual fixed count target (VTDEC, 2006; Barbour et al., 1999). Doberstein et al. (2000) demonstrated that the results of samples processed using fixed counts of less than 300 individuals differed significantly from whole sample counts of the same sample and that sub-sample counts of up to 1,000 individuals incrementally increased the similarity to whole sample results. Thus, fixed sub-sample count targets are often based on resource availability and may vary among protocols. For this reason, one should consult the protocols advocated by the relevant resource agency before selecting a fixed count target and general sorting procedures. In all cases and regardless of the target, the fraction of the sample processed may differ among samples based on stream productivity. Therefore, a record must be kept for each sample so estimated whole sample results can be standardized.

Identification

The recommended level of taxonomic identification (i.e., family, genus, species) can be highly variable. Several protocols call for the lowest practical level (Barbour et al., 1999; VTDEC, 2006), but researchers have differing opinions as to what taxonomic level is most appropriate (Bailey et al., 2001; Lenat and Resh, 2001; Hawkins et al., 2000; Reynoldson et al., 1997). The academic reasons (i.e., geographic location, ecological diversity, evaluation tool) to select one level of taxonomic specificity over another must be considered in concert with the required level of expertise necessary to achieve the desired results. Highly trained taxonomic experts and expensive equipment generally are required to identify aquatic macroinvertebrates to genus and species levels. In contrast, an experienced field biologist may be able to identify insects to the family level with the naked eye. Thus, one must consider resource availability when deciding on a prescribed taxonomic identification level.


Brook floater

Drawing © Ethan Nedeau / Biodrawversity

Regardless of taxonomic level of resolution chosen, the protocol must provide detailed identification directions to the people responsible for sample processing. Some groups of macroinvertebrates (i.e., chironomids, nematodes) require additional taxonomic expertise and steps for identification. A less specific identification endpoint is common for these groups. Correct identification serves as the foundation for building the final dataset. Therefore, it is critical that this phase of sample processing be performed in a consistent manner to produce accurate results.

Because of the debate regarding recommended sorting processes and identification levels, specific sample processing protocols are not included herein. If well-tested and widely accepted field and laboratory protocols are selected, evidence suggests that differences between methods can be small. However, it is important they meet minimal performance measures (Herbst and Silldorff, 2006). In Canada and the United States, national protocols exist and should be consulted for further guidance (Barbour et al., 1999; Lazorchak et al., 1998; Rosenberg et al., 1997). Ideally, state, provincial, or federal protocols will be available to guide sample processing.

QA/QC

After sample processing is complete, it is important to verify the results. A common practice for determining the quality of the results is to re-process a minimum of 10% of the samples. A rigorous quality assurance program should test the effectiveness of the sorting and identification phases. As recommended above, it is best to follow the QA/QC procedures advocated by the appropriate regulatory authority. The goals are to document that the reported results are repeatable and that minimal variation can be attributed to the processing methods. As an example, the following is a generic QA/QC procedure:

1. For previously sorted grids, have a second qualified individual re-examine each grid. If less than 95% of the individuals or 95% of the taxa were not removed in the original sort then the sample fails to meet the QA/QC requirements.

2. From a previously identified and enumerated sort, have a second qualified taxonomist re-identify and enumerate all individuals. If 5% or greater of the individuals are misidentified or incorrectly counted, then the sample fails to meet the QA/QC requirements.

3. Individual samples that fail by either (1) or (2) must be reprocessed and adequately justified. An overall sample failure of greater than 2% requires reprocessing for the entire lot of samples.

Use of Resulting Data

In contrast to chemical samples where individual parameter results are compared to their respective thresholds, results from macroinvertebrate samples initially are more complex. With multiple species and individual abundances for each species, long lists of scientific names must be translated into an understandable format. Contemporary efforts to understandably convey taxonomic composition and abundance information include two approaches. First, the multimetric approach relies on the differential tolerances, ecological roles and strategies, and overall composition of the macroinvertebrate taxa found in the sample. Multiple individual measures that are most important in describing community condition are aggregated together to produce a single index of biologic health. This multimetric approach is well documented and has been widely advocated for bioassessments (Karr and Chu, 1999; Barbour et al., 1995; Gerritsen, 1995). Alternatively, the multivariate approach uses detailed statistical estimates of community similarity to establish expected community compositions at minimally disturbed sites. Once these expectations are established, test sites are compared to the minimally disturbed sites to determine the difference in community composition. An observed (test site) to expected (reference expectation) (O/E) ratio is used as the measure of community health (or taxonomic loss). Ratios near 1 indicate minimal taxonomic loss while lower ratios indicate divergence of test sites from expectations. Originally developed in Great Britain and Australia, the multivariate approach has gained acceptance in North America (Reynoldson et al., 1997; Hawkins et al., 2000).

Regardless of the approach used, both techniques provide defensible alternatives to collapse taxonomic lists and respective abundances into understandable and similar assessment outcomes (Herbst and Silldorff, 2006). Prior to any sampling, protocols for collection and processing must be selected that are consistent with the approach and evaluation tool that will be used to assess the status of the macroinvertebrate community. In most cases, the appropriate regulatory authority should be contacted to suggest a recommended index that is locally applicable. In addition, the suggested index may have one or more threshold levels to assist in estimating biological condition and completing formal assessments for water quality reporting requirements.

Documentation

Integral to the success of all components of macroinvertebrate sampling is the maintenance and documentation of the associated data. Given the wide variety of potential sampling methods, laboratory protocols, and data summary approaches, a detailed record must be kept of all data elements. The primary data elements for sampling techniques are sampling device (including net mesh size, if applicable); type(s) of habitat sampled; approximate area sampled; number and approximate length of individual sampling efforts (i.e., five one-minute kicknet efforts); length of incubation (if artificial substrates are used); extent to which individual sampling efforts are grouped together; and the number of replicates. Laboratory processing data elements should include subsample fraction (percent of whole sample sorted); target number of individuals (i.e., 300 individual minimum); number of individuals per taxon; current scientific nomenclature for each taxon (with reference to naming organization); stage of development (larvae, pupa, adult); and QA/QC results for overall sample lot processing. In addition, laboratory metadata should include subsampling procedure (e.g., grid, number of cells, aeration); keys used to identify major taxonomic groups; and target level of identification for major taxonomic groups (i.e., family, genus, species). Data summary approach elements should include final metric and index results for each replicate/sample and reference to applicable index. The referenced index should detail the computation of individual metrics and the final index score, as well as the distribution of index scores for the reference condition and the method for threshold establishment. The ideal data storage vehicle is a relational database that allows for the efficient and long-term storage of large quantities of data in a consistent manner.

APPENDIX E: DATA SHEETS

This appendix contains data sheets for
- site information,
- monumented cross-sections,
- longitudinal profile,
- grain size distribution,
- water quality,
- riparian plant community structure, and
- photo stations.

Data sheets are available for downloading from www.gulfofmaine.org/streambarrierremoval.

Stream Barrier Removal Monitoring
Site Information

Stream Name:	**Site Name:**	**SITE ID#:**
Date of Removal:	**Watershed Area (mi^2):**	**Stream Order:**
Town:	**State:**	**Province:**

Latitude (__°__'__'')	**Longitude (__°__'__'')**
Benchmark Location:	**Project Datum:**

Circle One

Barrier Type	Dam	Culvert	Other	
Reason For Removal	Fish Passage	Habitat Improvement	Public Safety	Economics
Fish Passage Barrier?	Yes	No		
Impoundment?	Yes	No		
Adjacent Landuse	Urban (%)	Agricultural (%)	Residential (%)	Natural (%)

Assessors Name:	**Affiliation:**
Phone Number:	**Email:**

Cross-Section Survey Data Sheet

Form #___ of ____

Site Name:	**SITE ID #:**
Town, State/Province:	**Stream Name:**
Pre-restoration Post-restoration (circle	**Date:**
Form completed by:	**Time (24hr):**
Investigators:	

CROSS SECTION ID #	**Left Monument (UTM)**	**N**	**E**
	Right Monument (UTM)	**N**	**E**

Location Description	**Benchmark Description**
Left Monument Description	**Right Monument Description**

Station (STA)	**Backsight (BS)**	**Height of Instrument (HI)**	**Foresight (FS)**	**Elevation (ELEV)**	**Notes**
ft.	ft.	ft.	ft.	ft.	

Legend	**HI = ELEV + BS;**	**TP ELEV = HI - FS;**	**New HI = TP ELEV + BS**	
	LB: Left Bank RB: Right Bank	LEW: Left Edge of Water REW: Right Edge of Water	BKF: Bankfull CL: Center Line	BM: Benchmark TP: Turning Point

Cross-Section Survey Data Sheet (2)

Form #___ of ____

Site Name:	SITE ID #:	XS ID #
Date:	Investigators:	

Station (STA)	Backsight (BS)	Height of Instrument (HI)	Foresight (FS)	Elevation (ELEV)	Notes
ft	ft	ft	ft	ft	

Legend	HI = ELEV + BS;	TP ELEV = HI - FS;	New HI = TP ELEV + BS	
	LB: Left Bank RB: Right Bank	LEW: Left Edge of Water REW: Right Edge of Water	BKF: Bankfull CL: Center Line	BM: Benchmark TP: Turning Point

Longitudinal Profile Survey Data Sheet

Form #___ of ____

Site Name:	**SITE ID #**
Town, State/Province:	**Stream Name:**
Pre-restoration Post-restoration (circle one)	**Date:**
Form completed by:	**Time (24hr):**
Investigators:	

LONG PROFILE ID #	**US end (UTM) N**	**E**
	DS end (UTM) N	**E**

Starting Location Description	**Benchmark Description**

Station (STA)	**Backsight (BS)**	**Height of Instrument (HI)**	**Foresight (FS)**	**Elevation (ELEV)**	**Notes**
ft.	ft.	ft.	ft.	ft.	

Legend	**HI = ELEV + BS;**	**TP ELEV = HI - FS;**	**New HI = TP ELEV + BS**	
	LB: Left Bank RB: Right Bank	LEW: Left Edge of Water REW: Right Edge of Water	BKF: Bankfull CL: Center Line	BM: Benchmark TP: Turning Point

Longitudinal Profile Survey Data Sheet (2)

Form #___ of ____

Site Name: **SITE ID #:** **LP ID #:**

Date: **Investigators:**

Station (STA)	**Backsight** (BS)	**Height of Instrument** (HI)	**Foresight** (FS)	**Elevation** (ELEV)	**Notes**
ft.	ft.	ft.	ft.	ft.	

Legend	**HI = ELEV + BS;**	**TP ELEV = HI - FS;**	**New HI = TP ELEV + BS**	
	LB: Left Bank RB: Right Bank	LEW: Left Edge of Water REW: Right Edge of Water	BKF: Bankfull CL: Center Line	BM: Benchmark TP: Turning Point

Pebble Count Data Sheet

Form #___ of ____

Site Name:	**SITE ID #**
Town, State/Province:	**Stream Name:**
Pre-restoration Post-restoration (circle one)	**Date:**
Form completed by:	**Time (24hr):**
Investigators:	
Description/notes:	**CROSS SECTION ID #**

Size Class (mm)	Count	Total (#)	Frequency (%)	Cumulative (% Finer)
>=256				
<256				
<180				
<128				
<90				
<64				
<45				
<32				
<22.6				
<16				
<11.3				
<8				
<5.6				
<4				
	TOTAL:			

Water Quality Data Sheet

Form #____ of _____

Site Name:	**SITE ID #:**
Town, State/Province:	**Stream Name:**
Pre-restoration **Post-restoration** **(circle one)**	**Date:**
Form completed by:	
Investigators:	

Station	X Section ID #	Depth (ft)	Temp (° C)	Dissolved Oxygen (mg/l)	Oxygen Saturation (%)	Specific Conductance (uS/cm)	Time
A							
B							
C							
Replicate Station ___							

Vertical Profile- Station B	(ft)	(° C)	(mg/l)	(%)	(uS/cm)	
Weather Notes:	Surface					
	1					
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	10					

Wetland-Riparian Plant Community Monitoring Data Form

Form #___ of ____

Site Name:	**SITE ID #:**
Town, State/Province:	**Stream Name:**
Pre-restoration Post-restoration (circle one)	**Date:**
Form Completed By:	
Investigators:	

VEG PLOT ID #   **CROSS SECTION ID #**

Plant Species and Layer Type*	Stratum	% Cover	Plant Cover and Other Observations**

Large Woody Debris (number and description):

Leaf, Needle, and other Plant Cover (eg,, Mast, Invasive plants):

Notes

Cover Class	Range (%)	Mean (%)
T	<1	None
1	1-5	3
2	6-15	10.5
3	16-25	20.5
4	26-50	38
5	51-75	63
6	76-95	85.5
7	96-100	98

*Herbaceous (H), tree (T), and shrub and sapling (S) layers. Note, also record the percent barren ground.
**Description of plant condition may include plant height measurement, indication of flowering/inflorescence, presence of chlorosis, signs of disease, insect infestation or presence of animal browsing/grazing. Other observations may include indication of whether plant was planted or seeded and whether site has undergone natural or human disturbance.

Wetland-Riparian Plant Community Monitoring Data Form (2)

Form #___ of ____

Site Name:	**SITE ID #:**
Town, State/Province:	**Stream Name:**
Investigators:	**Date:**

VEG PLOT ID # **CROSS SECTION ID #**

Plant Species and Layer Type*	Stratum	% Cover	Plant Condition and Other Observations**

Notes

Cover Class	Range (%)	Mean (%)
T	<1	None
1	1-5	3
2	6-15	10.5
3	16-25	20.5
4	26-50	38
5	51-75	63
6	76-95	85.5
7	96-100	98

Photo Monitoring Data Form

Form #___ of ____

Site Name:	Stream Name:	SITE ID #
Form Completed By:	Photographer	Date:
Pre-restoration Post-restoration (circle one)		

Photo Station ID #	Photo Station Description	Photo #	Compass Bearing	Time	Cross Section ID #	Distance Along X-Section	Subject Description Upstream or Downstream

General Notes or Comments: (weather, rainfall data, cloud cover, time of sunrise and sunset, other pertinent information

This data sheet can be downloaded at www.gulfofmaine.org/streambarrierremoval

Appendix D – Hydrology, In Situ AquaTROLL 200

Equipment:

Manufacturer:
In-Situ, Inc.
221 East Lincoln Ave.
Fort Collins, Colorado 80524
www.in-situ.com
1-800-446-7488

In-Situ Aqua TROLL 200 water level, pressure, conductivity, temperature logger: User manual available at: https://in-situ.com/support/documents/aqua-troll-100-200-manual/download/305

In-Situ Antifouling TROLL Shield Guard: https://in-situ.com/support/documents/antifouling-troll-shield-guard-instruction-sheet/download/1082

In-Situ Antifouling TROLL Shield Nose: https://in-situ.com/support/documents/antifouling-troll-shield-nose-instruction-sheet/download/1085

In-Situ Aqua TROLL 100-200 Cables: https://in-situ.com/support/documents/aqua-troll-100-200-stripped-and-tinned-female-cable-instruction-sheet/download/870

In-Situ Large Desiccant with ABS Connector: https://in-situ.com/wp-content/uploads/2014/11/Large-Desiccant_Instruction.pdf

Specifications:

- Vented (gauged) pressure measurement through use of vented cables
- Full system specifications available at: https://in-situ.com/wp-content/uploads/2014/11/Aqua_TROLL_100_200_Specs.pdf

Software:

- Win-Situ 5, Version 5.6.28.6 for PC. Available at: https://in-situ.com/support/documents/win-situ-5-software/#tab-download

Innovations in Water Monitoring

Operator's Manual

Aqua TROLL® 100 & 200 Sonde

Multiple Part Numbers

0061340 | | 08/2016

Table of Contents

Introduction

This manual is intended to describe the characteristics, operation, calibration, and maintenance of the AquaTROLL 100 and AquaTROLL 200 Sondes.

System Description

The Aqua TROLL® Instrument is a compact, modular system for measuring conductivity and temperature in natural groundwater and surface water, as well as industrial, wastewater, and other installations. Aqua TROLL 200 Instruments have the added capability of measuring level. Components include the instrument, vented and non-vented cables, communication cables, external power accessories, desiccants, and other installation accessories, calibration solutions, and software.

How to Use This Manual

This Operator's Manual is designed as a start-up guide and a permanent reference for Aqua TROLL 100 and 200 Instruments.

- Section 1: Introduction to the Aqua TROLL Operator's Manual and to In-Situ Inc. — Warranty provisions — Instrument repair & return recommendations
- Section 2: System Components — Accessories — Product specifications

- Section 3: Getting Started — Attaching cable — Installing and opening the software
- Section 4: Using Win-Situ — Connecting for the first time — Customizing the Home screen — Setting the clock — Setting a device site — Calibrating conductivity — Preparing to log data — Disconnecting
- Section 5: The Conductivity Sensor: Description — Calibration — Available parameters
- Section 6: The Pressure (Level) Sensor: The two basic types of pressure sensors — Factory and field calibration
- Section 7: Field Installation — Guidelines and precautions for long-term deployment of the Aqua TROLL Instrument
- Section 8: Connecting for Use with SDI-12, Analog (4-20 mA), and Modbus Loggers and Controllers
- Section 9: Care and Maintenance
- Section 10: Troubleshooting

Conventions

Throughout this operator's manual you will see the following symbols.

Certification

The Aqua TROLL Instrument complies with all applicable directives required by CE and the FCC and found to comply with EN 61326, ICES-003, and FCC Part 15 specifications. Declarations of conformity may be found at end of this manual.

Unpacking and Inspection

Your Aqua TROLL Instrument was carefully inspected before shipping. Check for any physical damage sustained during shipment. Notify In-Situ and file a claim with the carriers involved if there is any such damage; do not attempt to operate the instrument. Accessories may be shipped separately and should also be inspected for physical damage and the fulfillment of your order.

Serial Number

The serial number is engraved on the body of the instrument. It is also programmed into the instrument and displayed when the instrument is connected to a computer running Win-Situ® 5 or Win-Situ® Mobile Software. We recommend that owners keep a separate record of this number.

To Our Customers

Thank you for your purchase of an In-Situ product. We are glad you chose us and our products to help you with your environmental monitoring needs. In-Situ Inc. has been designing and manufacturing world-class environmental monitoring instrumentation for over 25 years in the Rocky Mountains of the United States. As it was in the beginning, our expectation is that this product will provide you with many troublefree years of use. To that end, we pride ourselves on delivering the best customer service and support possible—24 hours a day, 7 days a week. We believe that this level of commitment to you, our customer, is imperative in helping you ensure clean, safe groundwater and surface water resources around the globe. We also understand the need for accurate, reliable assessments and we continue to make significant investments in Research and Development to ensure that we deliver the latest product and technological innovations to support your needs.

Whether you are gathering information about a body of water for a few moments, or over a period of years, you can rely upon us to provide you with a quality product and outstanding customer support at a fair price and have that product delivered to you when and where you need it.

We want your experience with In-Situ Inc. to be pleasant and professional, whether you are renting or purchasing from us. We would be pleased to hear from you and to learn more about your needs and your experiences with our products. Again, we thank you for choosing In-Situ Inc. and we look forward to serving your needs now, and in the future.

Warranty Provisions

In-Situ® Inc., (In-Situ) warrants that all new Aqua TROLL® 100 and 200 Instruments shall be free from defects in materials and workmanship for a period of two years when properly installed and operated in accordance with the instruction manuals provided by, or available through, In-Situ Inc., and when used within the design specifications for the product. Products and accessory products including batteries, which are manufactured by others, carry the warranty of that manufacturer, or 30 days, whichever is greater. The warranty period for all products begins on the day the product is shipped to the customer or distributor. The complete Warranty Policy is available on the In-Situ website.

How to Contact Us

Technical Support	1-800-446-7488, option 3
Toll-free 24 hours a day in the U.S.A. and Canada	

Address:	In-Situ Inc. 221 East Lincoln Ave. Fort Collins, CO 80524 U.S.A.
Phone:	970-498-1500
Fax:	970-498-1598
Internet:	www.in-situ.com
email:	support@in-situ.com

To Obtain Repair Service

If you suspect that your instrument is malfunctioning and repair is required, you can help ensure efficient servicing by following these guidelines:

1. Call or e-mail In-Situ Technical Support (support@in-situ.com). Have the equipment with you when you call.

2. Be prepared to describe the problem, including how the instrument was used and the conditions noted at the time of the malfunction.

3. If Tech Support determines that service is needed, they will ask that you download and complete a Return Materials Authorization Form available on the In-Situ website under Contact/Returns for Service.

4. Clean the instrument and cable. Decontaminate thoroughly if it has been used in a toxic or hazardous environment. See "Guidelines for Cleaning Returned Equipment" on page 5

5. Remove all sensors and accessories that are not required for the repair prior to returning unit.

6. Mark the RMA number clearly on the side of the box with a marker or label. Please keep your RMA number for future reference. Return unit for repair to the following address:

In-Situ Inc. Attn: RMA #XXXXX

221 E. Lincoln Ave.

Fort Collins, CO 80524

U.S.A.

To reduce waste, please use your original shipping container, if it is in good condition. The warranty does not cover damage during transit. We recommend the customer insure all shipments. Warranty repairs will be shipped back prepaid.

Guidelines for Cleaning Returned Equipment

Please help us protect the health and safety of our employees by cleaning and decontaminating equipment that has been subjected to any potential biological or health hazards, and labeling such equipment. Unfortunately, we cannot service your equipment without such notification. Please complete and sign the form on page 6 (or a similar statement certifying that the equipment has been cleaned and decontaminated) and send it along to us with each downhole instrument.

• We recommend a cleaning solution, such as Alconox®, a glassware cleaning product available from In-Situ (Catalog No. 0029810) and laboratory supply houses.

• **DO NOT remove the nose cone. DO NOT use any object to clean the sensor face.**

• Clean the pressure sensor by soaking only in cleaning solution or clean water.

• Clean all cabling. Remove all foreign matter.

• Clean cable connector(s) with a clean, dry cloth. Do not submerge.

• Clean the probe body—including the nose

Decontamination and Cleaning Statement

If an instrument is returned to our Service Center for repair or recalibration without a statement that it has been cleaned and decontaminated, or in the opinion of our Service Representatives presents a potential health or biological hazard, we reserve the right to withhold service until proper certification has been obtained.

Company name ____________________ Phone ____________________

Address ____

City ____________________ State __________ Zip __________

Instrument Type ____________________ Serial Number ____________________

Contaminants (if known) ____

____

Decontamination procedure used ____

____

Cleaning verified by ____________________ Title ____________________

Date ____________________

System Components

Instrument

The completely sealed Aqua TROLL Instrument contains conductivity and temperature sensors, real-time clock, microprocessor, sealed lithium battery, data logger, and memory. Aqua TROLL 200 Instruments include a vented or non-vented pressure sensor in a variety of ranges.

Cable

Several basic cable types are used in the Aqua TROLL system.

- RuggedCable® System, TPU-jacketed (Thermoplastic Polyurethane), vented or non-vented
- Vented Tefzel®-jacketed cable (ETFE fluoropolymer)
- Poly-coated stainless steel suspension wire for deployment of a non-vented instrument
- Communication cables for programming the device/ downloading the logged data

RuggedCable System

Cable includes conductors for power and communication signals, a weight-bearing structure, and a Kellems® grip to anchor the Aqua TROLL Instrument securely. Cable is available in standard and custom lengths. Uphole and downhole ends are identical female twist-lock connectors that connect to the Aqua TROLL Instrument, cable connect TROLL® Com devices, desiccants and other accessories.

Vented cable must be used with vented pressure/level sensors on the Aqua TROLL 200 to achieve gauged measurements. The cable vent tube ensures that atmospheric pressure is the reference pressure applied to the sensor diaphragm.

Vented cable ships with a small desiccant cap that should be replaced with a larger volume desiccant before you deploy the instrument in a humid environment.

Non-vented cable may be used with non-vented pressure/level sensors on the Aqua TROLL 100 or 200 Instruments to achieve absolute measurements. Vented cable can also be used.

RuggedCable Stripped-and-Tinned

In place of the uphole twist-lock connector, this cable ends in bare conductors for wiring to a logger or controller using SDI-12, analog (4-20 mA), or Modbus communication protocols. Vented cable includes an outboard desiccant to protect against condensation.

Also available in a shorter length ending in a male twist-lock connector to mate with RuggedCable.

See "Analog, SDI-12 and Modbus Connections" on page 36

Suspension Wire

Poly-coated stainless steel suspension cable is ideal for deployment of instruments with non-vented pressure sensors.

Small Desiccant

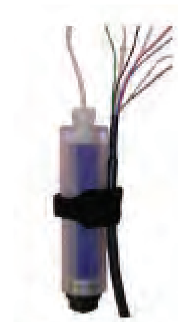
Vented cable includes a clear cap of indicating silica desiccant to protect the cable and electronics from condensation during shipping. In humid environments, replace the small desiccant with a larger-volume desiccant before deploying the instrument.

Large Desiccant

The optional high-volume desiccant pack attaches to vented cable and is available with a titanium or plastic twist-lock connector. Refill kits are available from In-Situ Inc. or your distributor.

Outboard Desiccant

Vented stripped-and-tinned cable includes an outboard desiccant pack attached to the cable vent tube, and is the same size as the large desiccant. Replacements and refills are available.



Accessory	Catalog No.
Small desiccant (3)	0052230
Large desiccant, ABS connector	0053550
Large desiccant, titanium connector	0051810
Outboard desiccant (replacement)	0051380
Refill kit for large & outboard desiccant	0029140

Communication Cables

TROLL Com devices enable an instrument to communicate with a desktop/laptop PC or handheld PDA for profiling, calibrating, programming, and downloading. TROLL Com devices include 0.9 m (3 ft) vented polyurethane cable, external power input jack, and a vent with replaceable membrane.

TROLL Com (Cable Connect)

Connects a RuggedCable to a serial or USB port. It is weatherproof and withstands a temporary immersion (IP67).

TROLL Com (Direct Connect)

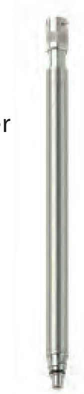
Connects an Aqua TROLL Instrument directly to a serial or USB port. It is a good choice for permanent connection to a PC, or for programming a non-vented Aqua TROLL Instrument that will be deployed without RuggedCable. It is not submersible or

Accessory	Catalog No.
RS232 TROLL Com, Cable Connect	0056140
USB TROLL Com, Cable Connect	0052500
RS232 TROLL Com, Direct Connect	0056150
USB TROLL Com, Direct Connect	0052510

Power Components

Internal Power
The Aqua TROLL Instrument operates on 3.6 VDC, supplied by a sealed, non-replaceable AA lithium battery. Battery life depends on sampling speed. The battery typically lasts for 5 years or 200,000 readings, whichever occurs first. One reading is defined as date, time, and all available parameters polled or logged from the device.

External Power
External Battery Pack
The sealed, submersible TROLL Battery Pack (lithium) supplies 14.4 V. When this power source is connected, the Aqua TROLL Instrument will use the external battery source first and switch to the internal batteries when external battery power is depleted. Typical external battery life when logging all available parameters at 2-minute intervals is approximately 2 years.



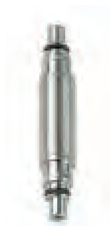
AC Adapter
In-Situ's AC adapter provides 24 VDC, 0.75 A, AC input 100- 250 V, includes North American power cord. The Programming Cable includes an external power input for connection to this adapter.

Accessory	Catalog No.
External Battery Pack	0051450
AC Adapter 24V	0052440

Installation Accessories

Twist-Lock Hanger
Titanium hanger to seal and suspend a non-vented Aqua TROLL Instrument while taking data; no venting, no communication capabilities

Catalog No. 0051480



Cable Extender
Connects two lengths of RuggedCable

Catalog No. 0051490

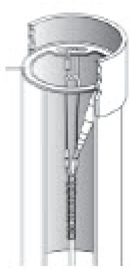
Wellcap
Locking and vented

2" Locking Wellcap:
Catalog No. 0020360

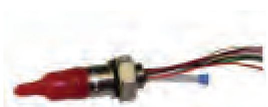
2" Vented Locking Wellcap:
Catalog No. 0020370

4" Locking Wellcap:
Catalog No. 0020380

4" Vented Locking Wellcap:
Catalog No. 0020390



Top of Well Installation Ring
Catalog No.
Well-dock 2", 4" or 6"



Bulkhead Connector
Panel-mounted bulkhead for connection to RuggedCable

Catalog No. 0053240

Control Software

Win-Situ® 5 Software is easy-to-use software for programming Aqua TROLL Instruments. Win-Situ provides instrument control for direct reads and profiling, calibration, long-term data logging, data downloads, data viewing, data export to popular spreadsheet programs, choice of units and other display options, and battery/memory usage tracking. Win-Situ® Plus enables configuration of networks and telemetry. Minimum system requirements: 400 MHz Pentium® II processor; 128 MB RAM, 100 MB free disk space; Internet Explorer® 6.01 or higher; Windows® 2000 Professional SP4 or higher, Windows XP Professional SP2 or higher, or Windows Vista SP1 or higher; Windows 7 or higher, CD-ROM drive; serial or USB port.

Win-Situ® Mobile Software provides the features and functions of Win-Situ 5 on a field-portable platform. Requirements: In-Situ RuggedReader® Handheld PC with Microsoft Windows Mobile® operating system (RuggedReader, Windows Mobile 5 or later), serial communications port, and at least 16 MB for data storage (SD card, CF card, or the device's built-in non-volatile memory). For installation and file exchange, Windows® 7 requires Windows® Mobile Device Center to be installed on the computer. Earlier versions of Windows require Microsoft® ActiveSync®.

Accessory	Catalog No.
Win-Situ 5 (no license required)	0051980
Win-Situ 5 Plus license	0053560
Win-Situ Mobile license for RuggedReader	0047520
Win-Situ Mobile license (upgrade from Pocket-Situ 4)	0047550

Product Specifications- General

Aqua TROLL 100 and 200 Instruments

Temperature ranges[1]	Operational: -5 to 50° C (23 to 122° F) Storage: -40 to 65° C (-40 to 149° F) Calibrated: 0 to 50° C (32 to 122° F)
Max Pressure for Aqua TROLL 100	500psi (1153 ft)
Dimensions and weight	Diameter (OD): 1.83 cm (0.72 in) Length: 31.5 cm (12.4 in) Weight: 0.5 kg (1.0 lb)
Materials	Titanium body and sensors; Delrin nose cone; PVC conductivity cell
Output options	Modbus/485; SDI-12; and 4-20 mA
Battery type and life[2]	3.6V lithium; 5 years or 200,000 readings[3]
External power	8-36 VDC
Memory **Data records[4]** **Data logs**	4 MB 190,000 50
Log types[5]	Linear, Linear Average and Event
Fastest logging rate	Linear: 1 per minute. Linear Average: 1 per minute. Event: 1 per second
Fastest output rate	1 per second

Product Specifications- Conductivity Sensor

Conductivity Sensor	Type: Balanced 4-electrode cell
Methods	EPA Method 120.1; Standard Methods 2510

Range, accuracy and resolution	Range: 5 to 100,000 µS/cm Accuracy: ±0.5% of reading + 1 µS/cm when reading less than 80,000 µS/cm ±1.0% of reading above 80,000 µS/cm Resolution: 0.1 µS/cm	
Parameters supported[6]	*Range*:	*Units*:
Actual conductivity	5 to 100,000 µS/cm	µS/cm, mS/cm
Specific conductivity[7]	5 to 100,000 µS/cm	µS/cm, mS/cm
Salinity[8]	0 to 42 PSU	PSU
Total dissolved solids	0 to 82 ppt	ppt, ppm
Resistivity	10 to 200,000 Ohms-cm	Ohms-cm
Density (water salinity)	0.98 to 1.14 g/cm^3	g/cm^3

Product Specifications- Pressure (Aqua TROLL Instrument)

Pressure/Level Sensor[9]	Type: Piezoresistive; Pressure/level are available only to the Aqua TROLL 200 Instrument	
Range	*Absolute (non-vented)* 30 psia: 10.9 m (35.8 ft) 100 psia: 60.0 m (197 ft) 300 psia: 200.7 m (658.7 ft) 500 psia: 341.3 m (1120 ft)	*Gauged (vented)* 5 psig: 3.5 m (11.5 ft) 15 psig: 11 m (35 ft) 30 psig: 21 m (69 ft) 100 psig: 70 m (231 ft) 300 psig: 210 m (692 ft) 500 psig: 351 m (1153 ft)
Burst pressure	Maximum 2x range; burst 3x range	
Accuracy and resolution[10]	Accuracy @ 15° C: ±0.05% full scale (FS)[11] Accuracy 0 to 50° C: ±0.1% FS[12] Resolution: 0.005% FS or better	
Units of measure	Pressure: psi, kPa, bar, mbar, mmHg, inHg, cmH_2O, inH_2O) Level: in, ft, mm, cm, m	

Product Specifications- Temperature

Temperature Sensor	
Method	EPA Method 170.1
Accuracy and resolution	Accuracy: ±0.1° C or better
Units of measure	Celsius of Fahrenheit

Product Specifications- Footnotes

[1]Temperature range for non-freezing liquids

[2]Typical battery life when used within the factory-calibrated temperature range

[3]1 reading = date/time plus all available parameters polled or logged from device

[4]1 data record = date/time plus 3 parameters logged (no wrapping) from device
[5]External power or battery pack is recommended when using Linear Average or Event logging modes

[6]Parameters derived from temperature at 25° C and actual conductivity range of 5 to 100,000 µS/cm with a ±0.5% + 1 µS/cm accuracy

[7]Derived from Standard Methods 2510B

[8]Defined by the Practical Salinity Scale 1978; Standard Methods 2520B

[9]Real-time level compensation based on water density

[10]Accuracy with 4-20mA output option: ±0.25% FS

[11]Across factory-calibrated pressure range

[12]Across factory-calibrated pressure and temperature ranges

Specifications are subject to change without notice.
Delrin is a registered trademark of E.I. duPont de Nemours and Company.
NIST is a registered trademark of the National Institute of Standards and Technology.

Getting Started

This section provides a quick overview of the initial steps necessary to get the instrument ready to communicate:

- Select the appropriate TROLL Com for communication. This determines the hardware connections, and may influence the software installation. The drawing on the following page shows the function of the different TROLL Com models.
- Install the software.
- Connect the hardware, based on the selected TROLL Com.
- Open the software and establish communication with the Aqua TROLL Insturment. See "Using Win-Situ® 5 Software" on page 17 for an overview of Win-Situ operations.

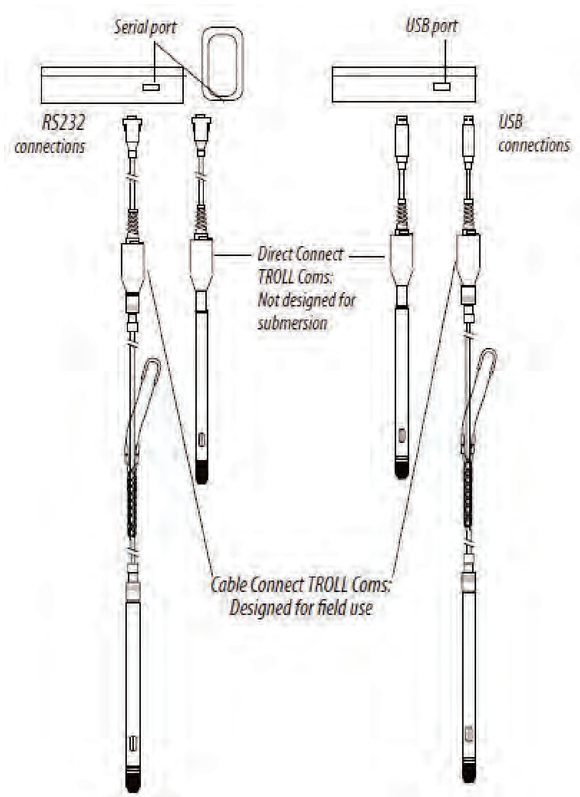
Select a TROLL Com for Communication

The figure below shows the function and connectability of the different models of TROLL Com.

✔ *TIPS: A Direct Connect TROLL Com may be preferred for programming an Aqua TROLL Instrument that will be deployed on wire.*

RuggedCable and a Cable Connect TROLL Com are required for communication with the device while deployed, but programming can be done with any TROLL Com connection.

An RS232 (serial) TROLL Com is needed for use with a RuggedReader



Install the Software

Install Win-Situ 5 Software from the In-Situ software/resource CD or from the In-Situ website:

- Click on Win-Situ 5, and follow the instructions to install Win- Situ 5 to your local hard drive.

USB TROLL Com Drivers

If using a USB TROLL Com, be sure to select the option "Install USB TROLL Com Drivers." Two drivers will be loaded to your hard drive, one for the USB TROLL Com, one for the USB TROLL Com serial port.

Win-Situ Mobile

For communication using a RuggedReader Handheld PC in the field, install the desktop component of Win-Situ Mobile on a desktop/laptop PC from the CD or website: The desktop component is called the Win-Situ Software Manager, and is needed to install Win-Situ Mobile on the RuggedReader.

1. Click on Win-Situ Mobile and follow the instructions to install the Win-Situ Software Manager to your local hard drive.

2. Connect the RuggedReader to the desktop computer, establish a connection in Microsoft ActiveSync®, launch the Win-Situ Software Manager, and follow the instructions to install Win-Situ Mobile on the RuggedReader.

Win-Situ Sync

If you plan to synchronize log files from the RuggedReader to a PC after collecting data in the field, install Win-Situ Sync from the CD or website.

Connect the Hardware

1. Connect the Aqua TROLL Instrument to the selected TROLL Com as illustrated earlier in this section.
   - **Direct Connect:** Attach via push-on connection to the Aqua TROLL back end.
   - **Cable Connect:** Connect the twist-lock connectors on the Aqua TROLL Instrument and the RuggedCable.
2. Insert the TROLL Com into the computer port.

USB TROLL Com

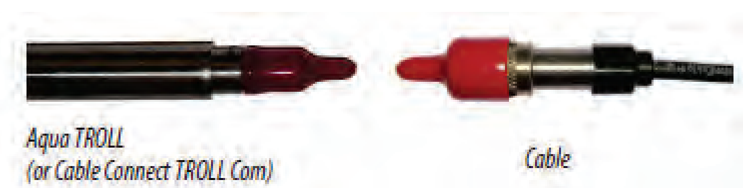
When you plug in a USB TROLL Com, the USB drivers that were downloaded when you installed Win-Situ 5 will be installed.

- After installation, check as follows to find which COM port the connected USB TROLL Com is using:
- Windows 2000, Windows XP: Control Panel > System > Hardware tab > Device Manager > Ports. Click the plus sign to display the ports.
- Windows Vista and 7: Control Panel > System > Device Manager (Administrator permission required) > Ports. Click the plus sign to display the ports.

After connections are made, you are ready to launch the software and program the Aqua TROLL Instrument. See "Using Win-Situ® 5 Software" on page 17. For more detailed information, see the Win-Situ Help menu.

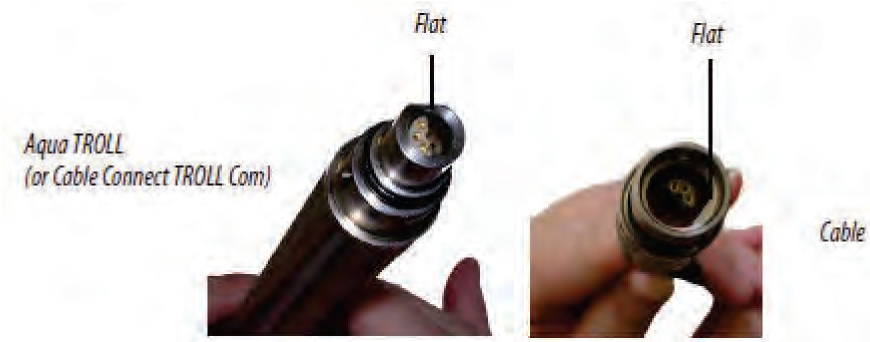
Twist-Lock Cable Connections

1. Remove the protective caps from the Aqua TROLL connector end and cable connector end.

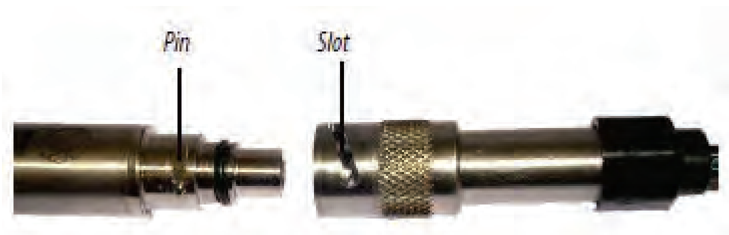


✔ ***TIP:*** *Retain the dust caps to protect the pins and O-ring from damage when cable is not attached.*

2. Look at the connectors. Each has a flat side.

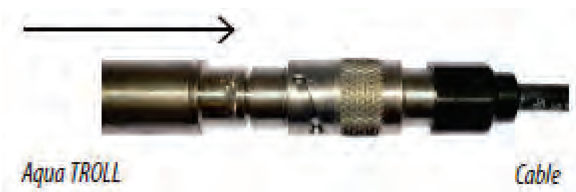


Note the pins on the instrument connector (one on each side) and the slots on the cable connector (one on each side).



3. Slide back the sleeve on the cable connector.

4. Position the flat edges so they will connect properly, and insert the instrument connector firmly into the cable connector.



5. Slide the sleeve on the cable toward the Aqua TROLL until the pin on the probe fits into the round hole in the slot on the cable connector.

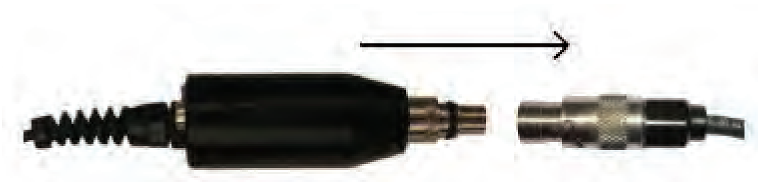
6. Grasp the textured section of the cable connector in one hand and the Aqua TROLL in the other. Push and twist firmly so that the pin on the body connector slides along the slot on the cable connector and locks securely into the other hole.

7. To attach a Cable Connect TROLL Com, first remove the desiccant from the cable by grasping the textured section of the cable connector in one hand and the desiccant in the other. Twist in opposite directions to unlock the desiccant from the cable.

✔ ***Tip**: Make sure you hear the "click." The "click" ensures the cable is securely attached.*

8. Position the flat edges so they will connect properly, and insert the TROLL Com connector firmly into the cable connector.

9. Push, twist, and click to lock.



Using Win-Situ® 5 Software

Win-Situ 5 Software is the In-Situ instrument control software for Aqua TROLL Instruments. Use Win-Situ to:

- Display real-time readings from the connected Aqua TROLL, in meter, tabular, or graphic format
- Program the device to log data; download the logged data
- Calibrate the conductivity sensor, select output parameters and units
- Customize the output of a pressure/level sensor to record drawdown, surface water elevation, gauge height, stage height, etc.
- Set communication options in the device—Modbus, SDI- 12, analog, IP, telemetry, etc.

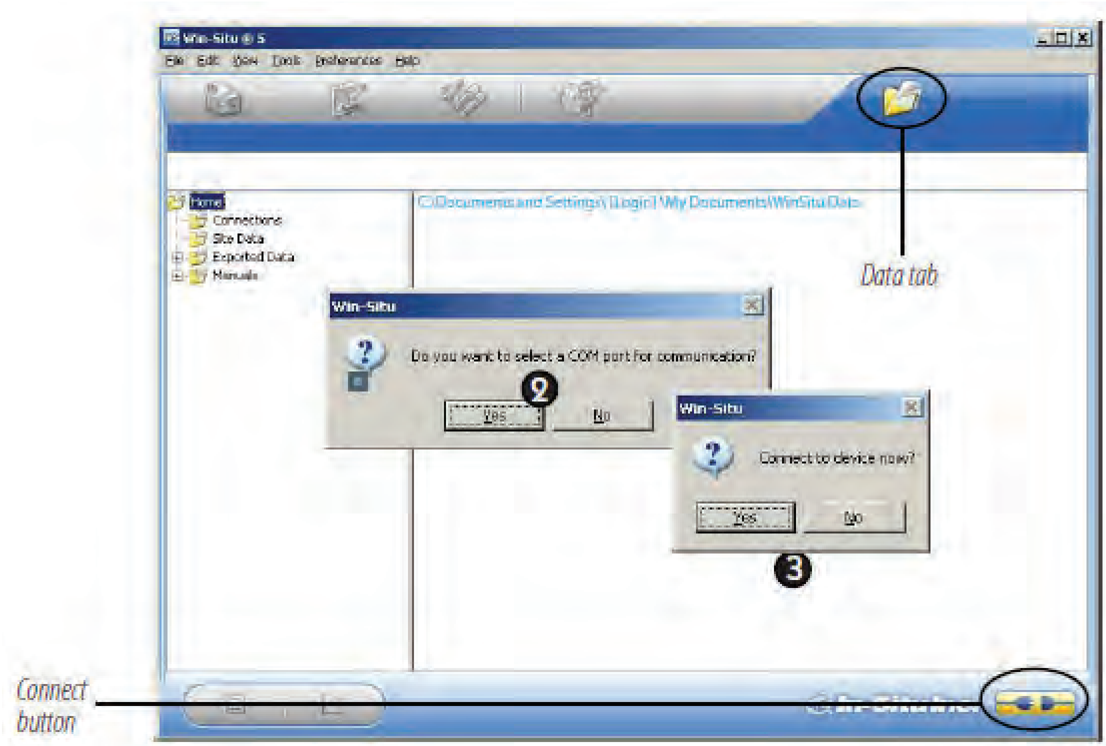
Launch the Software and Connect Instrument

1. Start Win-Situ by double-clicking the shortcut  created on the desktop during installation. Win-Situ opens and displays the Data area (“Data tab”), shown below.

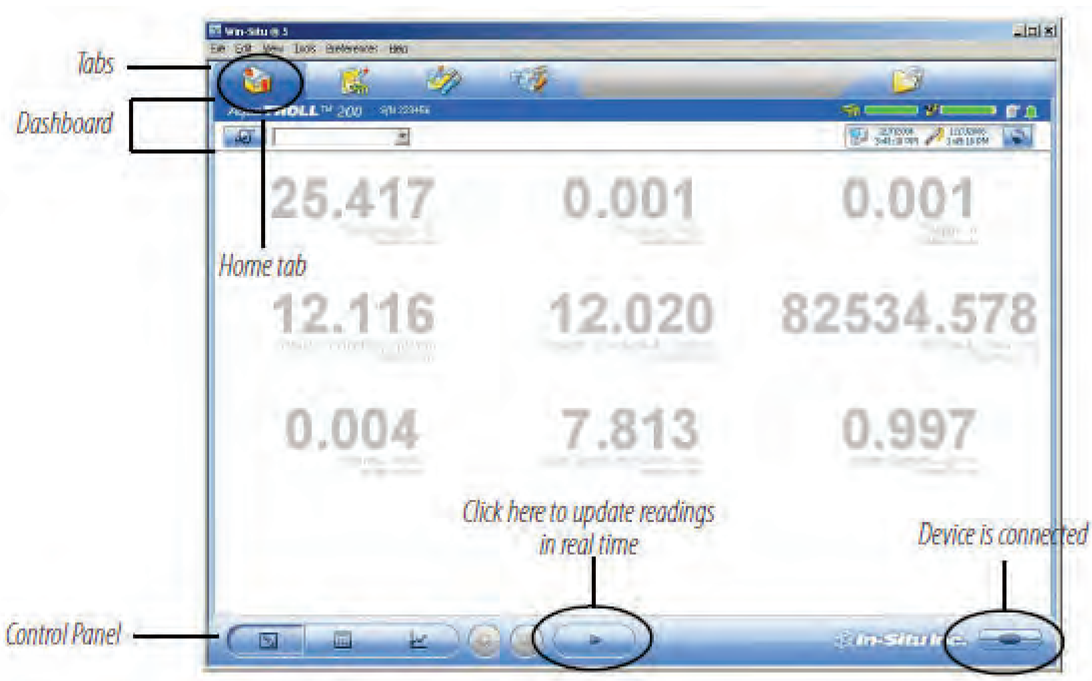
2. Check the COM port. The software may ask if you want to select a COM port. Do one of the following:

- Answer Yes to the prompt, then check or change the port in the Comm Settings dialog, and click OK  to close it, or
- Answer No to bypass this step.

3. Win-Situ asks if you want to connect to the device. If the Aqua TROLL instrument is connected to your computer as described in the previous section, answer Yes.



4. Software connects and displays a reading of all supported parameters.



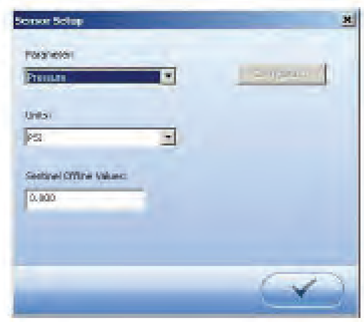
The Home Screen

- Note the Tabs at the top of the screen—this is the Home tab, which displays current readings from the connected device.
- The Dashboard (status area) shows the device model & serial number, battery and memory usage, clock, alarms, and logging status.
- The Control Panel contains action buttons. To update the readings in real time, press .
Note: When this button looks pressed in

, polling is active. Before you can perform certain software tasks, you will need to stop polling by pressing the button again.

Customizing the Home Screen

Changing Units



1. Click the Sensors tab , select the sensor for which you intend to change units.

2. Click the "Configure" button in the control panel.

3. In the Sensor Setup screen, select a parameter, then select a unit. Repeat for each parameter as necessary.

4. Click OK to return to the Sensors tab.

Changing the Rate at Which the Readings Update

Also called the "poll rate," this can range from 1 to 30 seconds.

1. Select Preferences > Home View Settings.

2. Adjust the Poll Rate. Default: 5 seconds.

Changing the Decimal Places Displayed

To change the number of decimal places displayed for each reading:

1. Select Preferences > General Settings.

2. Under Parameter Defaults, select a parameter, then the "significant decimal digits" for each parameter.

Real-Time Graphing

To view a real-time trend graph: click the "Graph" button

To view a graph with a data table below it, select Preferences > Graph Settings. Check the Data Panel option. Click OK.

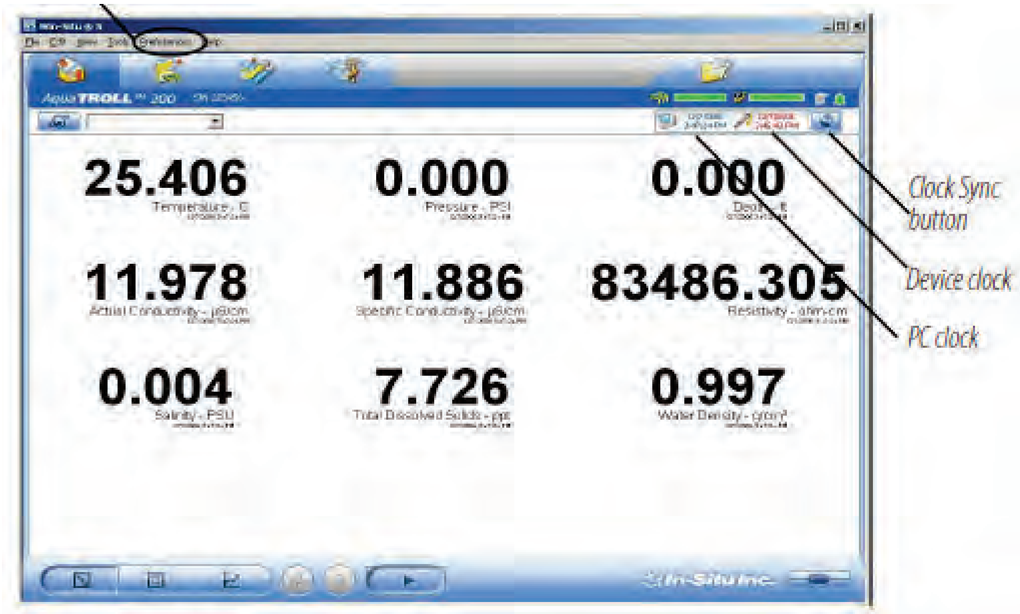
Set specific information in the software. Win-Situ provides many options. At a minimum:

- Set the Aqua TROLL clock.
- Enter a name for the site where the instrument will collect data.
- Calibrate the conductivity sensor.
- Enter data logging instructions.

A brief overview is provided here. For more detailed information, see the Win-Situ Help menu.

Set the Clock

Data collection schedules depend on the device's real-time clock. Both the device clock and the system (PC) clock are shown on the dashboard. The clocks update every 2 seconds. If the device clock differs by more than 2 seconds from the system clock, the device clock is displayed in red. To synchronize the clocks, click the "Sync" button .



Add a Site

Logged data are organized and filed by the site where the data were logged. This feature can help you manage data from multiple sites. You can create as many sites as you like, with or without an Aqua TROLL connected. Sites are stored in the site database in your Win-Situ working directory and are available to select for any Aqua TROLL, any log. You will need a site when setting up a data log. Here are the steps to set up a new site:

1. On the Data tab, click the Site Data folder.

2. Select File menu > New > Site.

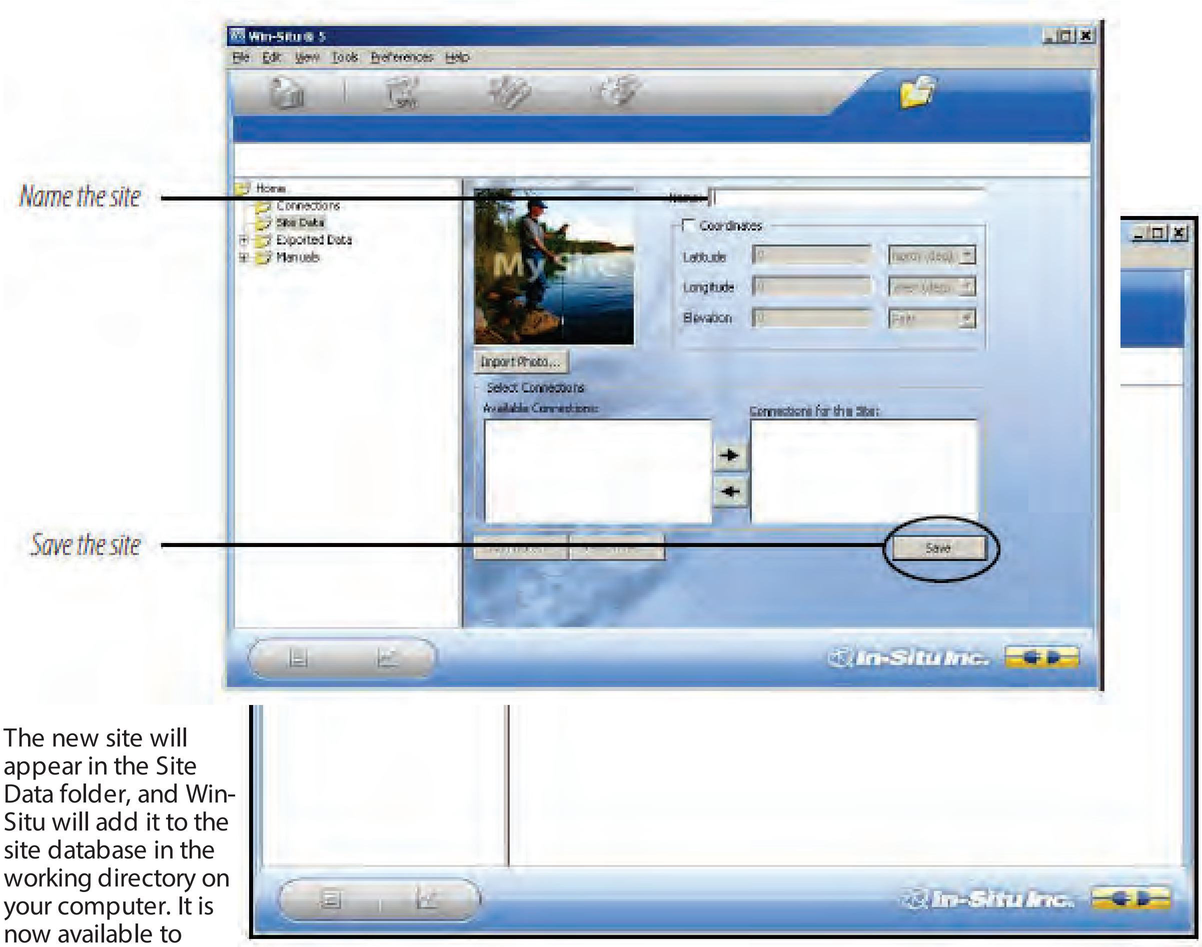
✔ ***TIP:*** *A default site is supplied and may be used, but it does not contain any specific information on the location data collection site. For more information on sites, see Win-Situ Help menu.*

✔ ***TIP:*** *You can also create a Site Group to organize multiple sites within a Site Group folder.*

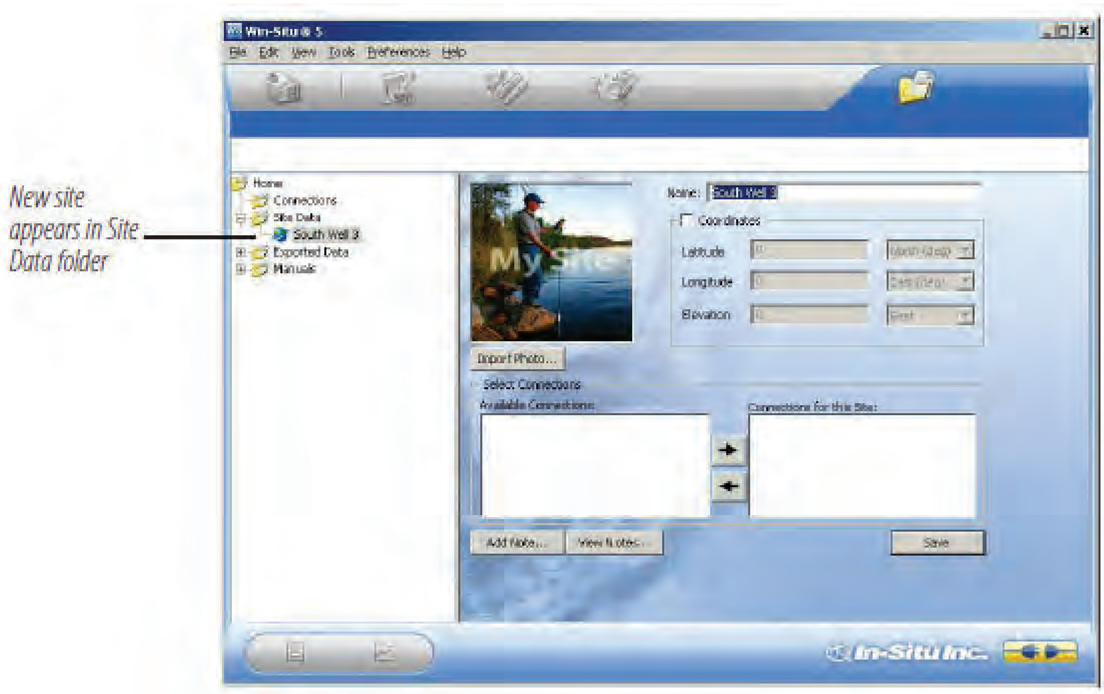
3. In the Site Information screen, enter a name for the site. A short, descriptive name is best—for example, a project, well, water body, gauging station, town, nearby landmark, etc. Length is limited to 32 characters.

A site name is the only required field, but there are many additional options for identifying a site. To include site Coordinates, check ☑ Coordinates, then enter Latitude (0.00 to 90.00, select North or South from listbox), Longitude (0.00 to 180.00, select East or West) and Elevation (select Feet or Meters). You can add a short descriptive Note, import a site Photo (bitmap), and/or specify a custom Connection. (If any connections have been defined, they will be displayed.)

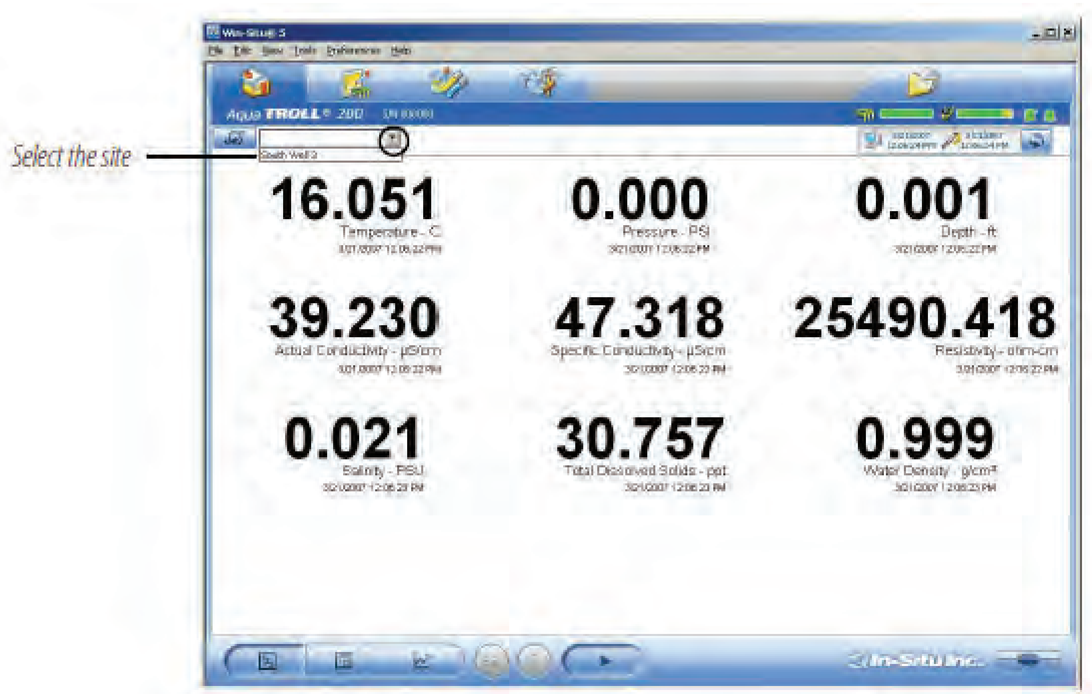
4. When finished, click Save to save the site.



The new site will appear in the Site Data folder, and Win-Situ will add it to the site database in the working directory on your computer. It is now available to select for any device, any log.



5. To set this new site in the connected Aqua TROLL Instrument: Return to the Home tab, click the down arrow beside the site box, and select your new site. This site now becomes the “current” site for the connected Aqua TROLL Instrument, and is available to use in data logs.



Check the Conductivity Calibration

The conductivity sensor in the Aqua TROLL has been calibrated during manufacturing to produce a linear response across the operating range.

We recommend you check the specific conductivity reading in the solution shipped with your instrument. If the device is reading accurately, there is no need to fieldcalibrate the instrument unless SOPs require it.

To perform a field calibration you will need:

- The In-Situ Cal Cup, or other suitable container that allows for complete immersion of the conductivity sensor, including the temperature "button," which can be seen on one side of the probe. The Cal Cup is recommended for the first calibration.
- The calibration standard solution supplied, or other solution of known specific conductivity in the range 100 to 60,000 µS/cm.

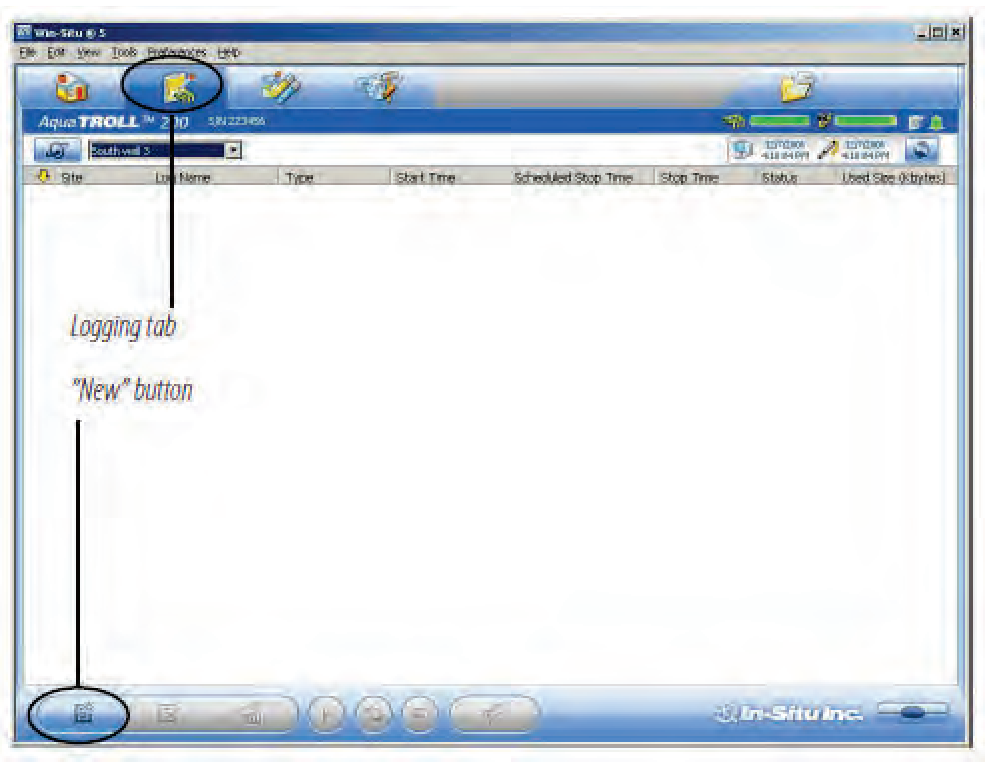
The complete calibration procedure takes only a few minutes and may be done in a field or office/lab setting with a software connection in Win-Situ 5 or Win-Situ Mobile Software. See "Calibration" on page 25 for calibration instructions, including:

- Preparation of the Aqua TROLL
- Software input
- Calculated output

Prepare to Log Data

1. To program the device to log data, go to the Logging tab.
2. Click the "New" button.

✔ ***TIP:*** *Stop "polling" in the Home screen before setting up a data log.*



✔ ***TIP:*** *For more complete information on setting up data logs, see the Win-Situ Help menu.*

The Logging Setup Wizard will guide you through the configuration of a data log—including the site, log name, parameters to measure, sample schedule, start time, stop time, level output, and other options.

Tips for Aqua TROLL Data Logs

- Nine parameters are available for the Aqua TROLL 200 Instrument. Seven parameters are available for the Aqua TROLL 100 Instrument. All selected parameters are logged, with implications for battery and memory usage.
- Only one active log can reside in the device at a time. An active log is a log that is Ready, Pending, Running, or Suspended as shown in the Status column of the Logging Tab.
- To avoid draining the Aqua TROLL battery prematurely, external power is required for Event logging, and recommended for Linear Average logging.
- For information on selecting a Level output, refer to the Win- Situ Help menu, or see "Pressure and Level" on page 29 in this manual.
- For a non-vented Aqua TROLL that will be deployed on wire, be sure to select a Scheduled Start so the log will start by itself, without a communication connection.
- For more complete information on setting up data logs, see the Win-Situ Help menu .

To Start logging:

- A "Pending" (scheduled) log will start at its programmed time.
- You can start a "Ready" (manual) log at any time while connected by selecting the log and pressing "Start" .

To Stop logging:

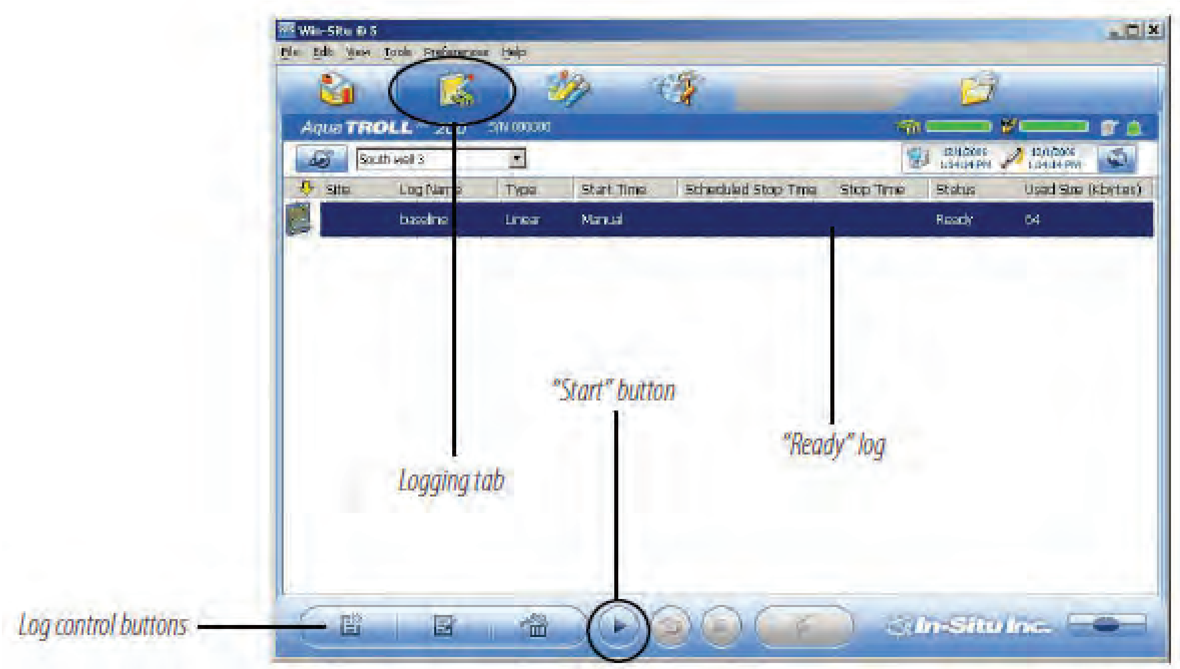
- Select the log and press the "Stop" button .
- Or suspend (temporarily stop) it with the "Pause" button .

To Download the log to the connected PC:

- Select the log and press the "Download" button .

To View the log after downloading:

- Go to the Data tab and select the log; for a graph press .



Disconnect

After the Aqua TROLL is programmed to log data, you are ready to:

- Exit the software (File menu > Exit).
- Disconnect the TROLL Com from the cable connector, by grasping the textured section of the cable connector in one hand and the TROLL Com in the other. Twist in opposite directions to unlock the TROLL Com from the cable.
- Vented cable: Attach desiccant to the cable connector—line up the flat sides of the connectors, push, twist, and click to lock the desiccant to the cable. Remove red dust cap from the desiccant's vent.
- Non-vented Aqua TROLL (or installations where vented pressure or communication are not required): Attach a nonvented cable or twist-lock hanger and suspension wire.
- Install the instrument in its field location. See "Field Installation" on page 34 for guidelines.

✔ ***Tips:*** *Remove the dust cap from the desiccant before deployment to allow air to reach the cable vent tube.*

Conductivity

About Conductivity

Conductivity measures the ability of a material to carry an electric current. Generally, the higher the concentration of dissolved salts and minerals in water, the better the water is as a conductor, therefore the electrical conductivity is higher. Deionized/distilled water is a poor conductor because almost all anions and cations are removed during the deionization/ distillation process. If conductivity changes in a body of water, it often indicates an environmental event. For example, a dramatic increase in the electrical conductivity of an underground fresh water aquifer located near the ocean could indicate the beginning of saltwater intrusion. On the other hand, an increase in the electrical conductivity of a small lake that is completely surrounded by farmland may simply be the result of runoff from recent precipitation.

How is Conductivity Measured

Conductance is the reciprocal of the resistance, in ohms, measured between two opposing electrodes of a 1 cm cube at a specific temperature. The unit 1/ohm or mho was given the name of Siemens (S) for conductance. It is not practical to require all conductance cells to have the dimensions of an exact cube. To enable the comparison of data from experiments with different conductance cells, the conductance is multiplied by the cell constant to show conductivity in Siemens per centimeter (S/cm). Cell constants are determined for each sensor using a standard solution of known conductivity. The cell constant depends on the electrode area and the amount of separation or distance between the electrodes.

The four-electrode conductivity cell contains two drive electrodes and two sensing electrodes. In the Aqua TROLL instrument, each drive electrode is composed of two interconnected pins, for a total of six pins. The sensing electrodes are positioned in a low current area to minimize electrode fouling. An alternating current is used to drive the cell. This reduces errors caused by polarization resulting from the application of a direct current.

Calibration

The conductivity sensor in the Aqua TROLL instrument has been calibrated during manufacturing to produce a linear response across the operating range. Standard Operating Procedures for measuring conductivity in the field typically specify that the sensor shall be calibrated before use, close to the expected temperature and conductivity conditions. The accuracy of the sensor depends on the calibration solution used and the operator's technique.

We recommend that you check the specific conductivity reading in the solution shipped with your instrument. If the device is reading accurately, there is no need to field-calibrate the instrument unless SOPs require it.

The Aqua TROLL instrument can be calibrated at any point in the operating range. However, best results will be obtained in the range of approximately 100 to 60,000 microSiemens/cm (µS/ cm).

When carbon dioxide from the air dissolves into water it increases the conductivity, sometimes by as much as one or two µS/cm. This could shift a 146.9 standard by as much as 3%. The amount of shift is not predictable, so it should be minimized by limiting exposure to air. Fill the calibration cup to the marked fill line and close it as soon as possible. A small air bubble in the cup is acceptable, and in fact it assists mixing during the inversions. Discard remaining portions of low range calibration standards within a few days after opening the bottle.

To perform a conductivity calibration of the Aqua TROLL Instrument you will need:

- The In-Situ Cal Cup supplied with your instrument.
- The calibration standard solution supplied, or other solution of known specific conductivity in the range 100 to 60,000 µS/cm.

Preparing to Calibrate

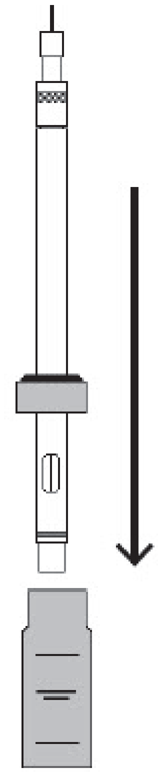
Three factors are essential to a successful conductivity calibration:

- A The calibration solution is not diluted or contaminated.
- B The probe and the solution are at the same temperature.
- C The sensing cell is completely filled with solution—no air bubbles on the sensor.

The following preparation steps can help to ensure a successful calibration and avoid erroneous field data.

A Eliminate water and rinse

1. Remove the nose cone (Aqua TROLL 200 only). Water trapped here can dilute the calibration solution. Air bubbles may also come from this area.
2. If the device is wet from previous use, dry the body and shake to clear any liquid inside the conductivity sensor.
3. Before opening the solution bottle, invert it a few times to redistribute any water condensation.
4. Remove the Cal Cup cap and fill the cup to the "Rinse" line with calibration solution.
5. Insert the Aqua TROLL through the grommet in the cap.
6. Attach the cap to the Cal Cup. The Aqua TROLL should rest on or near the bottom.
7. Shake vigorously to rinse the sensing cell.
8. Loosen the cap, remove the Aqua TROLL. There is no need to pull it out of the cap. Discard the solution.
9. For best results, rinse again using the same procedure.



B Equalize temperature

1. Fill the Cal Cup to the "Fill" line with calibration solution.
2. Install the Aqua TROLL and tighten the cap.
3. Invert multiple times for at least 30 seconds— longer if the probe and solution are at different temperatures.

C Remove air bubbles from the sensor

1. Hold the Aqua TROLL and the Cal Cup at a 45 degree angle.
2. Gently tap the Aqua TROLL against the inside of the Cal Cup to remove bubbles from the conductivity cell.
3. Repeat until all bubbles are removed.

✔ ***TIP:*** *With the correct fill level, and the instrument held at a 45° angle, the air bubble in the Cal Cup will not intrude into the conductivity sensor.*

Note: Sometimes dissolved gases in the solution will cause bubbles to form on the sensor, especially if the solution is cold. Thermal equilibrium may require extra time, and air bubbles may need to be removed before starting the calibration. If you can see bubbles on the inside of the Cal Cup, bubbles are probably on the sensor.

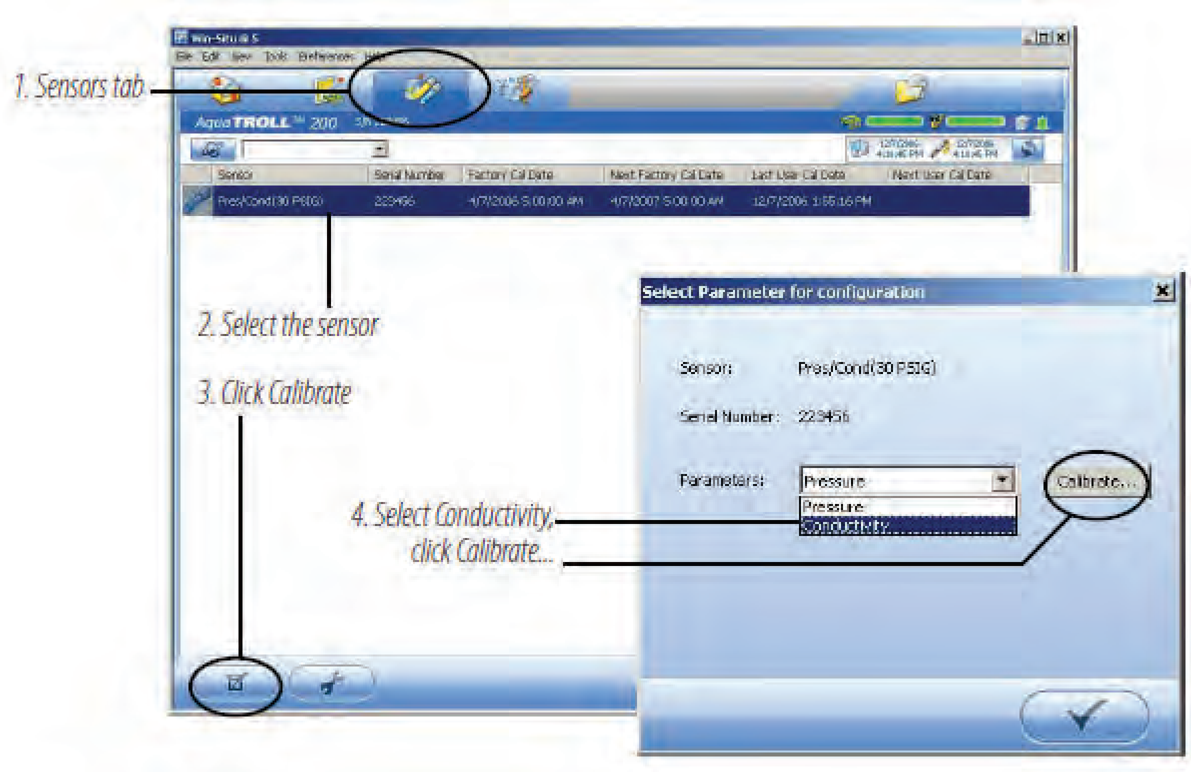
Calibration Procedure

TIP: *For best results when calibrating a completely dry sensor, allow it to soak for 15 minutes in the calibration solution before proceeding.*

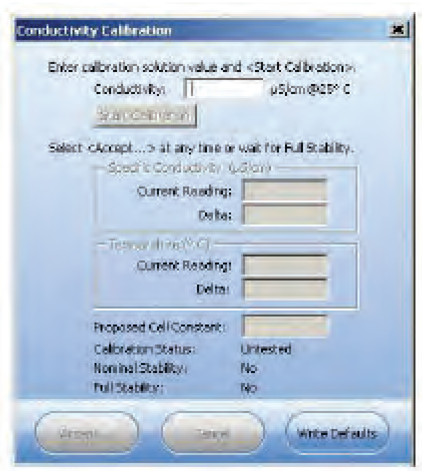
1. If you have not already done so, attach the cable to the Aqua TROLL Instrument and to the computer, open Win-Situ Software, and connect to the device.
2. Go to the Sensors tab and select the sensor.

3. Click the “Calibrate” button .

4. In the next screen, select the Conductivity parameter and click Calibrate...



After a review of the preparation steps the Conductivity Calibration screen appears.



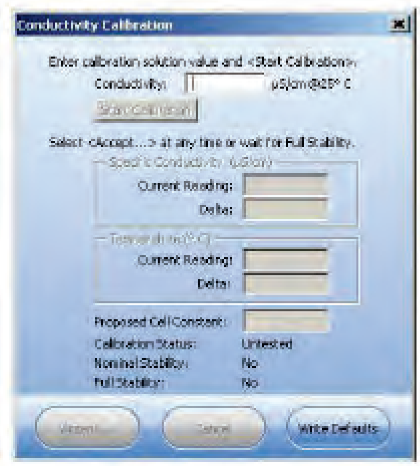
5. Enter the Specific Conductivity of the calibration solution into the box next to µS/cm @25° C.

6. Click Start Calibration. Software will monitor the conductivity and temperature readings, calculate the cell constant (sometimes called the “Kcell”), and inform you when the response meets the criteria for Nominal Stability.

7. You can click Accept... at any time to continue. For best results, wait until Full Stability is reached. At that time, the next screen is displayed automatically.

8. Look at the Proposed Cell Constant before you Commit the value to the sensor. It should be in the range of 0.90 to 1.10. Note: Aging sensors may display values between 0.70 and 1.30. If outside this range, we recommend returning to the factory for calibration.

If the cell constant is out of range, the cause could be an air bubble, incomplete rinsing, sensor fouling, or other factors. Repeat the preparation and calibration with fresh cal solution.



9. When you are satisfied with the proposed cell constant, click Commit to write the calculated cell constant to the sensor.

10. If the Aqua TROLL will be deployed immediately, remove it from the Cal Cup, rinse it, discard the calibration solution, and reinstall the black nose cone. Otherwise, store it wet in the Cal Cup (in cal solution or water) for later deployment.

✔ ***TIP:*** *If the proposed cell constant is outside the range 0.90 – 1.10, check conditions and repeat the calibration.*

Nominal Stability vs. Full Stability

To meet the criteria for a valid calibration point, the change in sensor response is monitored over time. The software is looking for the calibration solution temperature and the sensor readings to settle over a specific time period. The criteria for Full Stability are designed to meet the published specifications. The criteria for Nominal Stability are designed to shorten the calibration time when an approximate calibration is acceptable.

Available Parameters

The Aqua TROLL Instrument can also calculate and record derived parameters as listed below. For more information on measurement methodology, including the equations used to derive the calculated parameters, see the technical note “Aqua TROLL 200 Measurement Methodology” on the In-Situ software/resource CD, or on the In-Situ web site at www.In-Situ.com.

Actual Conductivity

Units: micro siemens per centimeter (µS/cm), default milli siemens per centimeter (mS/cm)

Specific Conductivity

A means of expressing what the actual conductivity of a solution would be at a standard reference temperature (25° C). Calculated from actual conductivity and temperature. The factory default coefficients calculate specific conductivity per Standard Methods 2510B.

Units: micro siemens per centimeter (µS/cm), default milli siemens per centimeter (mS/cm)

Salinity

Calculated from actual conductivity and temperature.
Units: Practical Salinity Units (PSU)

Total Dissolved Solids (TDS)

Calculated from specific conductivity using a conversion factor (Default: 0.65).

The TDS conversion factor may be edited in Win-Situ as follows: Select the sensor on the Sensors tab and click Configure . In the next screen select the Total Dissolved Solids parameter and click Configure. Enter a value between 0.001 and 10.000. Units: parts per thousand (ppt), default parts per million (ppm)

Resistivity

Resistivity is the reciprocal (inverse) of the actual conductivity, which is useful when monitoring pure water. Units: ohms-cm

Density of Water

Calculated from salinity and temperature. Units: g/cm3

✔ ***TIP:*** *Parameter configuration is not available if the device is polling or has an active log.*

✔ ***TIP:*** *Measured density values may be used to dynamically compute specific gravity when measuring Level. View Win-Situ Help or see "Pressure and Level" on page 29 of this manual for more information.*

Shallow Deployment

When deploying the Aqua TROLL Instrument in shallow water, bubble formation on the conductivity sensor can create false readings. We recommend the following to minimize the formation of bubbles:

Surface water: Gently agitate the instrument. Natural water flow will help to prevent bubbles.

Groundwater well or any location without flowing water, or where the instrument cannot be seen:

1. Lower the Aqua TROLL until it is below the surface of the water. (Tip: This can be determined if not visible by monitoring the pressure/depth readings.)

2. Allow the conductivity sensor to be thoroughly wetted (at least 30 seconds).

3. Briskly agitate up and down several times, while not taking the device above the water surface.

4. When the conductivity readings stabilize, the Aqua TROLL is ready for deployment.

Maintenance and Recalibration

The need to clean the sensor is determined by the site conditions, and the accuracy you want to obtain from the instrument. For example, when used in relatively clean water of low biological productivity, a conductivity sensor could maintain its accuracy specifications for several months. On the other hand, in water with a high potential for biological or mineral fouling, the sensor may need to be cleaned and re-calibrated more often. Visual inspection and measurement results are the best indicators that a device needs service recalibration.

It is the user's responsibility to develop and follow a maintenance program appropriate to the site. Most standard operating procedures (SOPs) instruct that the instrument be checked in a known standard at the end of a deployment. Calibration should always be checked after cleaning, and should be recalibrated when necessary.

For specific cleaning procedures, see "Care and Maintenance" on page 43.

Factory recalibration of the Aqua TROLL 200 Instrument should be performed every 12-18 months. See "How to Contact Us" on page 4 for In-Situ's contact information.

Pressure and Level

The Aqua TROLL 200 Instrument contains a pressure sensor. A pressure transducer senses changes in pressure, measured in force per square unit of surface area, exerted by water or other fluid on an internal media-isolated strain gauge. Common measurement units are pounds per square inch (psi) or newtons per square meter (pascals).

Non-Vented (Absolute) vs. Vented (Gauged) Sensors

A non-vented or “absolute” pressure sensor measures all pressure forces exerted on the strain gauge, including atmospheric pressure. Its units are psia (pounds per square inch “absolute”), measured with respect to zero pressure.

Non-vented pressure measurements are useful in vacuum testing, in short-term testing when atmospheric pressure would not be expected to change, in very deep aquifers where the effects of atmospheric pressure are negligible, and in unconfined aquifers that are open to the atmosphere.

With vented or “gauged” pressure sensors, a vent tube in the cable applies atmospheric pressure to the back of the strain gauge. The basic unit for vented measurements is psig (pounds per square inch “gauge”), measured with respect to atmospheric pressure. Vented sensors thus exclude the atmospheric or barometric pressure component.

This difference between absolute and gauged measurements may be represented by a simple equation:

$P_{gauge} = P_{absolute} - P_{atmosphere}$

Pressure, Depth and Level

Output options for pressure measurement are completely software-selectable. Each log configuration presents the following choices:

- Pressure in psi or kPa
- Depth in feet or meters
- Water Level with a reference (an “offset”)
    - Surface Elevation: positive up
    - Depth to Water (drawdown): positive down

For Depth and Level, the software presents additional options:

- The type of measurement you intend to log (the “output”)
- The Level Reference you intend to use

- The specific gravity of the water in which the device will be deployed:
    - Choose a fixed value for fresh, brackish, or saline water, or
    - Enter a custom specific gravity value, or
    - Choose Fixed density with gravitational compensation for a pressure-to-level conversion that compensates pressure readings for fluid density and local gravitational factor (based on your latitude and elevation), or
    - Choose Dynamic density with gravitational compensation, which will allow the software to dynamically compute specific gravity using density measured by the conductivity sensor and local gravitational factor.

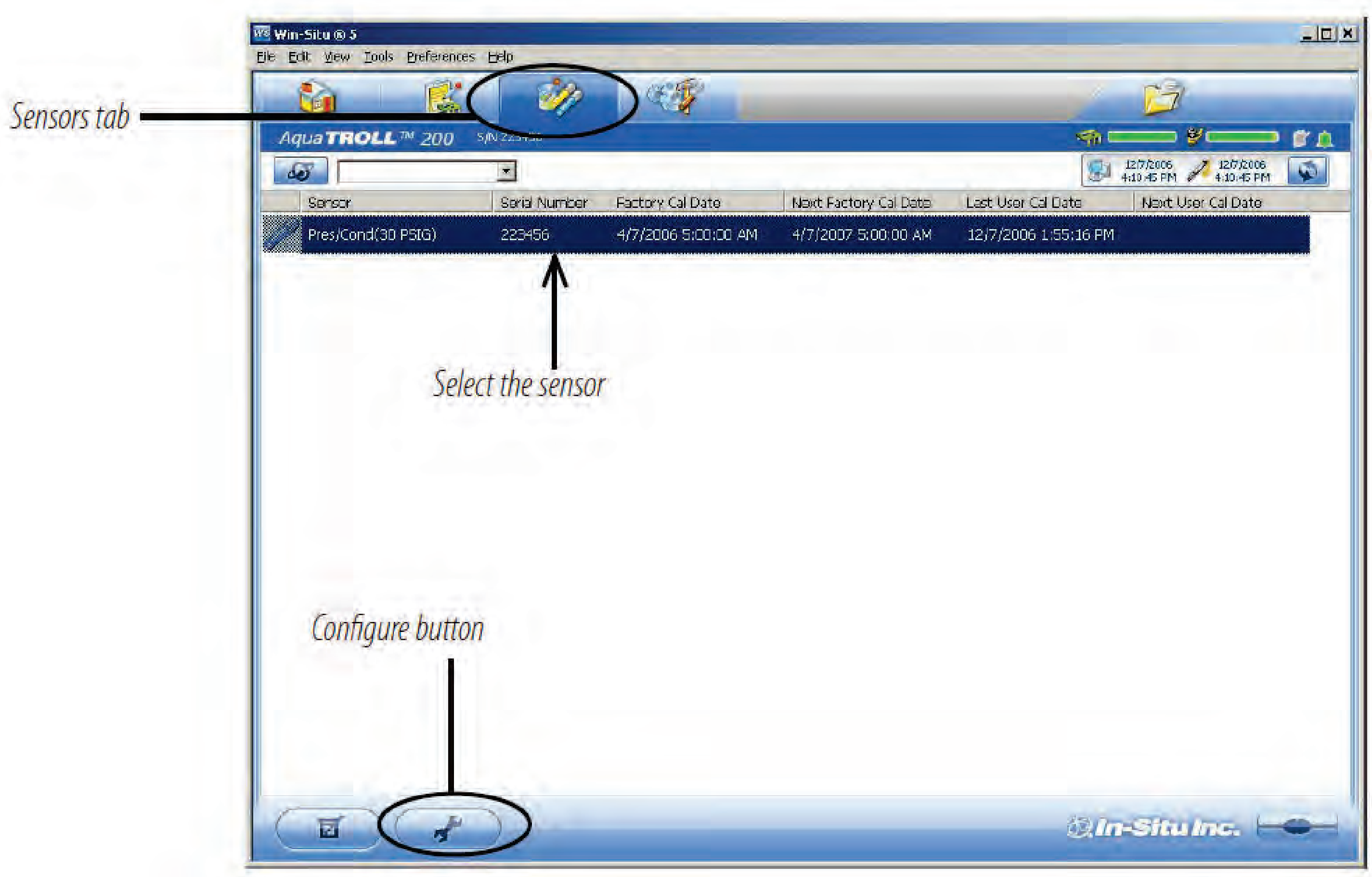
Configuring Depth and Level

This procedure stores the configuration settings in the Aqua TROLL Instrument. When setting up a log, the same options are presented.

1. While connected to the instrument in software, click the Sensors tab.

2. Select the sensor and click the Configure button .

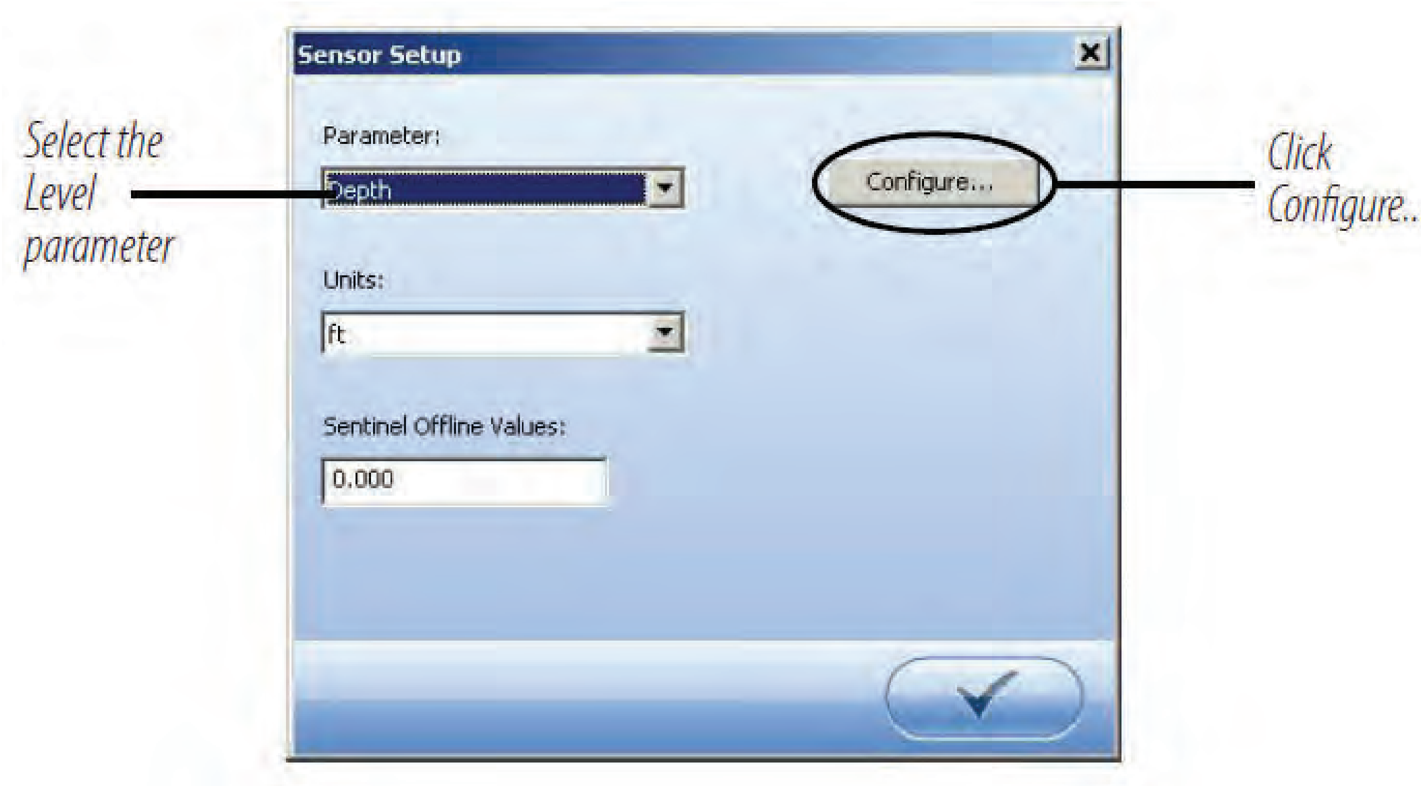
✔ ***TIP:*** *When you configure level using the Sensors tab, the settings are stored in the Aqua TROLL Instrument and are available for use in Modbus, SDI-12, and analog communications, as well as in Win-Situ. Different configurations may be selected when setting up a log.*



✔ ***TIP:*** *Go to the Home tab and stop polling before configuring any sensor parameter.*

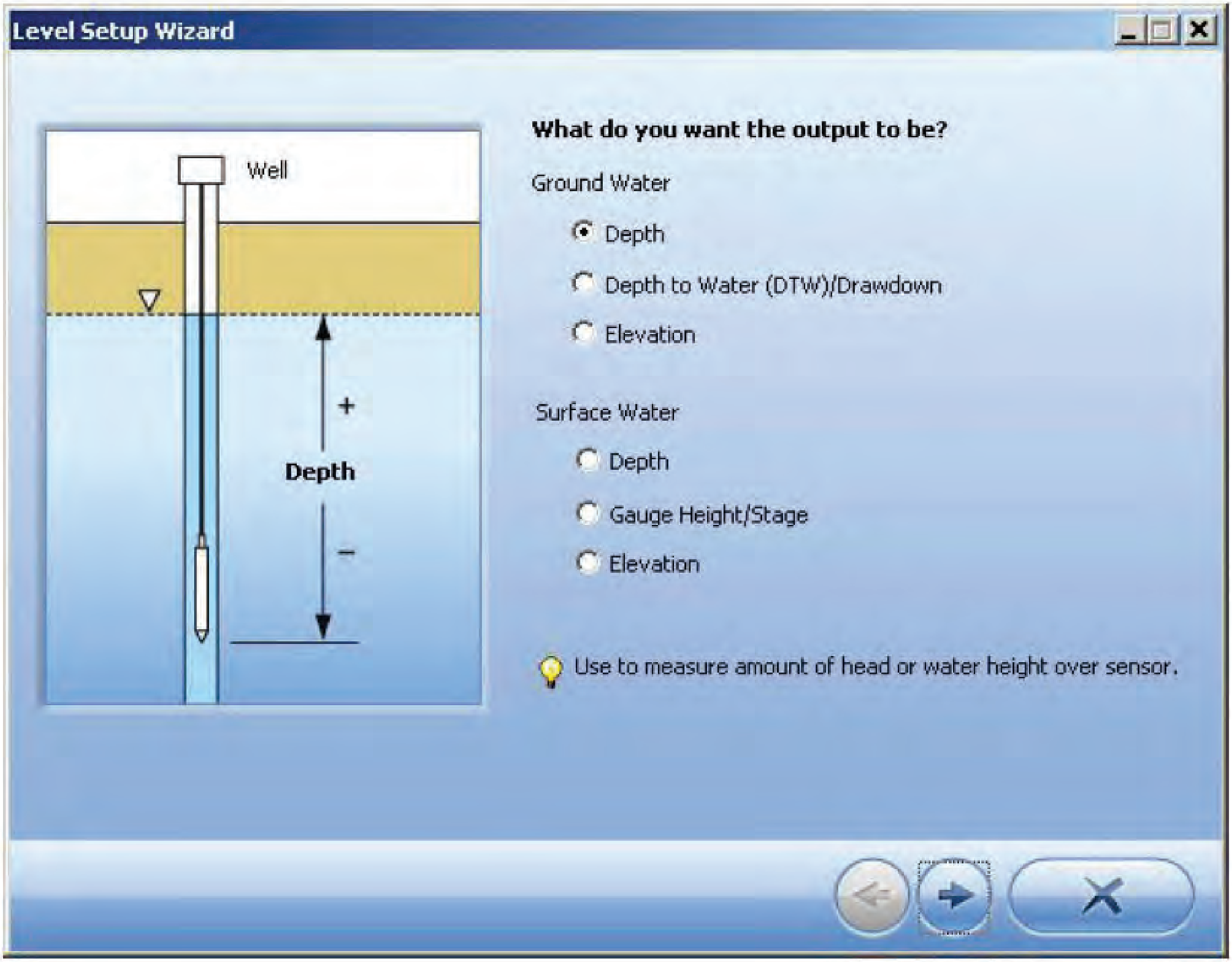
3. In the Sensor Setup window, select the Level parameter, then click Configure...

The Level parameter shown is the one currently stored in the device. This is the default or the most recent choice. You will have a chance to change the parameter later.



TIP: *Parameter configuration is not available if the device is polling or has an active log.*

4. In the Level Setup Wizard, select the options you want. Each choice includes an illustration to assist you in selecting the output. For more information, see Help in Win-Situ 5 Software.



Pressure Sensor Calibration

Factory Recalibration

Pressure sensor accuracy can be adversely affected by improper care and handling, lightning strikes and similar surges, exceeding operating temperature and pressure limits, physical damage or abuse, as well as normal drift in the device's electronic components. Aside from damage to the sensor, the need for factory recalibration is dependent upon the amount of drift a customer is willing to tolerate. Factory calibration every 12-18 months is recommended. Contact In-Situ Customer Service for information on the factory maintenance and calibration plan.

Field Recalibration

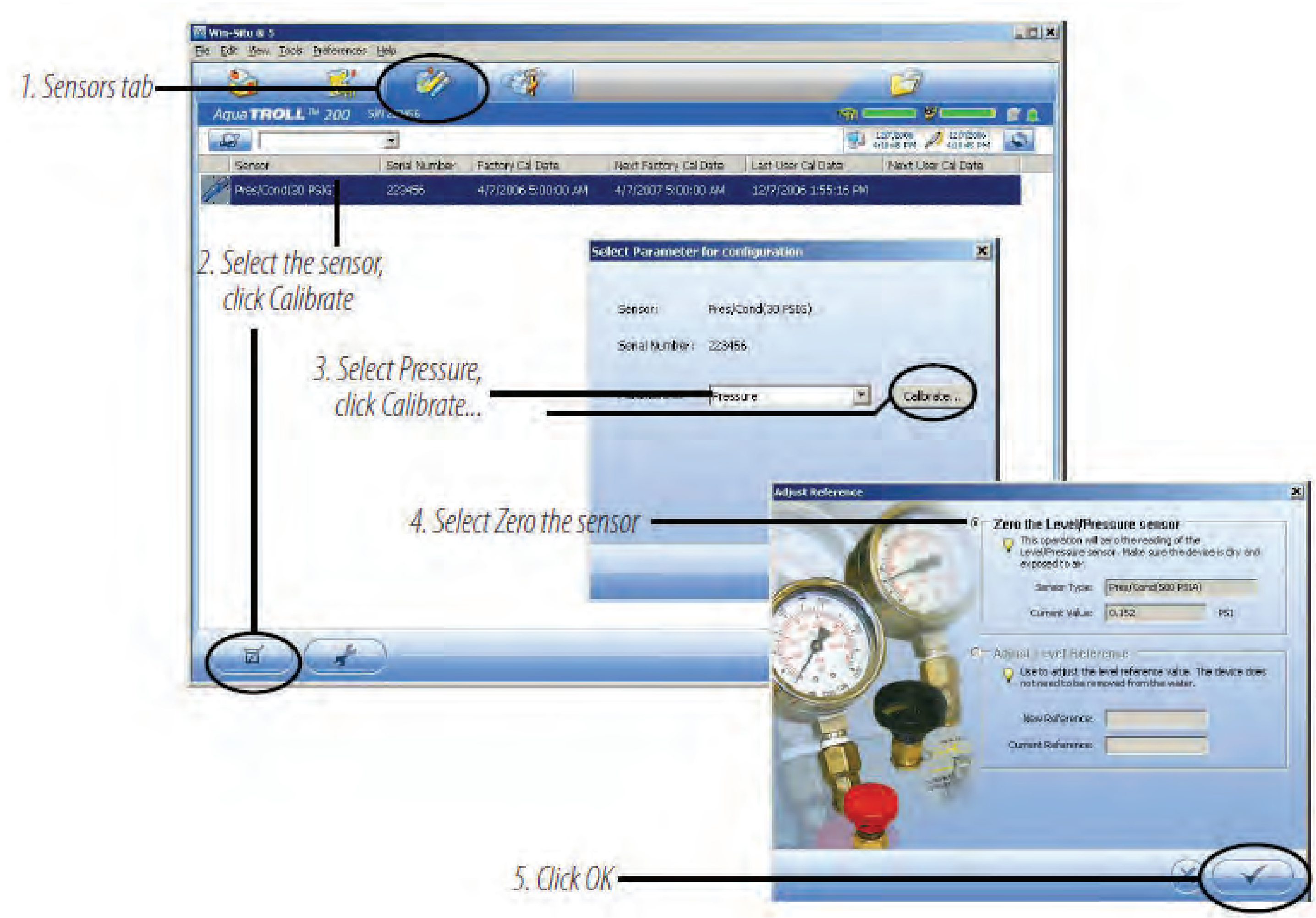
The following procedure may be used, with caution, to set to zero the offset of a vented pressure sensor to correct for electronic drift. The drifted offset is visible when the sensor is in air and reading other than zero. It is recommended you do not set to zero the offset if it is outside the specified accuracy of your pressure sensor, as shown in the table below. If the reading in air deviates from zero by more than the amounts shown, you may want to consider a factory recalibration.

Sensor Range	Accuracy (0°C to +50°C)	Acceptable Offset from Zero
5 psi	± 0.1% FS	± 0.005 psi
15 psi	± 0.1% FS	± 0.015 psi

30 psi	± 0.1% FS	± 0.03 psi
100 psi	± 0.1% FS	± 0.10 psi
300 psi	± 0.1% FS	± 0.30 psi
500 psi	± 0.1% FS	± 0.50 psi

Field Recalibration Procedure for a Vented Sensor

1. With the Aqua TROLL connected in software, go to the Sensors tab.
2. Select the pressure sensor and click the Calibrate button .
3. Select the Pressure parameter and click Calibrate...
4. Select Zero the Level/Pressure sensor. Make sure the device is dry and exposed to air.
5. Click OK . The software will inform you when the pressure reading is set to zero.



Barometric Compensation of Non-Vented Pressure & Level Data

Win-Situ® Baro Merge™ software can post-correct absolute (nonvented) level sensor data to eliminate barometric pressure from the measurements. Baro Merge provides three options:

Fixed Correction – A single offset value is applied to all selected log data. Use this option if you know what the barometric pressure was during the log, and know that it did not change.

Manual Entry – Specify two or more correction values to apply to the log data. Use this option if you know that barometric pressure changed during the log.

BaroTROLL® Instrument log file – Absolute level sensor data are corrected by barometric pressure values logged by an In-Situ BaroTROLL Instrument during the approximate time period.

Launching Baro Merge Software

Baro Merge may be opened as a stand-alone application from the program group In-Situ Inc., or accessed from Win-Situ's Tools menu when both are installed on the same system.

Input

In the Fixed Correction and Manual Entry options, it is important to know the barometric pressure for the general time period covered by the log or logs you want to correct.

Baro Merge uses a Wizard-like interface consisting of three main steps:

1. Select the type of compensation/correction you intend to use.
2. Select the absolute (non-vented) log file or files you intend to correct. Baro Merge displays these automatically.
3. Click OK and the barometric compensation is applied.

Output

The original log file is not changed. A new, corrected log file with the same name and path is created. The original ".wsl" extension is replaced by "-BaroMerge.wsl".

For help on using Win-Situ Baro Merge, press F1 at any Baro Merge screen.

For more detailed information on barometric compensation, see the technical notes on the In-Situ software/resource CD, or www.in-situ.com.

Field Installation

Positioning the Vented Aqua TROLL 200 Instrument

Positioning the Vented Aqua TROLL 200 Instrument For unattended deployment, lower the Aqua TROLL 200 Instrument gently to approximately the desired depth. Position the instrument below the lowest anticipated water level, but not so low that its range might be exceeded at the highest anticipated level. Refer to the tables below for usable depth.

✔ Do not let the instrument fall freely into the water because it can damage the pressure sensor.

Vented Aqua TROLL Instrument

Range		Usable Depth	
psig	kPa	Meters	Feet
5	34.5	3.5	11.5
15	103.4	11	35
30	206.8	21	69
100	689.5	70	231
300	2068	210	692
500	3447	351	1153

Non-Vented Aqua TROLL Instrument

Range	Effective Range*		Usable Depth	
psia	psia	kPa	Meters	Feet
30	15.5	106.9	11	35
100	85.5	589.5	60.0	197

300	285.5	1968	200	658
500	485.5	3347	341	1120

** At sea level (14.5 psi atmospheric pressure).*

Check Instrument Depth

At this point, if convenient, you can connect the Aqua TROLL 200 to a PC, launch the software, and take a reading. If the instrument is at the desired depth, secure it in position as suggested below, or reposition as necessary.

If you set the software to “Remind me later” to set a Level Reference, enter the level reference after installation when prompted.

Secure the Cable

Kellems grip

The RuggedCable includes a Kellems® grip near the surface end. You can slide it along the cable to the desired position by compressing it. When you pull on it, the grip tightens and stops sliding. You may need to pull on both ends of the Kellems grip to properly tighten it and keep it from slipping.

Use the loop of the Kellems grip to anchor the cable to a convenient stationary object. It works well with In-Situ’s well dock installation ring. Simply insert the loop into the locking clip on the well dock, and position the assembly on the top of a well.

Installation Tips

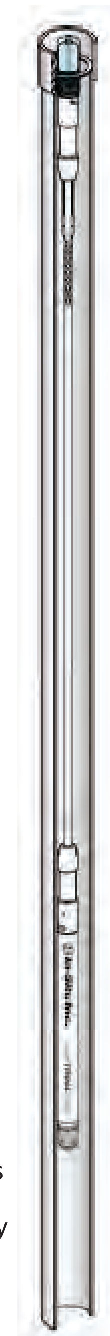
- Never let a probe fall freely down a well. The resulting shock wave when it hits the water surface can damage the strain gauge.
- Check the level of water above the probe, then move it and read again to be sure that the probe presents a reasonable reading and shows change. It might not be located where you think it is. For example, it could be wedged against the casing with a loop of cable hanging below it. A probe in such a position might become dislodged and move while logging, giving a false change in level. A secure placement is critical to accurate measurements.
- Do not allow the vented cable to kink or bend. If the internal vent tube is obstructed, water level measurements can be adversely affected. The recommended minimum bend radius is 13.5 mm (0.54 in), which is twice the cable diameter. The minimum bend radius for vented cable is 13.5 mm (0.54 in).
- For accurate measurements, the instrument should remain immobile while logging data.
- Be sure the uphole cable end is capped—desiccant on the vented cable connector, soft dust cap on non-vented cable— and positioned above the highest anticipated water level. Avoid areas that may flood when using vented cable.

✔ ***TIP:*** *The minimum bend radius for vented cable is 13.5 mm (0.54 in).*

✔ ***TIP:*** *Do not submerge the cable connector; do not immerse in any fluid.*

✔ ***TIP:*** *Be sure to replace the desiccant before it appears pink. Expired desiccant can allow moisture build up in the vent tube, causing a blockage resulting in inaccurate data.*

✔ ***TIP:*** *Do not deploy pressure transducers such that ice may form on or near the sensor or cable connections. Ice formation is a powerful expansive force and may over-pressurize the sensor or otherwise cause damage. Any damage associated with ice formation is not covered by the warranty.*



Stabilization Time

Allow the Aqua TROLL Instrument to stabilize to the water conditions for about an hour before logging data. A generous stabilization time is always desirable, especially in long-term deployments. Even though the cable is shielded, temperature stabilization and stretching can cause apparent changes in the level reading. A completely dry conductivity sensor may need a few minutes settling time after initial immersion. If you expect to monitor conductivity and water levels at the highest accuracy possible for the instrument, allow stabilization time.

Shallow Deployment

When deploying the Aqua TROLL Instrument in shallow water, bubble formation on the conductivity sensor can create false readings. We recommend the following to minimize the formation of bubbles:

Surface water: Gently agitate the instrument. Natural water flow will help to prevent bubbles.

Groundwater well or any location without flowing water, or where the instrument cannot be seen:

1. Lower the Aqua TROLL until it is below the surface of the water. (Tip: This can be determined if not visible by monitoring the pressure/depth readings.)

2. Allow the conductivity sensor to be thoroughly wetted (at least 30 seconds).

3. Briskly agitate up and down several times, while not taking the device above the water surface.

4. When the conductivity readings stabilize, the Aqua TROLL is ready for deployment.

Installation of a Non-Vented Aqua TROLL

Aqua TROLL 100 and non-vented Aqua TROLL 200 instruments do not require vented cable for proper operation. They may be deployed on non-vented RuggedCable or with a twist-lock hanger and stainless steel suspension wire.

- Because the twist-lock hanger has no communication capabilities, program the Aqua TROLL in advance, and download the data the same way.
- Logged pressure data will show the effects of changes in barometric pressure (unlike vented Aqua TROLL 200 sensors). However, post-processing tools such as Win- Situ Baro Merge may be used to eliminate the effects of barometric pressure changes from the data, if required.

TIP: *Be sure to program a non-vented Aqua TROLL before attaching the twist-lock hanger, as this accessory has no communication capability.*

TIP: *DO NOT submerge a non-vented Aqua TROLL without first attaching a twist-lock hanger, or a cable, because the unit could be damaged by flooding.*

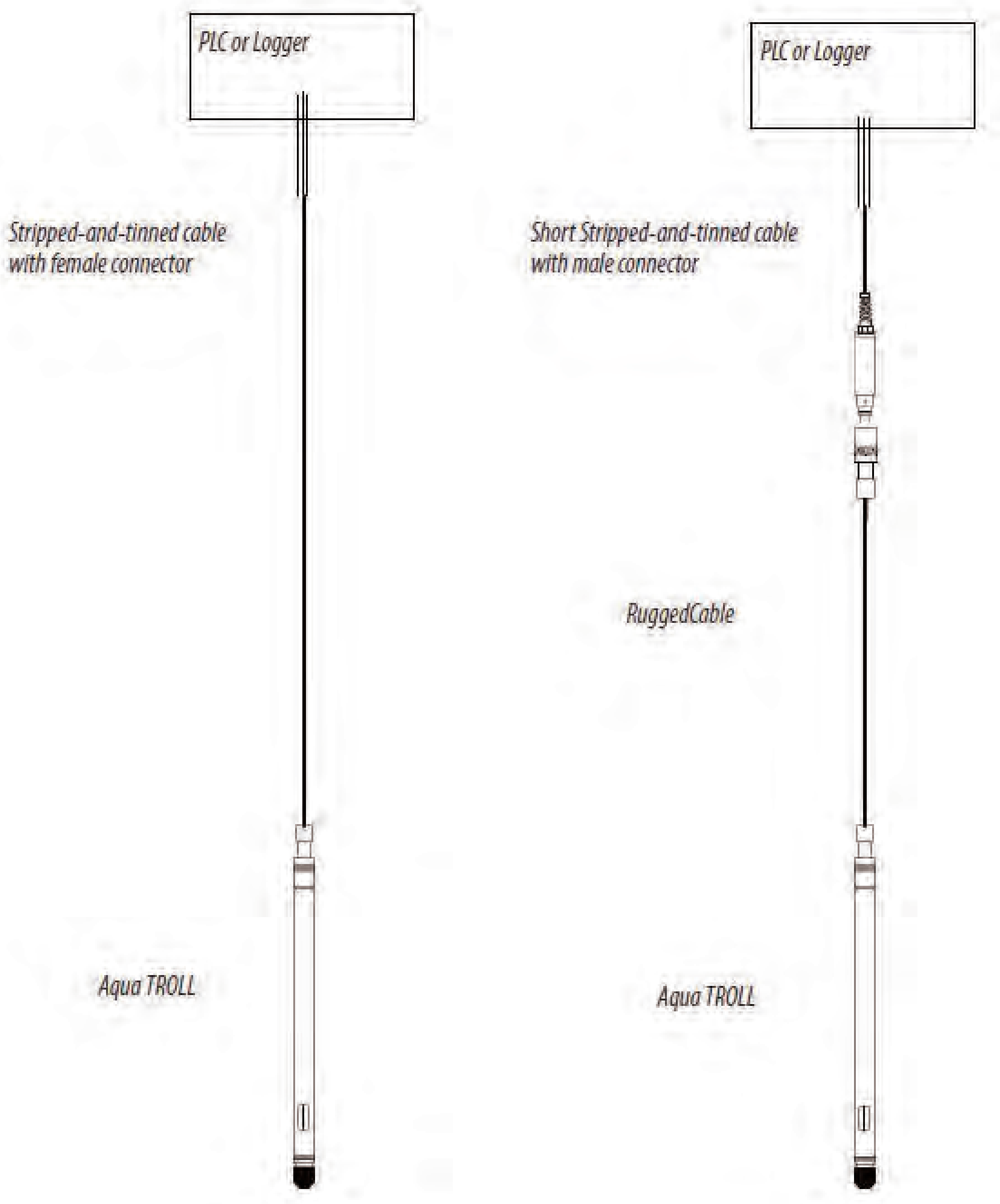
Analog, SDI-12 and Modbus Connections

The Aqua TROLL instrument may be connected to a controller or logger for communication via:

- Analog 4-20 mA (provides a configurable 4-20 mA current loop output)
- SDI-12
- RS485 Modbus
- RS232 to Modbus (with a customer-supplied converter)

Stripped-and-tinned cable has a female twist-lock connector on one end to connect with the Aqua TROLL Instrument. The uphole end terminates in bare wires for connection to a PLC or data logger.

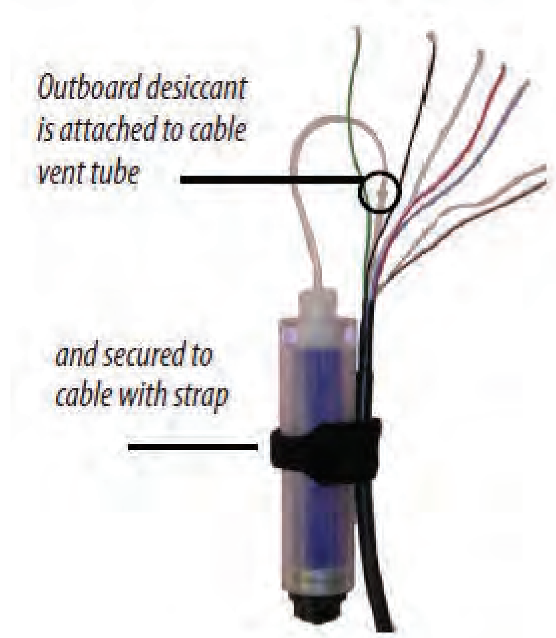
A shorter cable ending in a male twist-lock connector to connect with RuggedCable is also available.


PLC or Logger
Stripped-and-tinned cable
with female connector
Aqua TROLL
PLC or Logger
Short Stripped-and-tinned cable
with male connector
RuggedCable
Aqua TROLL

Desiccant

Vented cable must be installed with outboard desiccant to protect the cable vent tube and Aqua TROLL electronics from condensation in high-humidity environments.

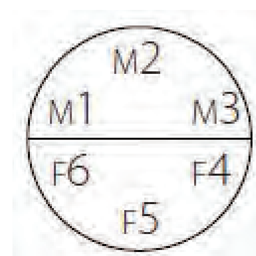
The desiccant may be removed from the vent tube, if needed, to trim the conductor wires. Pull the vent tube extender off the cable vent tube to remove, replace desiccant after trimming and connecting the wires.



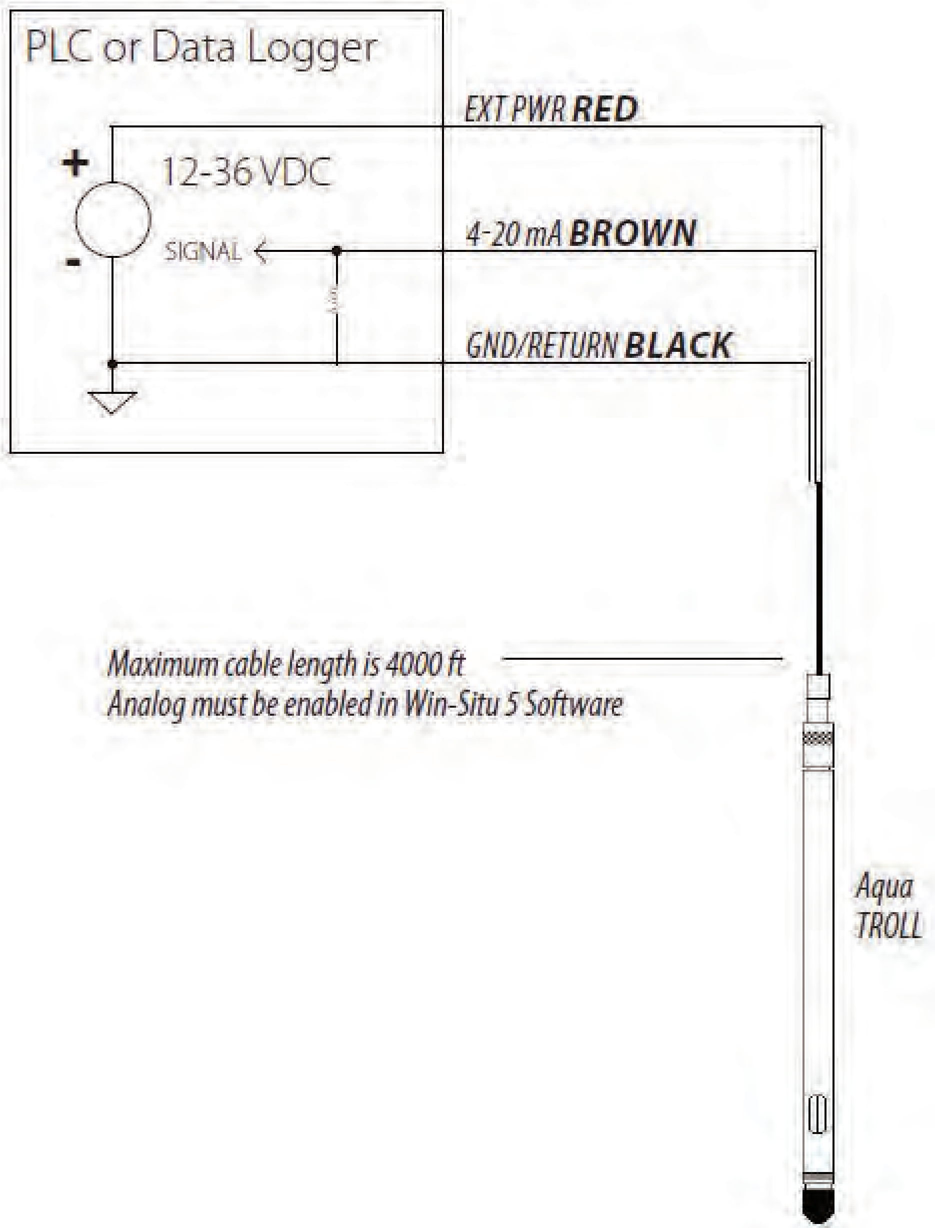
Wiring

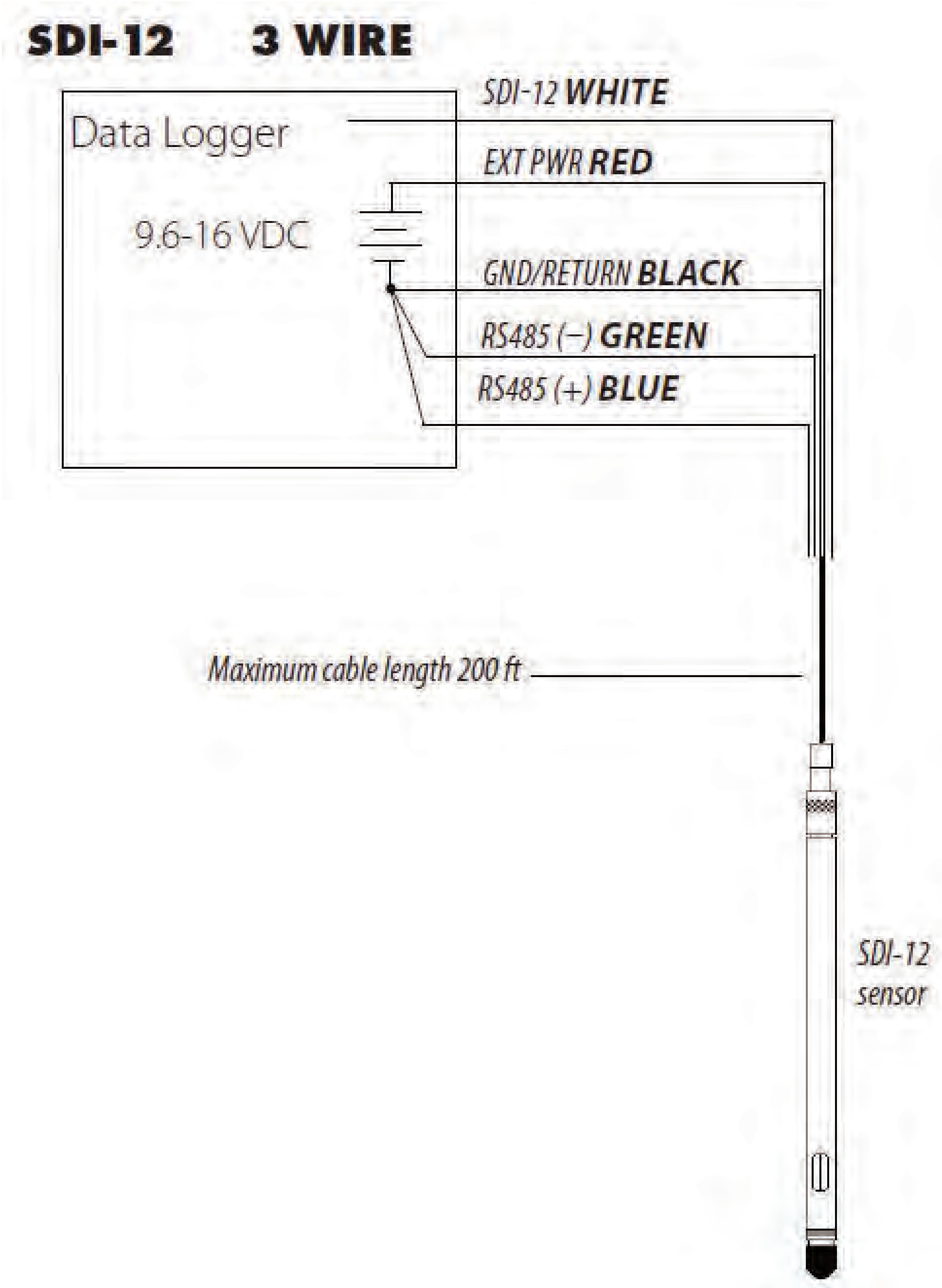
Refer to diagrams on the following pages. Trim back and insulate unused wires. The shield should be wired to a chassis ground or earth ground.

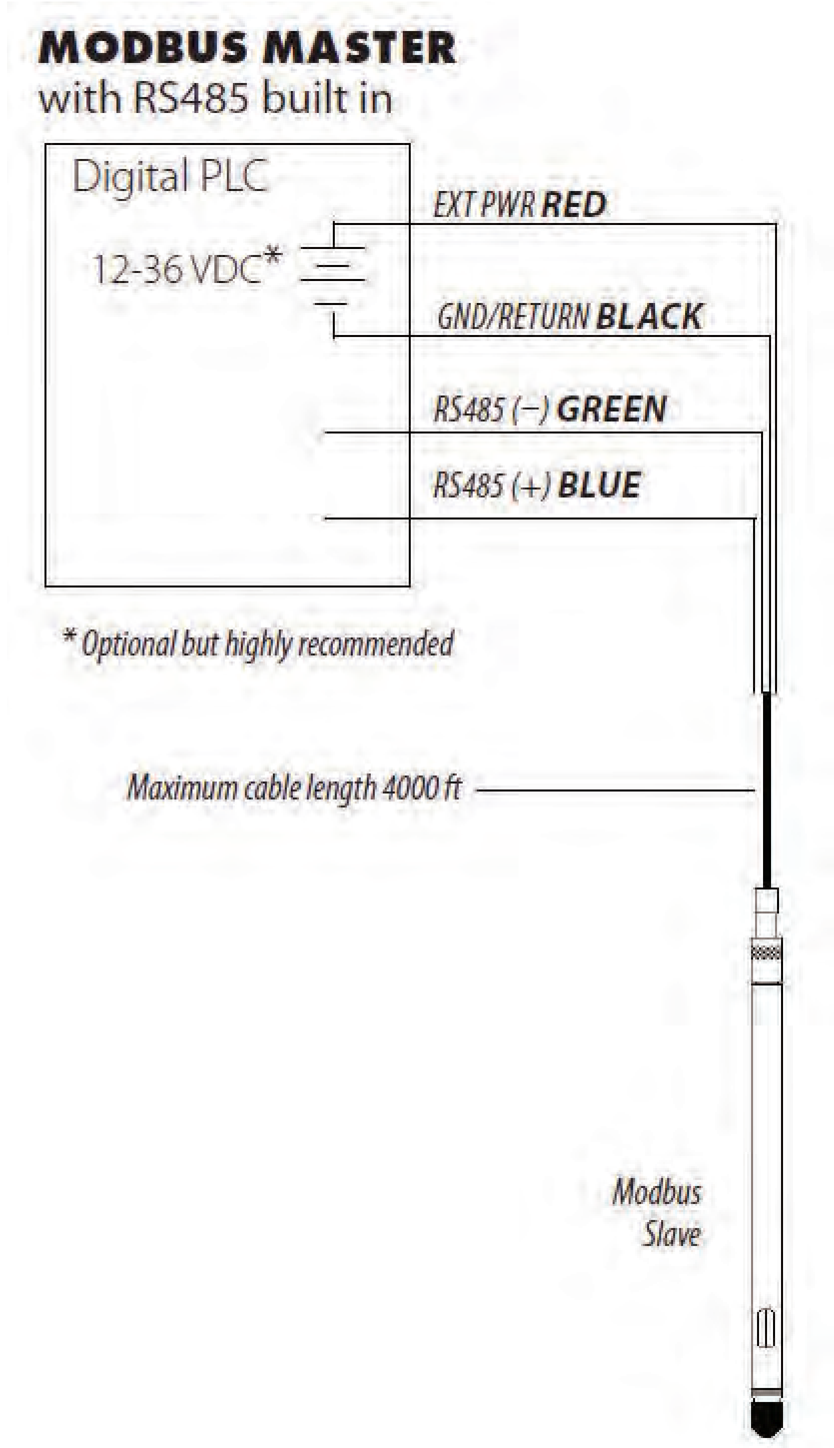
Signal	Color	Pin
Gnd/Return	BLACK	6
Ext Power	RED	5
4-20 mA	BROWN	4
RS485(–)	GREEN	3
RS485(+)	BLUE	2
SDI-12	WHITE	1

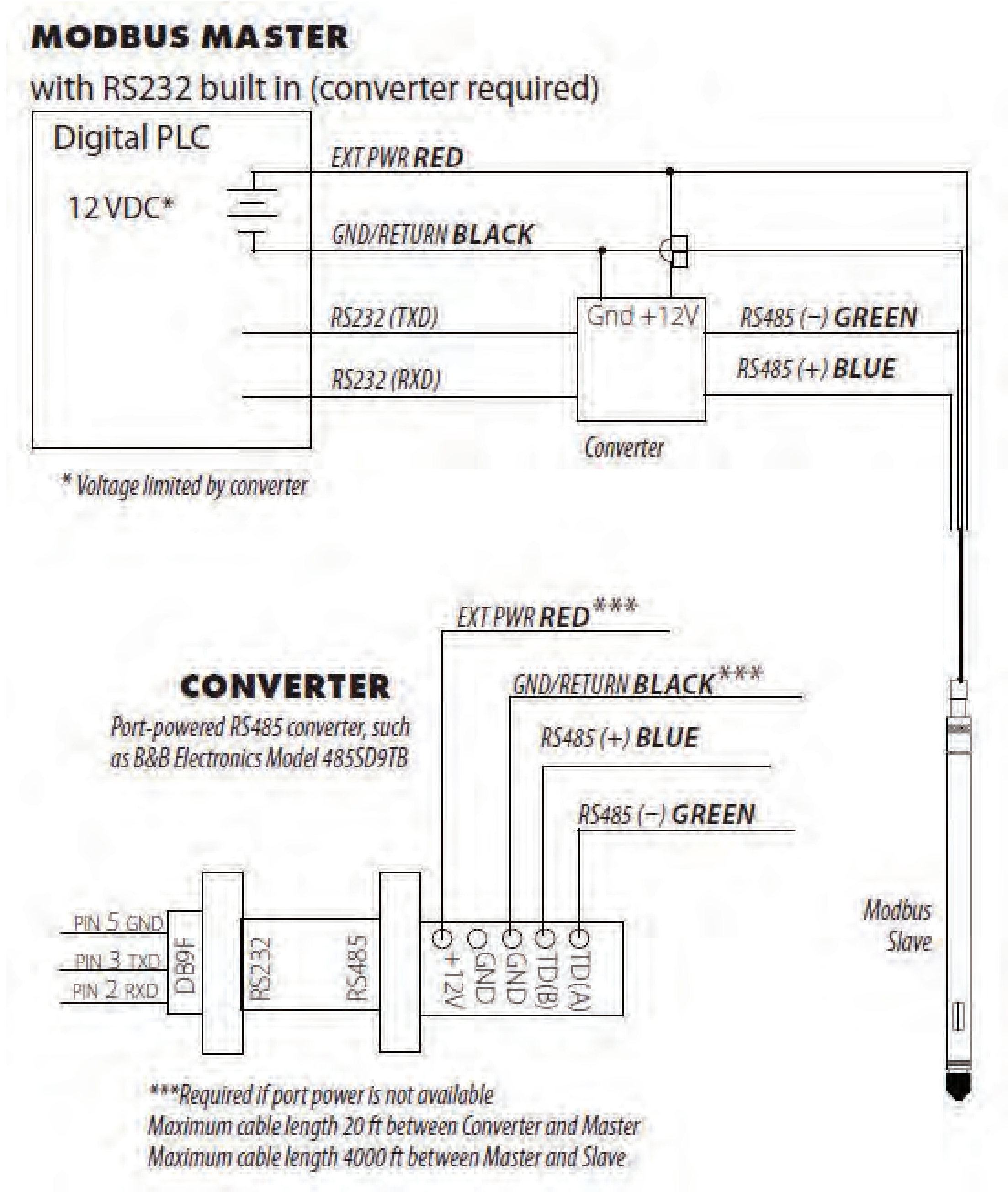


ANALOG (4-20 mA) 3 WIRE




SDI-12 3 WIRE
Data Logger
9.6-16 VDC
SDI-12 WHITE
EXT PWR RED
GND/RETURN BLACK
RS485 (–) GREEN
RS485 (+) BLUE
Maximum cable length 200 ft
SDI-12
sensor


MODBUS MASTER
with RS485 built in
Digital PLC
12-36 VDC*
EXT PWR RED
GND/RETURN BLACK
RS485 (–) GREEN
RS485 (+) BLUE
* Optional but highly recommended
Maximum cable length 4000 ft
Modbus
Slave



Power Connections

The red wire provides power for all Aqua TROLL communication modes. Analog output is disabled by default. However, the 4-20 mA current loop output can be continuous in Modbus or SDI-12 mode as long as Modbus device register 49507 is set to 1. This can be done with a connection in Win-Situ by selecting the Device Setup tab, Analog Setup button, and enabling analog output.

Communications

The device automatically switches between Modbus and SDI-12 modes depending on which of the two interfaces has activity. Modbus and SDI-12 cannot be used at the same time — whichever one is currently in use will block communication on the other.

Using Win-Situ Software

Win-Situ provides options for configuring analog/SDI-12 communications (Setup tab) and Modbus communications (File menu > Settings). In addition, the Aqua TROLL Instrument is capable of internal logging (programmed in Win-Situ) while participating in a Modbus, SDI-12, or analog network. However, Win-Situ cannot communicate with the Aqua TROLL Instrument while it is transmitting Modbus, SDI-12, or analog data, and conversely, the instrument cannot receive or respond to Modbus, SDI-12, or analog commands while connected to a PC serial port.

Redundant Logging Feature

- If the PLC or recorder somehow loses data, the Aqua TROLL data can be retrieved using Win-Situ.
- If the PLC or recorder ceases to function due to power loss, the Aqua TROLL will continue to collect data using its own internal batteries and clock.

A port-powered RS485 converter like that shown for Modbus connections may be used for temporary connection of the Aqua TROLL to a serial port on a PC.

For More Information

For additional information on Modbus and SDI-12 communications, including the SDI-12 commands and Modbus registers, see these In-Situ technical notes:

- SDI-12 Commands and Aqua TROLL Responses.
- In-Situ Modbus Communication Protocol.

They are available on the In-Situ software/resource CD and at www.in-situ.com.

Care and Maintenance

Operating Considerations

The Aqua TROLL Instrument has been designed to withstand harsh field conditions. However, as with any electronic instrument, it can be permanently damaged if used outside its operating specifications.

Temperature

The Aqua TROLL temperature sensor operates within a temperature range of -5° to 50° C (23° to 122° F) in non-freezing fluid.

Pressure Range

The Aqua TROLL 200 Instrument can withstand pressures of up to two times (2X) the rated range of the pressure sensor without damage, although it may not read correctly at such pressure. If the pressure range is exceeded by 3X, the pressure sensor will be destroyed.

Factory Calibration

Accuracy can be adversely affected by improper care and handling, lightning strikes and similar surges, exceeding operating temperature and pressure limits, physical damage or abuse. Factory calibration every 12-18 months is recommended. Contact In-Situ Customer Service for information on the factory maintenance and calibration plan.

Storage

Store the Aqua TROLL Instrument clean and dry. Place the protective red dust cap on the cable end, or store with cable attached to protect the connector pins and O-ring. Store the instrument where it will not fall onto a hard surface. Protect the instrument from temperature extremes. Store within a temperature range of -40° C to 65° C (-40° F to 149° F).

General Maintenance

Twist-Lock Connectors

Keep the pins on all connectors free of dirt and moisture by using the soft protective dust cap when cable is not attached to an instrument.

⚠ *Do not submerge the cable connector; do not immerse in any fluid.*

Cable Vent Tube (Vented Cable)

Vented cable ensures that atmospheric pressure is the reference pressure to the vented pressure sensor diaphragm. The vent tube should not be blocked, kinked, or otherwise obstructed. Such obstructions will cause barometric pressure to appear in measurements, and errors will be introduced due to thermal expansion and contraction of air within the vent tube and probe.

✔ ***TIP:** The recommended minimum bend radius is 13.5 mm (0.54 in), which is twice the cable diameter.*

✔ ***TIP:** Be sure to replace the desiccant before it appears pink. Expired desiccant can allow moisture build up in the vent tube, causing a blockage resulting in inaccurate data.*

Batteries

Internal batteries in the Aqua TROLL Instrument are not user replaceable. The approximate percentage remaining is displayed on the Win-Situ 5 Dashboard when the instrument is connected.

Cleaning

Probe and Front End

Clean the Aqua TROLL with water and a soft brush or plastic scouring pad, or soak overnight in a mild acidic solution, such as household vinegar.

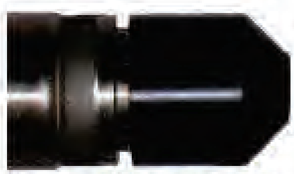
If the pressure ports of the Aqua TROLL 200 in the front end are clogged with silt or mud, try the following:

- Agitate the instrument vigorously in a bucket of clean water.
- Apply a gentle stream of water from a wash bottle.
- In severe cases, remove the nose cone and clean out the holes with a soft brush or pipe cleaner.

⚠ *Damage caused by digging or scraping in the pressure sensor opening to remove silt, mud, etc. is not covered by the warranty.*

To avoid damage to the pressure sensor diaphragm, do not insert any object into the sensor opening or attempt to dig out dirt or other materials. If contamination cannot be removed using the recommendations above, please contact In-Situ Inc. for cleaning.

⚠ *When the nose cone is removed from the Aqua TROLL 200, the sensitive pressure sensor diaphragm is completely exposed. Do not touch this area with any object. Replace the nose cone as soon as possible.*



Aqua TROLL 200 front end with nose cone in place

Nose cone removed - do not touch the exposed diaphragm

If contamination cannot be removed using the recommendations above, please contact In-Situ Inc. for cleaning.

Conductivity Sensor

Fouling from mineral and biological sources can alter the sensor's response.

- Rinse under running water to remove loose material.
- Always finish with a rinse in clean water.
- After cleaning, always check the calibration before redeployment, and recalibrate the sensor when necessary.

Acceptable cleaning processes fall into the following categories:

Process 1: Light scrubbing with a soft swab and mild soap such as a dilute solution of dish detergent. Be careful not to damage the plastic material of the conductivity cell. Aqua TROLL Instruments are shipped with polyurethane foam swabs for this purpose. You can also clean the conductivity cell using a thin cotton pipe cleaner and a a gentle back-and-forth motion.

Process 2: Light scrubbing with a foam swab and an aggressive soap such as Alconox detergent can be used for more stubborn deposits.

Process 3: Dilute (10:1) acetic acid, or consumer-packaged white vinegar, can be used to pre-soften calcium deposits. Follow this with Process 1 or Process 2, depending on the degree of residual contamination. The Aqua TROLL can soak for any length of time in dilute acetic acid. If this does not completely remove the material, try Process 4.

Process 4: Dilute phosphoric acid (< 27%) or the consumer product Lime-A-Way® can be topically applied with a soft swab to remove iron or calcium deposits that remain after using Process 3. Do not soak for more than 10 minutes. Rinse well with water.

If contamination cannot be removed using the recommendations above, please contact In-Situ Inc. (See page 4.)

✔ ***TIP:*** *Foam swabs are shipped with the Aqua TROLL Instrument; replacements are available from In-Situ Inc. (Catalog No. 0056820).*

✔ ***TIP:*** *Alconox is available from In-Situ Inc. (Catalog No. 0029810).*

⚠ *DO NOT SOAK in phosphoric acid or Lime-A-Way® for more than 10 minutes.*

Troubleshooting

TROUBLESHOOTING CONNECTIONS

Problem: Win-Situ 5 Software cannot connect to the Aqua TROLL instrument.

Probable Cause: The wrong COM port is selected, communication settings are incompatible, batteries are low, or cable connections are loose or dirty.

Suggested Remedy: Check the following:

- All cable connections are tight, connectors are clean and dry.
- The cable is securely attached to the instrument.
- The correct COM port is selected (select Preferences menu > Comm Settings to check this).
- The communication settings in Win-Situ and in the Aqua TROLL match. To reset the device communication settings to the serial defaults, click "Reset all Devices" in the Comm Settings dialog (Preferences menu > Comm Settings)
- The internal battery has voltage remaining or external power is supplied.

Problem: Real-time readings are in the wrong units.

Probable Cause: Default units are being used.

Suggested Remedy: Click the Sensors tab, select the sensor, click the Configure button , and select the desired units for each parameter in the Sensor Setup window. Click OK . Be sure to stop "polling" in the Home screen before selecting units.

TROUBLESHOOTING DATA LOGS

Problem: Cannot add a new log.

Probable Cause 1: Only one active log can reside in the device at a time—an active log is a log that is Ready, Pending, Running, or Suspended as shown in the Status column of the Logging Tab.

Suggested Remedy: Stop or delete the log if possible. Alternatively, configure the new log after the active log is completed.

Probable Cause 2: The device has its maximum number of logs already stored—although this is not a likely cause for the Aqua TROLL 200, which has a capacity of 50 logs.

Suggested Remedy: Download, and then delete a log you are finished using. This will make room for an additional log on the device.

Problem: New log exceeds available memory (message from software).

Probable Cause: The log as configured would exceed the device memory.

Suggested Remedy: Edit the log and try these:

- Select a longer sampling interval.
- If available, select the Wrap data option (current data will overwrite older data when the memory is full).
- For a log with a scheduled start, select None as the stop condition, or select a stop time that is closer to the start time.

TROUBLESHOOTING PARAMETER CONFIGURATION

Problem: Cannot configure level or other parameters using the Configure button on the Sensors tab. The Sensor setup screen is shown, but the Configure... button is dim.

Probable Cause 1: The Aqua TROLL is actively polling (continually updating real-time readings) in the Home tab.

Suggested Remedy: Return to the Home tab and stop real-time readings by clicking .

Probable Cause 2: The Aqua TROLL has an active log—a log that is Ready, Pending, Running, or Suspended as shown in the Status column of the Logging Tab. Only one active log can reside in the device at a time.

Suggested Remedy: Stop or delete the log if possible. Alternatively, configure parameters after the log is completed.

TROUBLESHOOTING CONDUCTIVITY CALIBRATION

Problem: The calculated cell constant (Kcell) is lower than the recommended range of 0.98 – 1.02.

Probable Cause: The electrical resistance of the calibration solution was lower than expected for the nominal value.

Suggested Remedy: Check the following and then repeat the calibration:

- Visually inspect the sensor for the presence of fouling (most likely conductive material, possibly a bio-film); clean as described in Section 9 of this manual.
- Ensure the calibration solution is not contaminated, mislabeled, or partially evaporated.
- Rinse the Aqua TROLL Instrument and the Cal Cup thoroughly with fresh calibration solution before calibrating.

Problem: The calculated cell constant (Kcell) is higher than the recommended range of 0.98 – 1.02.

Probable Cause: The electrical resistance of the calibration solution was higher than expected for the nominal value, or an air bubble was present in the sensing cell during calibration.

Suggested Remedy: Check the following and then repeat the calibration:

- Visually inspect the sensor for the presence of fouling (most likely an obstructing material or organism); clean as described in Section 9 of this manual.
- Ensure the calibration solution is not contaminated, mislabeled, or partially diluted.
- Rinse the Aqua TROLL Instrument and the Cal Cup thoroughly with fresh calibration solution before calibrating.
- "Roll and tap" the Aqua TROLL Instrument in the Cal Cup to dispel air bubbles as described and illustrated in Section 5.

Declaration of Conformity

Manufacturer: In-Situ, Inc.

221 East Lincoln Avenue

Fort Collins, CO 80524 USA

Declares that the following product:

- Product name: Aqua TROLL
- Model: Aqua TROLL 200
- Product Description: The Aqua TROLL 200 measures and logs level, temperature, and conductivity in natural groundwater and surface water.

is in compliance with the following Directives:

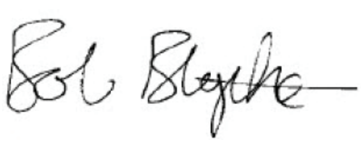
- 89/336/EEC for Electromagnetic Compatibility (EMC) Directive 73/23/EEC for Safety Directive

and meets or exceeds the following international requirements and compliance standards:

- Immunity
  EN 61326:1997, Electric Equipment for Measurement, Control and Laboratory Use
- Emissions
  Class A requirements of EN 61326:1997, Electric Equipment for Measurement, Control and Laboratory Use

Supplementary Information:

The device complies with the requirements of the EU Directives 89/336/EEC and 73/23/EEC, and the CE mark is affixed accordingly.



Bob Blythe

Declaration of Conformity

Manufacturer: In-Situ, Inc.

221 East Lincoln Avenue

Fort Collins, CO 80524 USA

Declares that the following product:

- Product name: TROLL Com
- Model: USB TROLL Com Product Description: RS485 to USB converter

is in compliance with the following Directive

- 89/336/EEC for Electromagnetic Compatibility (EMC) Directive 73/23/EEC for Safety Directive

and meets or exceeds the following international requirements and compliance standards:

- Immunity
  EN 61326, Electrical Equipment for Measurement, Control and Laboratory Use, Industrial Location
- Emissions
  Class A requirements of EN 61326, Electrical Equipment for Measurement, Control and Laboratory Use

Supplementary Information:

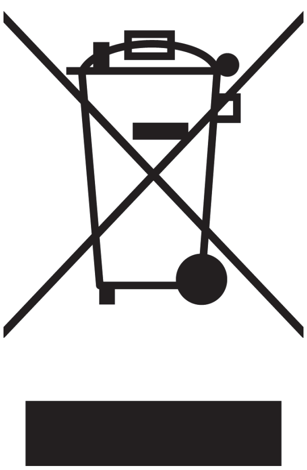
The device complies with the requirements of the EU Directives 89/336/EEC and 73/23/EEC, and the CE mark is affixed accordingly.

Todd Campbell

New Product Development Program Manager

In-Situ, Inc.

June 17, 2006



The presence of the Waste Electrical and Electronic Equipment (WEEE) marking on the product indicates that the device is not to be disposed via the municipal waste collection system of any member state of the European Union.

For products under the requirement of WEEE directive, please contact your distributor or local In-Situ Inc. office for the proper decontamination information and take back program, which will facilitate the proper collection, treatment, recovery, recycling, and safe disposal of the device.

Appendix E – Hydrology & Conductivity/Salinity SOPs, Onset HOBO

Equipment:

Manufacturer:
Onset Computer Corporation
470 MacArthur Blvd.
Bourne, Massachusetts 02532
www.onsetcomp.com
1-877-564-4377

Contents:
Onset HOBO U20 Water Level Logger: User manual available at:
http://www.onsetcomp.com/files/manual_pdfs/12315-E-MAN-U20.pdf

Onset HOBO U24 Conductivity Logger Manual:
http://www.onsetcomp.com/files/manual_pdfs/15070-C-MAN-U24x.pdf

Onset HOBO USB Micro Station Data Logger:
http://www.onsetcomp.com/files/manual_pdfs/20874-C%20MAN-QSG-H21-USB.pdf

Onset Smart Barometric Pressure Sensor:
http://www.onsetcomp.com/files/manual_pdfs/12291-F%20MAN-S-BPB.pdf

Software:
- HOBOWare User's Guide Available at: http://www.onsetcomp.com/files/manual_pdfs/12730-W%20HOBOware%20User's%20Guide.pdf
- HOBOWare Pro Barometric Compensation Assistant User's Guide: http://www.onsetcomp.com/files/manual_pdfs/Barometric-Compensation-Assistant-Users-Guide-10572.pdf
- HOBOWare Pro Conductivity Assistant User's Guide: http://www.onsetcomp.com/files/manual_pdfs/Conductivity-Assistant-Users-Guide-15019.pdf

Cleaning:
- Onset Product Cleaning Reference Guide: http://www.onsetcomp.com/files/manual_pdfs/15667-D-Product-Cleaning-Reference-Guide.pdf

Deployment:
National Park Service report: Continuous water level data collection and management using Onset HOBO data loggers: A Northeast Coastal and Barrier Network methods document.
https://irma.nps.gov/DataStore/DownloadFile/563851

HOBO® U20 Water Level Logger (U20-001-0x and U20-001-0x-Ti) Manual

The HOBO U20 Water Level Logger is used for monitoring changing water levels in a wide range of applications including streams, lakes, wetlands, tidal areas, and groundwater. The loggers are typically deployed in existing wells or stilling wells installed specifically for deploying the loggers. This logger features high accuracy at a great price and HOBO ease-of-use, with no cumbersome vent tubes or desiccants to maintain.

The logger uses a maintenance-free absolute pressure sensor and features a durable stainless steel or titanium housing (depending on model) and ceramic pressure sensor. The HOBO Water Level Titanium is recommended for saltwater deployment for recording water levels and temperatures in wetlands and tidal areas. The logger uses precision electronics to measure absolute pressure and temperature and has enough memory to record over 21,700 combined pressure and temperature measurements.

HOBO Water Level Logger

Models:

- U20-001-01 (30-foot depth) and U20-001-01-Ti (30-foot depth/Titanium)
- U20-001-02 (100-foot depth) and U20-001-02-Ti (100-foot depth/Titanium)
- U20-001-03 (250-foot depth) and U20-001-03-Ti (250-foot depth/Titanium)
- U20-001-04 (13-foot depth) and U20-001-04-Ti (13-foot depth/Titanium)

Required Items:

- Coupler (COUPLER-2-B) with USB Optic Base Station (BASE-U-4) *or* HOBO Waterproof Shuttle (U-DTW-1)
- HOBOware® Pro

Accessories:

- Cable (CABLE-1-300 or CABLE-1-50) and Cable Crimp (CABLE-1-CRIMP)
- Replacement Coupler (COUPLER2-B)

Specifications

Pressure (Absolute) and Water Level Measurements U20-001-01 and U20-001-01-Ti

Operation Range	0 to 207 kPa (0 to 30 psia); approximately 0 to 9 m (0 to 30 ft) of water depth at sea level, or 0 to 12 m (0 to 40 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 207 kPa (10 to 30 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 0.5 cm (0.015 ft) water Maximum error: ±0.1% FS, 1.0 cm (0.03 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.62 kPa (0.09 psi) maximum error
Resolution	<0.02 kPa (0.003 psi), 0.21 cm (0.007 ft) water
Pressure Response Time (90%)***	<1 second; measurement accuracy also depends on temperature response time

Pressure (Absolute) and Water Level Measurements U20-001-02 and U20-001-02-Ti

Operation Range	0 to 400 kPa (0 to 58 psia); approximately 0 to 30.6 m (0 to 100 ft) of water depth at sea level, or 0 to 33.6 m (0 to 111 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 400 kPa (10 to 58 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	500 kPa (72.5 psia) or 40.8 m (134 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 1.5 cm (0.05 ft) water Maximum error: ±0.1% FS, 3 cm (0.1 ft) water
Raw Pressure Accuracy**	±0.3% FS, 1.20 kPa (0.17 psi) maximum error
Resolution	<0.04 kPa (0.006 psi), 0.41 cm (0.013 ft) water
Pressure Response Time (90%)***	<1 second; measurement accuracy also depends on temperature response time

Pressure (Absolute) and Water Level Measurements U20-001-03 and U20-001-03-Ti

Operation Range	0 to 850 kPa (0 to 123.3 psia); approximately 0 to 76.5 m (0 to 251 ft) of water depth at sea level, or 0 to 79.5 m (0 to 262 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 850 kPa (10 to 123.3 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	1200 kPa (174 psia) or 112 m (368 ft) depth
Water Level Accuracy*	Typical error: ±0.05% FS, 3.8 cm (0.125 ft) water Maximum error: ±0.1% FS, 7.6 cm (0.25 ft) water
Raw Pressure Accuracy**	±0.3% FS, 2.55 kPa (0.37 psi) maximum error

Specifications (continued)

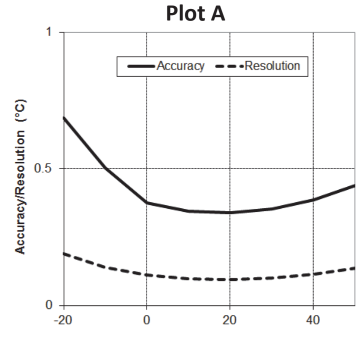
Pressure (Absolute) and Water Level Measurements U20-001-03 and U20-001-03-Ti (continued)	
Resolution	<0.085 kPa (0.012 psi), 0.87 cm (0.028 ft) water
Pressure Response Time (90%)* **	<1 second; measurement accuracy also depends on temperature response time
Pressure (Absolute) and Water Level Measurements U20-001-04 and U20-001-04-Ti	
Operation Range	0 to 145 kPa (0 to 21 psia); approximately 0 to 4 m (0 to 13 ft) of water depth at sea level, or 0 to 7 m (0 to 23 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 145 kPa (10 to 21 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.075% FS, 0.3 cm (0.01 ft) water Maximum error: ±0.15% FS, 0.6 cm (0.02 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.43 kPa (0.063 psi) maximum error
Resolution	<0.014 kPa (0.002 psi), 0.14 cm (0.005 ft) water
Pressure Response Time (90%)***	<1 second; measurement accuracy also depends on temperature response time
Temperature Measurements (All Models)	
Operation Range	-20° to 50°C (-4° to 122°F)
Accuracy	±0.44°C from 0° to 50°C (±0.79°F from 32° to 122°F), see Plot A
Resolution	0.10°C at 25°C (0.18°F at 77°F), see Plot A
Response Time (90%)	5 minutes in water (typical)
Stability (Drift)	0.1°C (0.18°F) per year
Logger	
Real-time Clock	± 1 minute per month 0° to 50°C (32° to 122°F)
Battery	2/3 AA, 3.6 Volt lithium, factory-replaceable
Battery Life (Typical Use)	5 years with 1 minute or greater logging interval
Memory (Non-volatile)	64K bytes memory (approx. 21,700 pressure and temperature samples)
Weight	Stainless steel models: approximately 210 g (7.4 oz) Titanium models: approximately 140 g (4.8 oz)
Dimensions	2.46 cm (0.97 inches) diameter, 15 cm (5.9 inches) length; mounting hole 6.3 mm (0.25 inches) diameter
Wetted Materials	Stainless Steel models: 316 stainless steel, Viton® O-rings, acetal cap, ceramic sensor Titanium models: Titanium, Viton O-rings, acetal cap, ceramic sensor
Logging Interval	Fixed-rate or multiple logging intervals, with up to 8 user-defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to the HOBOware software manual.
Launch Modes	Immediate start and delayed start
Offload Modes	Offload while logging; stop and offload
Battery Indication	Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

* Water Level Accuracy: With accurate reference water level measurement, known water density, accurate Barometric Compensation Assistant data, and a stable temperature environment.

** Raw Pressure Accuracy: Absolute pressure sensor accuracy includes all sensor drift, temperature, and hysteresis-induced errors.

*** Changes in Temperature: Allow 10 minutes in water to achieve full temperature compensation of the pressure sensor. Maximum error due to rapid thermal changes is approximately 0.5%.

Plot A



Software

HOBOware Pro software is required for logger operation. Using a reference water level, HOBOware Pro automatically converts the pressure readings into water level readings. The software also supports compensation for temperature, fluid density, and barometric pressure.

Communication

For launching and reading out the Water Level logger in the field, you can use a laptop computer with HOBOware Pro and an Onset Optic USB Base Station (BASE-U-4), with a coupler (COUPLER2-B) or the HOBO Waterproof Shuttle (U-DTW-1) with a coupler (COUPLER2-B).

The optical interface allows the logger to be offloaded without breaking the integrity of the seals. The USB compatibility allows for easy setup and fast downloads.

Barometric Compensation

The HOBO Water Level Logger records absolute pressure, which is later converted to water level readings by the software. In this application, absolute pressure includes atmospheric pressure and water head. Atmospheric pressure is nominally 100 kPa (14.5 psi) at sea level, but changes with weather and altitude. Left uncompensated, barometric variations could result in errors of 0.6 m (2 ft) or more.

To compensate for barometric pressure changes, you can use the HOBO U20 Water Level Logger as a barometric reference. The barometric reference is typically deployed in the same well or at the same location as the water level of interest, but rather than being placed in the water column, it is deployed above the water in air.

Barometric pressure readings are consistent across a region (except during fast-moving weather events), so you can generally use barometric pressure readings that are taken within 15 km (10 miles) of the logger or more, without significantly degrading the accuracy of the compensation.

Therefore, one U20 or weather station (HOBO U30 or H21 recommended) can be used to compensate all of the water level loggers in an area. The U20-001-01 model with its 0–9m (0–30 ft) range or the U20-001-04 with its 0–4 m (0–13 ft) range are both good barometric references due to their smaller range, temperature-compensated accuracy, and rugged stainless steel case. HOBOware Pro includes a Barometric Compensation Assistant for easy and accurate barometric compensation.

LEDs

A light (LED) in the communications window of the logger confirms logger operation.

The following table explains when the logger blinks during logger operation:

When:	The Light:
The logger is logging	Blinks once every one to four seconds (the shorter the logging interval, the faster the light blinks); blinks when logging a sample
The logger is awaiting a start because it was launched in Start At Interval or Delayed Start mode	Blinks once every eight seconds until logging begins

Calibration

The pressure sensor in each HOBO Water Logger is individually calibrated. During calibration, raw pressure sensor data is collected at multiple pressures and temperatures over the calibrated range of the logger (see the specifications table). This data is used to generate calibration coefficients that are stored in the logger's non-volatile memory. The calibration coefficients are then checked to be sure that the logger meets its stated accuracy over the calibrated range.

The pressure sensor can be used at pressures and temperatures that are outside of the calibrated range, but the accuracy cannot be guaranteed.

Important: Never exceed the burst pressure of the sensor!

Sleep Mode

The logger consumes significantly more power when it is "awake" and connected to a base station or shuttle. To conserve power, the logger will go into a low-power (sleep) mode if there has been no communication with your computer for 30 minutes. To wake up the logger, remove the logger from the coupler, wait a moment, then re-insert the logger.

Sample and Event Logging

The logger can record two types of data: samples and events. Samples are the sensor measurements recorded at each logging interval (for example, the pressure every minute). Events are independent occurrences triggered by a logger activity, such as Bad Battery or Host Connected. Events help you determine what was happening while the logger was logging.

The logger stores 64K of data, and can record over 21,700 samples of pressure and temperature.

Setup

Before you deploy the HOBO U20 Water Level Logger in the field, perform the following steps in the office:

1. Start HOBOware.
2. Connect the logger to the computer. See the next section.
3. Verify the status. Click Status on the toolbar and observe that the absolute pressure is near barometric pressure for the location and the temperature is near the actual temperature.

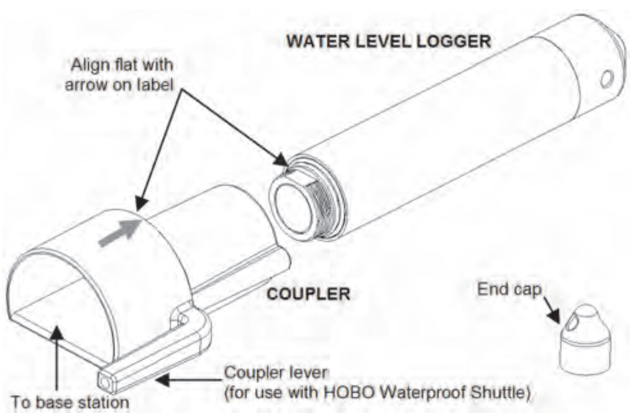
4. Launch the logger. See the *HOBOware User's Guide* for details.
   - Make sure both *Abs. Pressure* and *Temperature* are selected (temperature is required for temperature compensation of pressure).
   - *Logging Battery Voltage* is not essential since you can check the battery voltage using the Status screen at launch or readout of logger.

Connecting the Logger to a Computer

The HOBO Water Level Logger requires a coupler (COUPLER2-B) and USB Optic Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1) to connect to the computer.

1. Follow the instructions that came with your base station or shuttle to attach the base station or shuttle to a USB port on the computer.
2. Unscrew the black plastic end cap from the logger by turning it counter-clockwise.
3. Attach the coupler to the base station or shuttle
4. Insert the logger into the coupler with the flat on the logger aligned with the arrow on the coupler label. Gently twist the logger to be sure that it is properly seated in the coupler (it should not turn).

NOTE: If you are using the Waterproof Shuttle, briefly press the coupler lever to put the shuttle into base station mode.

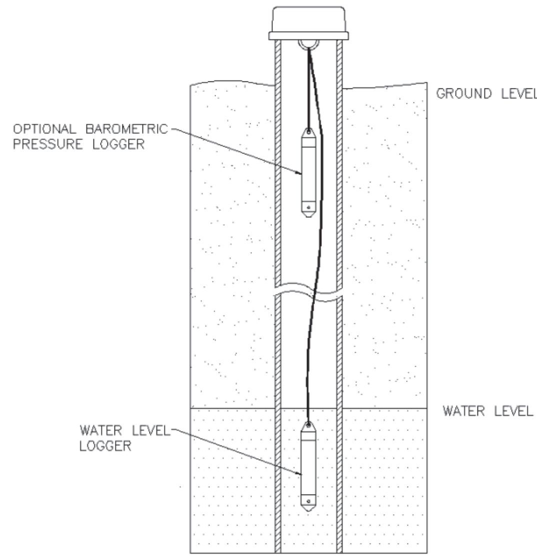


If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer.

Important: USB communications may not function properly at temperatures below 0°C (32°F) or above 50°C (122°F).

Deploying the Logger

The HOBO Water Level Logger is designed to be easy to deploy in many environments. The logger uses an absolute pressure sensor, so no vent tube is required. The small size of the logger is convenient for use in small wells and allows the logger to be mounted and/or hidden in the field.



Deployment Guidelines

Full Temperature Equilibrium
The pressure sensor is temperature compensated over the range of 0° to 40°C (32° to 104°F). To obtain the highest level of accuracy, the logger should be allowed to come to full temperature equilibrium (approximately 20 minutes) before the reference level is recorded.

Sudden Temperature Changes
Sudden temperature changes should be avoided. When deploying a HOBO Water Level Logger for barometric pressure reference, some consideration should be made to minimize the rate of temperature fluctuations. Ideally, the barometric pressure reference logger should be hung several feet below ground level in an observation well where ground temperatures are stable (while making sure the logger remains above the water level). If that is not possible (or if a well is not used), try to put the logger in a location where it will not be subject to rapid daily temperature cycles.

Venting
When deploying a HOBO Water Level logger in a well, make sure the well is vented to the atmosphere. Typically, a small hole can be drilled in the well cap to ensure that the pressure inside and outside the well is at equilibrium. If this is not possible, the barometric pressure reference logger should be used inside the same well.

Wire
Use a no-stretch wire to hang the water level logger. Any change in length of the wire will result in a 1-to-1 corresponding error in the depth measurement. Always pull-test a cable prior to deploying a logger in a well to make sure it does not stretch.

Stilling Well
If you are deploying the logger in a lake, river, or stream, you must first build a stilling well to protect the logger from vibration, shock, and movement.

A simple stilling well can be constructed with PVC or ABS pipe. A properly constructed stilling well helps to protect the logger from currents, wave action, and debris. Suspend the logger in the stilling well so it is always underwater, but not on the bottom to be buried by silt.

For more information, see the Technical Application Note for Constructing a Stilling Well at:
http://www.onsetcomp.com/water_level_stilling_well.html

Burst Pressure
Be very careful not to exceed the burst pressure for the logger. The pressure sensor will burst if the maximum depth is exceeded (see specifications table). The logger should be positioned at a depth where the logger will remain in the water for the duration of the deployment, but not exceed the rated bursting depth.

Deployment Procedure

1. Cut wire to suspend logger.
   a. Measure the physical depth to the surface of the water from the suspension point.
   b. Cut a piece of stranded, stainless steel wire (Teflon coated is best) so that the logger will be deep enough to always be in the water. Estimate the low water level and make the cable length such that the logger will be about 2 feet below that level.
2. Attach the wire to the suspension point and to the logger cap.
3. Relaunch the logger if desired (if a PC or a HOBO U-Shuttle is available).
4. Lower the logger into the well or stilling well.
5. Measure the water depth from the desired reference point (top of pipe, ground level, or sea level).
   - To maximize accuracy, allow 20 minutes after deploying the logger before measuring water depth to allow the logger to reach temperature equilibrium with the water.
   - If the well is too small in diameter to measure the water depth after deployment, measure the water depth before deployment, then deploy the logger immediately and record deployment time.
   - For well deployments: If the water level surface is below the reference point (such as referencing groundwater measurements to the top of the well), record the water level as a negative number. If the water level surface is above the reference point (such as height above sea level), record the water level as a positive number.
   - For lake, stream, and river deployments: If the water level is being referenced to some point above the logger (such as the top of the stilling well), record the water level as a negative number. If the water depth is being referenced to a point below the water surface such as the bottom of the stream, record the water level as a positive number.
6. Record the reference measurement date and time.

Deploying a U20 Logger for Barometric Pressure Data (Optional)

If you are using a U20 logger to record barometric pressure data, install one logger in one of the wells as follows:

1. Cut wire for suspending the logger.
   a. Measure the physical depth to the surface of the water from the suspension point.
   b. Cut a piece of stranded, stainless steel wire (Teflon coated is best) so that the logger will hang about 2 feet below the ground surface but always above the water surface.
2. Attach the wire to the suspension point and to the logger cap.
3. Relaunch the logger if desired (if a PC or a HOBO U-Shuttle is available)
4. Lower the logger into the well or stilling well. Make sure the logger does not go below the water surface.
5. Record the deployment time.

Collecting Data

For reading out the Water Level logger in the field, you can use either of the following:

- Laptop computer with HOBOware Pro and an Optic USB Base Station (BASE-U-4), with a coupler (COUPLER2-B)
- HOBO Waterproof Shuttle (U-DTW-1) with a coupler (COUPLER2-B)

1. Measure the water depth using the original reference point with the correct sign.
2. Record depth and date and time.
3. Pull the logger out of the well.
4. Remove the logger from its cap, leaving the suspension undisturbed.
5. Readout the data using one of the options listed above.
6. Save the data in a test folder location.
7. Redeploy the logger (optional). See below.

Barometric Pressure Data
To read out a U20 logger used for barometric pressure data:

1. Remove the logger from the well.
2. Readout the data using one of the options listed above.
3. Save the data in a test folder location.
4. Redeploy the logger (optional). See the next section.

Redeploying the Logger
If you are redeploying the logger, you must first make sure that it is launched. If you used the HOBO Waterproof Shuttle to offload data, the shuttle automatically performs a synchronized relaunch of the logger so that data is logged on the same measurement intervals. If you wish to change the launch settings, you must launch the logger using HOBOware Pro.

The existing suspension can be reused as long as the water level logger remained in the water and the barometric logger remained out of the water for the entire test interval. Take a new reference reading with the date and time as described in *Collecting Data*. Record this information in your field notebook to use later to calibrate your data, which will zero out any drift error.

Processing Data using Barometric Pressure Data

To determine water level using barometric pressure data, use the **Barometric Compensation Assistant** in HOBOware Pro, as described below.

If you are using barometric pressure data from a HOBO weather station, you can use the data file as if it were U20 barometric data. For data from sources other than Onset products, see *Barometric Data from Other Sources* below.

1. In HOBOware Pro, open the water depth data file. The **Plot Setup** window appears.
2. Uncheck all boxes except *Abs. Pressure*.
3. Run the Barometric Compensation Assistant.
    a. Click the **Process** button.
    b. Select the water density box that best describes the water that you are measuring or enter the actual water density.
    c. Check the *Use a Reference Water Level* box and enter the reference water level that you measured at the beginning of the deployment.
    d. Select the date and time from the pull-down menu that is closest to the recorded date/time for the measurement. If you measured the depth before deployment because of pipe size, then select a date/time after the start of the deployment.
    e. Check *Use Barometric Data file*.
    f. Click the **Choose** button. This will allow you to select the data file to use for barometric pressure compensation.
    g. Select and open the data file.
    h. Click the **Create New Series** button. A new Plot Setup window appears.
4. Select the *Water Level* box and any other series that you want plotted. Click the **Plot** button to obtain a plot of the resulting water level data.

Measurement Error
Measurement error can be caused by manual measurement error, sensor drift, or change in the suspension cable length.

To quantify measurement error (which is ideally zero), compare the calculated water level at the end of the plot with the water level measured just before you removed the water level logger.

Barometric Data from Other Sources

Third Party Weather Station or Barometric Logger
If you choose to use barometric pressure from a third party weather station or barometric logger, you need to convert the date, time, and pressure data to a text file with special header requirements. For information on how to set up the text file, see the HOBOware Help or User Guide. It is easiest to do this work in EXCEL and then save it as a text file.

Online Weather Station
If you choose to use barometric pressure from an online weather station, such as the National Weather Service, the measured barometric pressure is modified to be at sea level. This sea level pressure is useable since all pressure offsets are zeroed when you enter the reference measurement.

In the Barometric Compensation Assistant, when you select the Barometric Data File, select the text file that you generated. HOBOware Pro will ask for the data format and data separation characters (tab or comma) and then import the barometric data.

Maintenance

Protecting the Logger

Important: Do not attempt to open the logger housing! Unscrewing the metal nose cone of the logger will cause serious damage to the pressure sensor and logger electronics. There are no user serviceable parts inside the case. Contact Onset technical support if your logger requires servicing.

This logger can be damaged by shock. Always handle the logger with care. The logger may lose its calibrated accuracy or be damaged if it is dropped. Use proper packaging when transporting or shipping the logger.

Biofouling
Periodically inspect the logger for fouling. Biological growth on the face of the pressure sensor will throw off the pressure sensor's accuracy. Organisms that grow inside the sensor nose cone and on the sensor itself can interfere with the sensor's operation and eventually make the sensor unusable. If the deployment area is prone to biofouling, check the logger periodically for marine growth.

Solvents
Check a materials-compatibility chart before deploying the logger in locations where untested solvents are present.

The logger is shipped with Viton O-rings installed. Viton has an excellent resistance to most solvents and is suitable for deployments in water that contain a mixture of most fuels, solvents and lubricants. However, the Viton O-rings are sensitive to polar solvents (acetone, ketone), ammonia, and brake fluids.

The black acetal cap is provided to help protect the communications window. Acetal is resistant to most solvents, fuels, and lubricants.

The polycarbonate communications window is sealed as an additional barrier to water and dirt entering the logger housing.

Compensating for Drift

All pressure sensors drift over time. The drift for the pressure sensor and electronics in the HOBO Water Level logger is less than 0.3% FS (worst case) per year. In most applications, drift is not a significant source of error, because the offset created by any drift is zeroed out when you take a manual reference level measurement and use the logger software to automatically calculate the level readings relative to the reference measurement. In effect, you are re-zeroing the sensor each time you apply a reference reading to the data file.

Pressure sensor drift matters only when absolute pressure values are needed, or if there are no recent reference level or depth measurements available. For example, if the logger is deployed for one year and no new reference level readings are taken during the deployment, it is possible that the sensor could have drifted as much as 0.3% FS by the end of the deployment.

It is possible to determine the actual amount of drift during a deployment if a reference level is taken at the beginning and the end of a long-term deployment. The results of applying the two different reference levels (once at the beginning of the data file, and again at the end of the data file) can be compared. Any difference between the files indicates the amount of sensor drift (assuming accurate reference levels).

Verifying Accuracy

You can check the *differential accuracy* of your loggers for water level measurements by deploying the loggers at two depths and comparing the difference in level readings. When verifying the accuracy this way, be sure to allow the loggers' temperature to stabilize at each depth. Use the logger software to convert the readings from pressure to level. The level readings should be taken close enough together that the barometric pressure does not change.

You can check the *absolute pressure accuracy* of your HOBO Water Level Logger by comparing its ambient pressure readings to a second HOBO logger. Their readings should be within each other's specified accuracy. Alternatively, you can check the pressure reading against an accurate local barometer. If you use a non-local source of barometric information, such as the NOAA website, adjust for altitude.

Recalibration

If you would like to have your logger's absolute accuracy verified against a NIST standard, or to have your logger recalibrated, contact Onset or your place of purchase for pricing and return arrangements.

The Battery

The battery in the HOBO Water Level Logger is a 3.6 Volt lithium battery.

Battery Life

The battery life of the logger should be about five years or more. Actual battery life is a function of the number of deployments, logging interval, and operation/storage temperature of the logger. Frequent deployments with logging intervals of less than one minute, and continuous storage/operation at temperatures above 35°C will result in significantly lower battery life. For example, continuous logging at a one-second logging interval will result in a battery life of approximately one month.

To obtain a five-year battery life, a logging interval of one minute or greater should be used and the logger should be operated and stored at temperatures between 0° and 25°C (32° and 77°F).

Voltage

The logger can report and log its battery voltage. If the battery falls below 3.1 V, the logger will record a "bad battery" event in the datafile. If the datafile contains "bad battery" events, or if logged battery voltage repeatedly falls below 3.3 V, the battery is failing and the logger should be returned to Onset for battery replacement.

Replacing the Battery

To have your logger's battery replaced, contact Onset or your place of purchase for return arrangements. Do not attempt to replace the battery yourself. Severe damage to the logger will result if the case is opened without special tools, and the warranty will be voided.

⚠ **WARNING:** Do not cut open, incinerate, heat above 100°C (212°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

1-800-LOGGERS (564-4377) • 508-759-9500
www.onsetcomp.com/support/contact

This product has been manufactured by Onset Computer Corporation and in compliance with Onset's ISO 9001:2008 Quality Management System.

Patent #: 6,826,664

12315-H MAN-U20

HOBO® U24 Conductivity Logger (U24-00x) Manual

The HOBO U24 data logger family measures actual conductivity and temperature, and can provide specific conductance at 25°C and salinity with the HOBOware® Conductivity Assistant. These easily deployable, rugged loggers provide the data you need for monitoring water purity, the impact of pollutants, salt water intrusion, and coastal ecosystems. The U24-001 model is ideal for deployment in fresh water, while the U24-002 model is designed for saltwater bays and estuaries. There is also an optional U2X Protective Housing accessory (HOUSING-U2X) available for both HOBO U24 models to further protect the logger and simplify mounting in harsh environments.

HOBO Conductivity Logger

Models: U24-001
U24-002

Required Items:

- Coupler (COUPLER2-C) with USB Optic Base Station (BASE-U-4) *or* HOBO Waterproof Shuttle (U-DTW-1)
- HOBOware Pro 3.2 or later with the Conductivity Assitant 2.1 or later

Accessories:

- U2X Protective Housing (HOUSING-U2X)

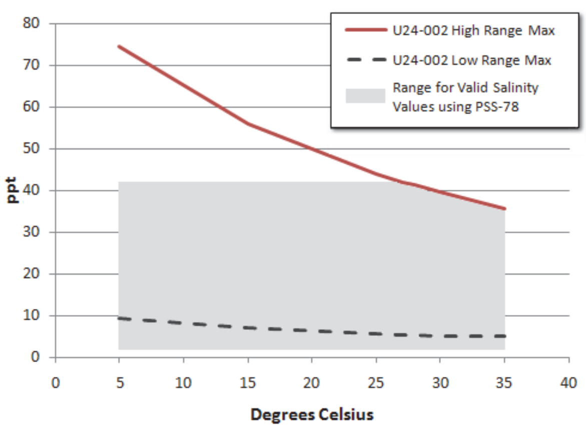
Specifications

	U24-001	U24-002
Measurements	Actual Conductivity, Temperature, Specific Conductance at 25°C (calculated)	Actual Conductivity, Temperature, Specific Conductance at 25°C (calculated), Salinity (calculated using PSS-78, the Practical Salinity Scale 1978)
Conductivity Calibrated Measurement Ranges	Low Range: 0 to 1,000 µS/cm Full Range: 0 to 10,000 µS/cm (see Plot B on next page for specific conductance; see Plot C on next page for a comparison of ranges)	Low Range: 100 to 10,000 µS/cm High Range: 5,000 to 65,000 µS/cm (see Plots A and B on next page for salinity and specific conductance; see Plot C for a comparison of ranges)
Conductivity Calibrated Range - Temperature Range	5° to 35°C (41° to 95°F)	5° to 35°C (41° to 95°F)
Conductivity Extended Ranges	Low Range: 0 to 2,500 µS/cm Full Range: 0 to 15,000 µS/cm	Low Range: 50 to 30,000 µS/cm High Range: 1,000 to 65,000 µS/cm (readings below these ranges reported as 0)
Temperature Measurement Range	-2° to 36°C (28° to 97°F)	-2° to 36°C (28° to 97°F)
Specific Conductance Accuracy (in Calibrated Range)	Low Range: 3% of reading, or 5 µS/cm, and Full Range: 3% of reading, or 20 µS/cm, whichever is greater, using Conductivity Data Assistant and calibration measurements	3% of reading, or 50 µS/cm, whichever is greater for up to 50,000 µS/cm, using Conductivity Data Assistant and calibration measurements, and up to 10% for up to 65,000 µS/cm in NaCl solutions (see Plot D)
Conductivity Resolution	1 µS/cm	2 µS/cm
Temperature Accuracy (in Calibrated Range)	0.1°C (0.2°F)	
Temperature Resolution	0.01°C (0.02°F)	
Conductivity Drift	Less than 3% sensor drift per year in saltwater, exclusive of drift from fouling	
Response Time	1 second to 90% of change (in water)	
Operating Range	-2° to 36°C (28° to 97°F) - non-freezing	
Memory	18,500 temperature and conductivity measurements when using one conductivity range; 14,400 sets of measurements when using both conductivity ranges (64 KB total memory)	
Sample Rate	1 second to 18 hrs, fixed or multiple-rate sampling with up to 8 user-defined sampling intervals	
Clock Accuracy	±1 minute per month	

Specifications (continued)

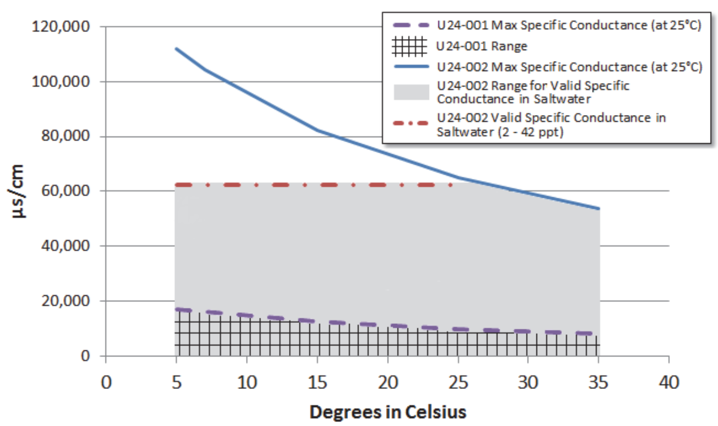
Battery	3.6 Volt lithium battery
Battery Life	3 years (at 1 minute logging)
Maximum Depth	70 m (225 ft)
Weight	193 g (6.82 oz), buoyancy in freshwater: -59.8 g (-2.11 oz)
Size	3.18 cm diameter x 16.5 cm, with 6.3 mm mounting hole (1.25 in. diameter x 6.5 in., 0.25 in. hole)
Wetted Housing Materials	Delrin®, epoxy, stainless steel retaining ring, polypropylene, Buna rubber O-ring, titanium pentoxide (inert coating over sensor); all materials are suitable for long-term use in saltwater
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

Plot A: Salinity Range (U24-002)*

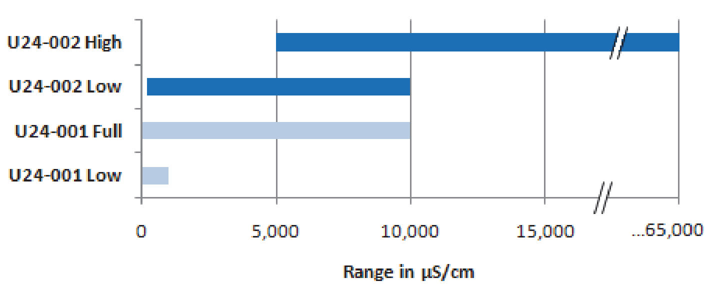


* The Practical Salinity Scale 1978 (PSS-78) used to calculate salinity is valid for salinities in the range of 2 to 42 ppt. For salinities outside of this range, use the measured conductivity and temperature data from the logger with a calculation appropriate for your salinities.

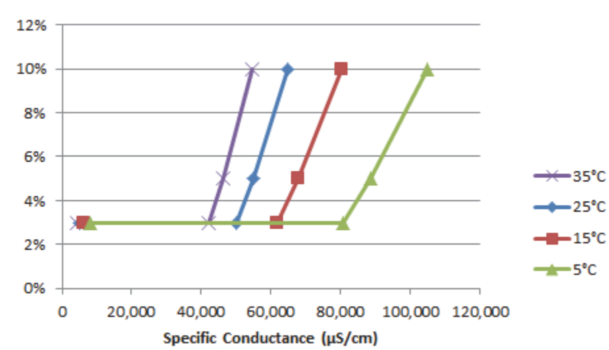
Plot B: Specific Conductance Range in Saltwater



Plot C: Comparison of Conductivity Calibrated Measurement Ranges



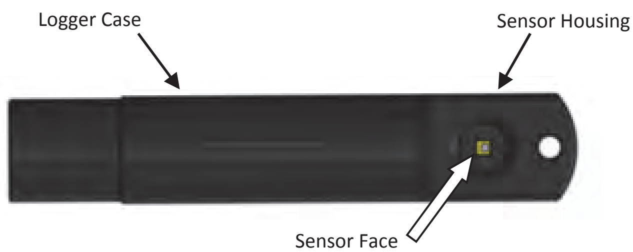
Plot D: Specific Conductance High-Range Accuracy (U24-002)



Protecting the Logger

IMPORTANT: This logger can be damaged by shock. Always handle the logger with care. The logger may be damaged if it is dropped. Use proper packaging when transporting or shipping the logger.

Do not attempt to open the logger case or sensor housing. Disassembling of the logger case or sensor housing will cause serious damage to the sensor and logger electronics. There are no user-serviceable parts inside the case. Contact Onset Technical Support at 1-800-LOGGERS (1-800-564-4377) or an authorized Onset dealer if your logger requires servicing.



Do not scratch the sensor face with a sharp tool.

Operation

An LED in the communications window of the logger confirms logger operation. When the logger is logging, the LED blinks once every one to four seconds (the shorter the logging interval, the faster the LED blinks). The LED also blinks when the logger is recording a sample. When the logger is awaiting a start because it was launched in “Start at Interval” or “Delayed Start” mode, the LED blinks once every eight seconds until logging begins.

The logger can record two types of data: samples and events. Samples are the sensor measurements recorded at each logging interval. Events are independent occurrences triggered by a logger activity, such as Bad Battery or Host Connected. Events help you determine what was happening while the logger was logging.

Communication

To connect the logger to a computer, use either the Optic USB Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1) with a coupler (COUPLER2-C).

IMPORTANT: USB 2.0 specifications do not guarantee operation outside the range of 0°C (32°F) to 50°C (122°F).

To launch and read out the logger in the field, use one of these methods:

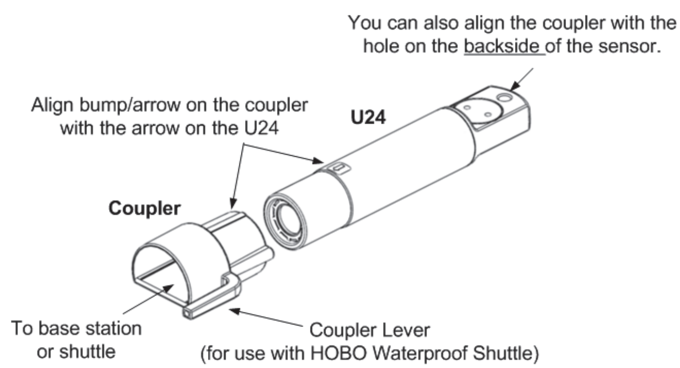
- Laptop computer with Optic USB Base Station (BASE-U-4) and a coupler (COUPLER2-C)
- HOBO Waterproof Shuttle (U-DTW-1, Firmware Version 3.2.0 or later) and a coupler (COUPLER2-C)
- HOBO U-Shuttle (U-DT-1, Firmware Version 1.14m030 or later) with Optic USB Base Station and coupler (COUPLER2-C)

The optical interface allows the logger to be offloaded without breaking the integrity of the seals. The USB compatibility allows for easy setup and fast downloads.

Connecting the Logger to a Computer or Waterproof Shuttle

1. Follow the instructions that came with your base station or Waterproof Shuttle to attach it to a USB port on the computer.
2. Attach the coupler to the base station or shuttle.
3. Wipe off any residue or slime from the area of the logger that will go into the coupler, including the communication window. This will help the logger slide in and out of the coupler more easily, and help with communication.
4. Insert the logger into the coupler, aligning the bump/arrow on the coupler with the arrow on the logger. Be sure that it is properly seated in the coupler. If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer.

   NOTE: If you are using the HOBO Waterproof Shuttle as a base station with a computer, briefly press the Coupler Lever to put the shuttle into base station mode.



WARNING: Do not leave the logger in the coupler for extended periods of time. When connected to a coupler, the logger is “awake” and consumes significantly more power than when it is disconnected and considered “asleep.” Always remove the logger from the Optic Base Station or HOBO Waterproof Shuttle as soon as possible after launching, reading out, or checking the status to avoid draining the battery.

Launching the Logger

Before deploying the logger in the field, perform the following steps in the office:

1. Start HOBOware.
2. Connect the logger to the computer as described in the previous section.
3. Verify the status. Click the status button on the toolbar and observe that the temperature is near the actual temperature.
4. Launch the logger with the correct range. Refer to the specifications on page 1 for both calibrated and extended

ranges (the calibrated ranges are also printed on the logger housing). The logger will not record readings outside of the extended range selected. (For the U24-002, readings below the extended range are reported as 0.) If in doubt on the range needed for your deployment, or for environments with wide fluctuations, select both ranges. This will shorten the deployment duration from 18,500 samples to 14,400 samples per parameter (not logging battery voltage). See the *HOBOware User's Guide* or online help for details on launching.

Note: Logging battery voltage is not essential because you can check the battery using the Status screen at launch or readout of the logger. Logging the battery voltage will reduce the number of conductivity and temperature readings you can log.

Taking Calibration Readings

It is important to take temperature and conductivity calibration readings with a portable conductivity meter at both the beginning (launchtime) and end of a deployment (readout) because these readings are necessary for data calibration and to compensate for any measurement drift during deployment. The conductivity calibration readings should be the *actual conductivity* without temperature compensation (*not* in specific conductance at 25°C), and should be recorded in a notebook with the time and location of the reading. You will use these readings in the HOBOware Conductivity Assistant to calibrate the readings for the corresponding data series offloaded from the logger.

There are three methods for obtaining accurate calibration readings. The first method involves placing the meter's probe into the water next to the logger. The second method involves placing the logger and meter probe in a field water sample in a jar. In both methods, the conductivity meter probe must be close to the data logger—but not touching—so that it is measuring water at the same conductivity and salinity as the logger. The third method involves taking a sample back to the office to measure with a meter there.

If the conductivity and salinity in the water where the logger is deployed is stable and it is easy to reach the logger, then you can obtain calibration readings by placing the probe directly into the water next to the logger. However, taking calibration readings in areas that have tidal and freshwater mixing is more challenging due to the rapidly changing salinities. Similarly, taking calibration readings in wells can also be difficult because it may be hard to get the meter probe next to the logger. In these instances, you should fill a jar with a water sample from where the logger is deployed to take the calibration readings. To obtain the water sample from a well or stilling well, you can use a bailer with a diameter that is small enough to fit down the well.

Note: Some salt residue may remain on the logger from factory calibration. Carefully rinse the logger in distilled water or clean freshwater to remove any residual salt before taking your first calibration readings.

Method 1:
Taking readings directly in the water (recommended for locations with access for the field meter probe and with conductivity that is stable)

1. If you have just deployed the logger, allow enough time for the logger temperature to stabilize for the best accuracy (approximately 15 minutes).
2. Gently tap the logger to remove any bubbles from the surface. Tug the cable if you cannot reach the logger itself.
3. Measure the temperature and actual conductivity with the field meter, making sure the meter probe readings stabilize per the meter's specification. Record the values, time, and location of the readings in a field notebook for use later in the HOBOware Conductivity Assistant.

Method 2:
Taking readings in a jar (recommended for readings in wells or in water with rapidly changing conductivity, such as areas with saltwater and freshwater mixing)

1. Take a sample of water in a jar that is large enough to hold both the logger and the probe from a portable conductivity meter, leaving an inch of space between the probe and the logger. For wells, use a bailer to obtain the water sample.
2. Leave the logger and the meter probe submerged in this jar of water long enough so they reach temperature equilibrium and the logger has logged at least three readings (allow at least 15 minutes for the best accuracy). (Three readings are necessary because this will help you identify which readings were taken while the logger is in the jar.)
3. Measure the temperature and actual conductivity with the field meter. Record the values, time, and location of the reading in a field notebook for use later in the HOBOware Conductivity Assistant.
4. When using the Conductivity Assistant, look for the spot in the data where there are three similar readings in a row and link the last of those readings to the meter reading. (The time you noted may be slightly different than the logger time so looking for the three similar readings will help isolate the correct reading.) The Conductivity Assistant uses that value to calibrate the specific conductance and salinity readings for that data series.

Method 3:
Taking a sample back to the office in a sealable jar to measure there (recommended for locations with conductivity that is stable when you do not have a field meter or it is not convenient to access the logger)

1. Place a sample of the water taken from next to the logger in a jar and immediately seal it to ensure that none of the water evaporates. This allows the specific conductance and salinity of the sample to be maintained, which in turn results in usable temperature and conductivity readings when you measure it with the meter at a later time.
2. Write down the time you take the sample for use later in the HOBOware Conductivity Assistant.

3. At the office, measure the temperature and actual conductivity of the sample with a meter and write down the values next to the time you noted in step 2.

Note: If you've taken the calibration readings in specific conductivity, you can convert the readings back to actual conductivity. Use the temperature readings from the meter or logger to convert the conductivity reading following the specific conductivity calculation used by your meter (consult the meter documentation). If the meter uses a standard linear compensation, you can use the following formula to convert it. This equation calculates the electrical conductivity (Y_e) from a measured water temperature (T) and from a measured specific conductance at 25°C (C_s) using the linear temperature coefficient entered into the meter.

$$Y_e = C_s * (1 - ((25-T) * a / 100))$$

Where: Y_e = Calculated Electrical Conductivity
T = water temperature in degrees C measured by the meter
C_s = Specific Conductance measured by the meter
a = linear temperature coefficient (% / degrees C) entered into the meter to calculate specific conductance

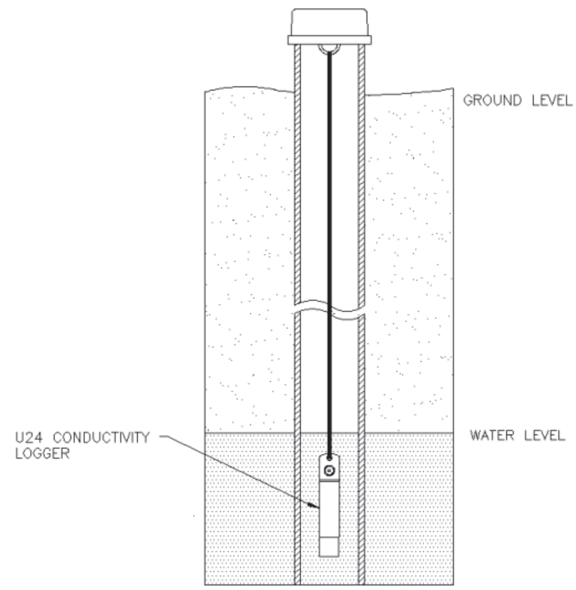
Deploying the Logger

The HOBO U24 Conductivity logger is designed to be easy to deploy in many environments. The small size of the logger is convenient for use in small wells and allows the logger to be mounted and/or hidden in the field. Follow these guidelines when deploying the logger:

- Make sure the logger is located where it will receive a steady flow of the water that is being monitored.
- When deploying the logger in rivers, streams, and ponds, insert the logger in a PVC or ABS pipe if possible. The PVC pipe should have enough holes to ensure good circulation of water.
- To avoid bubbles collecting on the sensor, make sure the sensor face is vertical and avoid sudden temperature changes.
- Do not place any conductive materials or metals within 2.5 cm (1 in.) of the sensor.
- Avoid deploying the logger in freezing water with moving ice.
- Use the U2X Protective Housing (HOUSING-U2X) for added protection to the logger in harsh environments.

To deploy the logger at each site:

1. Launch the logger with a laptop or shuttle.
2. Take a calibration reading as described on page 4.
3. Deploy the logger in the water (if it hasn't already been placed in the water) following the guidelines recommended above.
4. Repeat steps 1 through 3 for each logger deployed. Be sure to take a new calibration reading for each logger that you deploy.



Reading Out the Logger and Calibrating Data with HOBOware

Your readout and maintenance schedule will be determined by the amount of fouling at the site. To read out the logger in the field:

1. Calibrate the field conductivity meter before using it to take field readings.
2. Measure the actual conductivity and temperature values with the field meter using one of the calibration methods on page 4.
3. Remove the logger from the water (if it hasn't already been removed for the calibration measurement).
4. Read out the data from the logger using a shuttle.
5. Relaunch the logger.
6. Clean the sensor (see *Maintenance* on page 6 for more details).
7. Redeploy the logger in the stream, and take another calibration measurement.

Use HOBOware to calibrate data and convert to specific conductance or salinity

1. Offload the most recent data files from the shuttle or loggers to your computer.
2. Open a data file in HOBOware.

3. Use the HOBOware Conductivity Assistant to calibrate the readings and adjust for drift caused by fouling. You will need to enter the field meter conductivity and temperature readings and times from the beginning and, optionally, the end of that segment of the logger's deployment. Refer to the Help for the Conductivity Assistant for more details. Save your changes to a project file.
4. Repeat steps 1 through 3 for all data files.

Maintenance

The logger requires the following periodic maintenance to ensure optimal operation:

- **Clean the sensor.** Mix several drops of dish detergent or biodegradable soap in a cup of tap water with a clean cotton swab. Clean the sensor face using the cotton swab and then rinse the sensor with clean or distilled water. Do not scratch the sensor face with a sharp tool.
- **Check for biofouling.** Biofouling and excessive marine growth on the logger will compromise accuracy. Organisms that grow on the sensor can interfere with the sensor's operation and eventually make the sensor unusable. If the deployment area is prone to biofouling, check the logger periodically for marine growth.
- **Be careful of solvents.** Check a materials compatibility chart before deploying the logger in locations where untested solvents are present. Refer to the specifications for wetted housing materials on page 1.

Battery Guidelines

- **Battery Life.** The battery life of the logger should be three years or more. Actual battery life is a function of the number of deployments, logging interval, and operation/storage temperature of the logger. Frequent deployments with logging intervals of less than one minute, continuous storage/operation at temperatures above 35°C (95°), and keeping the logger connected to the coupler will result in significantly lower battery life. For example, continuous logging at a one-second logging interval will result in a battery life of approximately one month.

  To obtain a three-year battery life, a logging interval of one minute or greater should be used and the logger should be operated and stored at temperatures between 0° and 25°C (32° and 77°F).
- **Battery Voltage.** The logger can report and log its battery voltage. If the battery falls below 3.1 V, the logger will record a "bad battery" event in the datafile. If the datafile contains "bad battery" events, or if logged battery voltage repeatedly falls below 3.3 V, the battery is failing and the logger should be returned to Onset for battery replacement. Note that the logger does not have to be recording the battery channel for it to detect bad battery events. The logger will record these events regardless of what channels are logged.
- **Replacing the Battery.** To have your logger's battery and sensor replaced, contact Onset or your place of purchase for return arrangements. Do not attempt to replace the battery yourself. Severe damage to the logger will result if the case is opened without special tools, and the warranty will be voided.

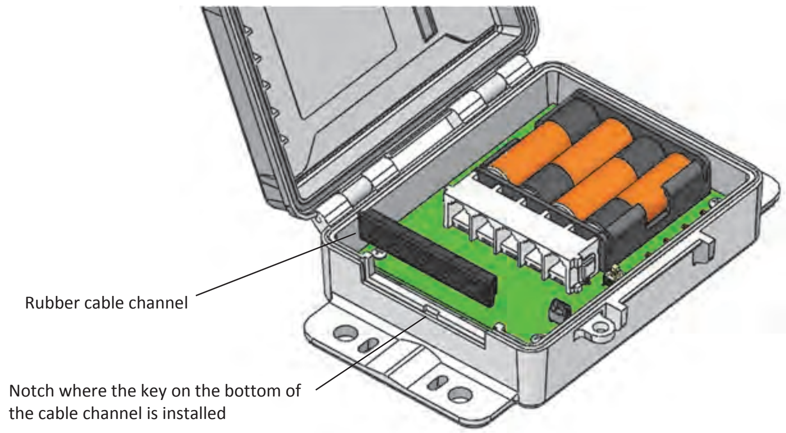
WARNING: Do not cut open, incinerate, heat above 100°C (212°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.

1 **Install the batteries.** Open the logger door and insert four AA batteries observing polarity.

2 **Plug in smart sensors and install the rubber cable channel.**

> **Important:** Proper installation of the rubber cable channel is required for outdoor and weatherproof deployments and in harsh indoor environments.

a. Remove the rubber cable channel making note of how it is oriented.

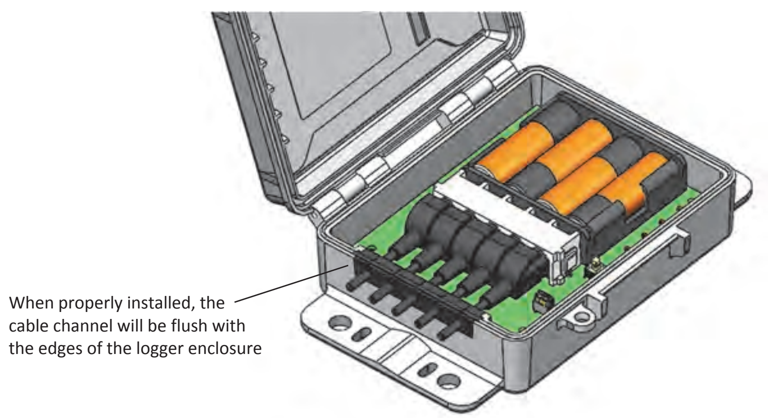


b. Plug the smart sensors into the connectors. When using multiple smart sensors, it is easiest to start by plugging one into the leftmost or rightmost connector and then working your way across the connectors in order.

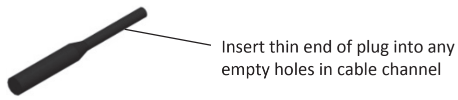
c. Lightly coat each smart sensor cable with a small amount of silicone grease (about the size of a pea). Only the portion of the cable that will be in the channel needs to be greased. Also lightly coat the bottom and two sides of the cable channel.

d. Place the cables in the cable channel. There is a break in the rubber above each hole to guide the cable into the hole. Make sure the cable channel is oriented with the breaks pointed up and the key pointed down and closer to the sensor connectors to ensure proper reinstallation in the next step. Slightly bend the ends of the channel to reveal the breaks and push the cable into the hole that lines up with the corresponding sensor connector. Repeat for any additional sensors.

e. Reinstall the cable channel making sure the key on the bottom is inserted in the notch in the logger enclosure pointed out in the diagram above. Once the cable channel is properly seated, the top will be flush with the edge of the logger enclosure. Adjust the cable slack as necessary so a minimum amount of cable is inside the case as shown below.



f. If you will be using less than five smart sensors, use the rubber plugs to fill any empty holes in the cable channel. Lightly coat the rubber plugs with a small amount of grease. Insert the thin part of the plug into the hole. While pulling the thin end of the plug from the inside of the case, push the other end of the plug from the outside until the thick part of the plug fills the hole.



3 **Set up HOBOware.** Even though this logger uses a USB cable to communicate with HOBOware, the software and computer must be configured for a serial COM port for each H21-USB station (even if your computer does not have a serial port). HOBOware 3.7.10 or later is recommended.

If you need to install or upgrade HOBOware:

a. Connect the logger to the computer with the USB cable. Device hardware drivers will be installed automatically the first time an H21-USB logger is connected. This may take a few minutes to complete.

> **Important:** The computer must be connected to the Internet while the device hardware drivers are being installed. Device drivers only need to be installed once per computer. If you need to use another computer with an H21-USB Micro Station, you will need to repeat this installation. Contact Onset Technical Support at www.onsetcomp.com/support/contact if you encounter any problems with device hardware driver installation.

b. Download HOBOware at www.onsetcomp.com/hoboware-free-download and install the software.

c. When the HOBOware Setup Assistant appears, select “USB and serial devices” for the device types. A COM port should be listed. Complete the remaining Setup Assistant steps and click OK.

If HOBOware is already installed:

a. Connect the logger to the computer with the USB cable. Device hardware drivers will be installed automatically the first time an H21-USB logger is connected. This may take a few minutes to complete.

> **Important:** The computer must be connected to the Internet while the device hardware drivers are being installed. Device drivers only need to be installed once per computer. If you need to use another computer with an H21-USB Micro Station, you will need to repeat this installation. Contact Onset Technical Support at www.onsetcomp.com/support/contact if you encounter any problems with device hardware driver installation.

b. Open HOBOware. From the File menu (Windows) or the HOBOware menu (Macintosh), select Preferences.

c. In HOBOware Preferences, select Communications. Click Device Types and make sure “USB and serial devices” is selected.

d. Click Serial Ports. A new COM port is listed under Serial Ports, which will be used for the Micro Station. Check the box next to the new COM port or click Select All (do not use Select All if there are devices other than HOBOs using serial ports).

e. Click OK in Preferences.

Note: If you are using a version of HOBOware prior to 3.7.10, you may need to enable a COM port in Preferences as described above each time you connect a different H21-USB to the computer.

4 **Launch the logger.**

a. From the Device menu in HOBOware, select Launch.

b. Select the logging interval, when to start and stop logging, and any other launch options as desired.

c. Click the Start button to load the settings to the logger. Logging will begin based on the settings you selected. If you configured the logger with a push button start, press the button on the logger for 3 seconds when you are ready for logging to begin.

5 **Deploy the logger.** Refer to the product manual at www.onsetcomp.com/manuals/h21-usb for guidelines for deploying and mounting the logger.

6 **Read out the logger.** Connect the logger to the computer with the USB cable to read it out. From the Device menu in HOBOware, select Readout. After the readout is complete, plot the data.

For detailed specifications and information about this logger, refer to the complete product manual. Scan the code at left or go to www.onsetcomp.com/manuals/h21-usb.

Barometric Pressure Smart Sensor (S-BPB-CM50) Manual

Barometric Pressure Smart Sensor

S-BPB-CM50

Items Included:

- Two cable ties
- Two self-tapping screws

Accessories:

- Smart sensor extension cables (S-EXT-M-0xx)
- Weatherproof connection housing (S-EXT-CASE)
- Cable caddy (M-CDY)

The S-BPB barometric pressure smart sensor easily plugs into HOBO® stations with smart sensor inputs. All calibration parameters are stored inside the smart sensor, which automatically communicates configuration information to the station without any programming or extensive user setup.

The S-BPB barometric pressure smart sensor has a rugged, outdoor rated, weatherproof housing. The sensor is mounted outside the logger enclosure, so the logger does not need to be open to the atmosphere.

Specifications

Measurement Range	660 to 1070 mbar (19.47 to 31.55 in. Hg)
Accuracy	±3.0 mbar (0.088 in. Hg) over full pressure range at 25°C (77°F); maximum error of ±5.0 mbar (0.148 in. Hg) over -40° to 70°C (-40° to 158°F)
Resolution	0.1 mbar (.003 in. Hg)
Drift	1.0 mbar (0.03 in. Hg) per year
Operating Temperature Range	-40° to 70°C (-40° to 158°F)
Environmental Rating	Weatherproof
Dimensions	6.4 cm (2.5 in) diameter x 5.1 cm (2 in) height
Weight	96 gm (3.4 oz)
Bits per Sample	12
Number of Data Channels*	1
Measurement Averaging Option	Yes
Cable Length Available	50 cm (20 in.)
Length of Smart Sensor Network Cable*	50 cm (20 in.)
CE	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

* A single HOBO station can accommodate 15 data channels and up to 100 m (328 ft) of smart sensor cable (the digital communications portion of the sensor cables).

Operation

The barometric pressure smart sensor supports measurement averaging. When measurement averaging is enabled, data is sampled more frequently than it is logged. The multiple samples are then averaged together and the average value is stored as the data for the interval.

For example, if the logging interval is set at 10 minutes and the sampling interval is set at 1 minute, each data point in the data file will be the average of 10 measurements. Measurement averaging is useful for reducing noise in the data. Onset recommends that measurement averaging be used when the barometric pressure smart sensor is used in a windy location. Note that fast sampling intervals (less than 1 minute) may significantly reduce battery life.

Maintenance

Use a damp sponge or rag to clean the barometric pressure smart sensor housing if it gets dirty. Under no circumstances should the unit be immersed in water or any other cleaning solvent.

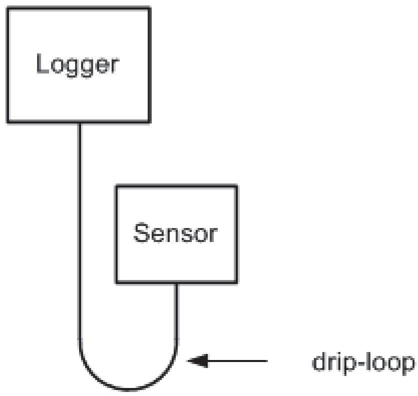
Do not open the sensor as there are no user-serviceable parts inside.

> **Important**: The sensor will give inaccurate measurements if exposed to light by removing the cap.

Mounting the Sensor

Guidelines

- Mount the S-BPB barometric pressure smart sensor outside the logger, either on a mast or a flat, vertical surface.
- The sensor must be mounted vertically to prevent water from collecting under the cap.
- Mount the sensor so that the cable is hanging straight down and create a drip-loop to prevent moisture from entering the logger connection.

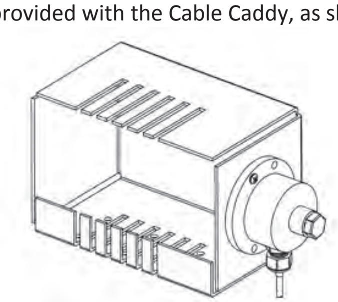


Mounting Options

Tripod: To mount the S-BPB on a pole or Onset tripod mast, use the cable ties provided, as shown in below.

S-BPB Mounted to a Tripod Mast

Onset Cable Caddy: To mount the sensor on the side of the Onset Cable Caddy (M-CDY), use the 8-32 x 3/8 Phillips pan head screws provided with the Cable Caddy, as shown below.



S-BPB Mounted to Cable Caddy

Flat Surface: To mount the sensor on a flat, vertical surface, use the #8 x 1 self-tapping screws provided.

CAUTION: Do not screw the sensor to the side of the HOBO station case. Inserting screws in the side of the HOBO station case will violate the integrity of the unit. You can use double-sided tape.

Connecting the Sensor to a Station

To connect the sensor to a station, stop the station from logging and insert the smart sensor's modular jack into an available smart sensor port on the station. See the station manual for details on operating stations with smart sensors.

Verifying Sensor Accuracy

It is recommended that you check the accuracy of the barometric pressure smart sensor annually. The barometric pressure smart sensor cannot be re-calibrated. Onset uses precision components to obtain accurate measurements. If the smart sensor is not providing accurate data, then it may be damaged and should be replaced.

ONSET

HOBOware® User's Guide

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Phone: 1-800-LOGGERS (1-800-564-4377) or 508-759-9500
Fax: 508-759-9100
Technical Support Hours: 8AM to 8PM ET, Monday through Friday
Customer Service Hours: 8AM to 5PM ET, Monday through Friday

12730-W

Chapter 1: An Overview of HOBOware

HOBOware software is used for launching, reading out, and plotting data from HOBO® data loggers. With HOBOware, you can also check logger status, filter and export data, save changes to graphs in project files, and scale data with the Linear Scaling and Pulse Scaling data assistants. There are two versions of HOBOware: HOBOware and HOBOware Pro. HOBOware Pro offers the following additional features:

- Support for Conductivity, Dissolved Oxygen, and Water Level loggers, which use HOBOware Pro Data Assistants
- Support for HOBO U-Shuttle and Waterproof Shuttle
- HOBOnode Manager and support for wireless HOBO data nodes
- Launch and readout time-saving options
- Additional data assistants (Barometric Compensation, Conductivity, Dissolved Oxygen, Grains Per Pound, Growing Degree Days, and kWh)
- Importing of text data
- Bulk Export Tool
- Pie charts for UX90 series loggers
- Additional plot preferences (font type, style, and color, and series and value axis rules)
- Subset statistics tool for graphing a subset of data
- Series cropping on plots
- 21 CFR Part 11 Compliance

To upgrade from HOBOware to HOBOware Pro, call 1-800-564-4377 and ask for Onset Customer Service. To check for the latest version of HOBOware, select Check for Software Updates from the Help menu. **Note:** If you are using HOBOnode Manager with a HOBO ZW wireless network, you must stop device communication before you can upgrade HOBOware.

Note: HOBOware supports the following languages: English, Simplified Chinese, Traditional Chinese, French, German, Japanese, Korean, Portuguese, and Spanish. The HOBOware user interface can display all of these languages as configured by your computer (see Setting the Language/Format on Your Computer). HOBOware documentation is available in English only.

Videos for using HOBOware and data loggers are available on YouTube (search for Onset data loggers) or go to https://www.youtube.com/user/hobodataloggers/videos.

New HOBOware Features

The following features are available in HOBOware 3.7.11:

- Support for Traditional Chinese and Korean languages in the software user interface (Help and user guides are available in English only).
- A new preference for handling the warning message that may appear when setting up HOBO ZW data node alarms with email server authentication.

- Several bug fixes.

New Features in Previous Releases

HOBOware 3.7.9:

- The ability to filter series on monthly or weekly intervals. See Filter Series at Launch or Filtering Series for details.
- A preference for usage tracking, allowing anonymous information to be shared with Onset Computer Corporation for future HOBOware enhancements.

HOBOware 3.7.6:

- Simplified Chinese language support for the software user interface (Help and user guides are available in English only).
- The ability to select a time zone offset when importing text files. Previously, the time zone used for imported text files was the computer's time zone.

HOBOware 3.7.5:

- The ability to view the latest conditions for the RX3000 Remote Monitoring Station via the RX3000 Manager.
- Support for Windows 10.

HOBOware 3.7.3:

- Support for the new HOBO Temperature/RH/CO2 Logger (MX1102), including launch capability, pre-launch filters, alarms, burst logging, statistics logging, and CO2 sensor calibration.

HOBOware 3.7.2:

- Support for Japanese in the software user interface; Help and user guides are available in English only.
- HOBOware now requires Java 7 or higher (Java 1.7.0_17) for both Windows and Macintosh. Download the latest Java Runtime Environment (JRE) at www.java.com.
- The ability to quickly hide and show a series from the plot by right-clicking the series in the Details pane or by using the Edit menu or the right-click menu in the plot.

HOBOware 3.7.1:

- Introduction of HOBOware, formerly known as HOBOware Lite. See an Overview of HOBOware for details on features in HOBOware and HOBOware Pro.

HOBOware 3.7:

- Support for the new HOBO Plug Load logger (UX120-018), including launch capability, pre-launch filters, statistics logging, and the ability to stop and restart logging during a single deployment.

HOBOware 3.6:

- Support for the new HOBO 4-Channel Analog logger (UX120-006M), including launch capability, pre-launch filters, alarms, burst logging, statistics logging (maximum, minimum, average, and standard deviation), and the ability to stop and restart logging during a single deployment.
- A new preference for exporting the information in the Details Pane and series data from the Points Table in the same file.

HOBOware 3.5:

- Support for the new HOBO 4-Channel Thermocouple logger (UX120-014M), including launch capability, pre-launch filters, alarms, burst logging, statistics logging (maximum, minimum, average, and standard deviation), and the ability to stop and restart logging during a single deployment.

- The ability to assign labels to sensors for all logger models in the Launch Logger window, a feature previously only available for station loggers, such as the HOBO U30 and Micro Station.
- Enhancements to the export table data feature, including the ability to set the default order of measurement types in the Export Settings preferences and to quickly reorder series in the Export window by dragging them.

HOBOware 3.4.1:

- Device menu options specific to HOBO U30 Stations are now available through a new "Manage U30" menu choice.

HOBOware 3.4:

- Support for the new HOBO UX100 series data loggers, including launch capability, pre-launch filters, alarms, burst logging, statistics logging (maximum, minimum, average, and standard deviation), and the ability to stop and restart logging during a single deployment.
- Pie charts for loggers with state series that you can view, print, and save as .png files for additional analysis beyond line graphs. This is especially helpful for light and occupancy data from UX90-005x and -006x loggers.
- A firmware upgrade tool that automatically detects when a new firmware file is available for UX90 and UX100 series data loggers and walks you through the update process.
- Improvements to the process of exporting data points, including the ability to select individual series or event types and to sort columns.
- A new preference for setting the logger launch description as the serial number so that you can easily differentiate files when launching and reading out several loggers of the same type.
- The ability to shows gaps in series when merging datafiles or when plotting a UX100 logger that had stopped and resumed logging.
- Improved the Network Map feature in HOBOnode Manager. (This requires a ZW Receiver firmware upgrade.)
- Support for the new Windows 8 operating system. The current list of supported operating systems is Windows 8, Windows 7 (Pro, Ultimate, and Home Premium), and Windows XP (Pro and Home) on the PC and OS X Versions 10.6.x, 10.7.x, and 10.8.x on Mac.

Note: The Alarm & Readout Tool is no longer installed with HOBOware as of version 3.4. It is no longer supported as of version 3.5.

HOBOware 3.3.2:

- Support for the following languages and their associated formats in the software user interface: Spanish (Spain), Portuguese (Portugal), and German (Germany); Help and user guides are available in English only.
- Improved field calibration accuracy in the Conductivity Assistant.

HOBOware 3.3.1:

- Support for the new HOBO U26 Dissolved Oxygen logger, including launch and readout capability, a Lab Calibration tool to calibrate the logger to 100% and/or 0% saturation, and a Dissolved Oxygen Data Assistant that corrects for measurement drift from fouling and generates salinity-adjusted DO concentration as well as percent saturation data.
- The ability to update firmware for receivers and data nodes in the HOBO ZW Wireless System, with the option to update a single device at a time or multiple data nodes in a group.

- A data encoding preference added to the General preferences that controls whether data in HOBOware is imported and exported based on UTF-8 or operating system standards.
- French language support for the software user interface (Help and user guides are available in English only).

HOBOware 3.3:

- Support for the new HOBO UX90 series data loggers, including launch capability, advanced sensor configuration, and pre-launch filters. The models supported with this release are the State/Pulse/Event/Runtime logger (UX90-001x), Light On/Off logger (UX90-002x), Motor On/Off logger (UX90-004x), and Occupancy/Light logger (UX90-005x/-006x).

HOBOware 3.2.2:

- Enhanced display preferences for sorting data series in the Status and Plot Setup windows.
- A utility for upgrading the HOBOnode Manager database to improve performance.
- Performance improvements for the HOBO data nodes data delivery feature.
- A change to the FTP option for the HOBO data nodes data delivery feature so that it uses passive mode, which allows for better connections through firewalls.
- An update to the Conductivity Assistant, which includes refinements in the calculation of temperature compensation and a new option for non-linear, sea water compensation based on PSS-78.
- A revision to the calculation for T-CDI-5200-10S and T-CDI-5400-20S sensors when used with U-Series loggers ensuring data is displaying properly.
- Support for Java 7®.

HOBOware 3.2.1:

- The integration of the Alarm & Readout Tool, which is now automatically installed and available for use from the Tools menu. **Note:** This tool is no longer supported as of HOBOware 3.5.
- The ability for all non-administrator users to run HOBOware on Windows (administrator privileges are required to install HOBOware, map and unmap file assocations, and load new Data Assistants).
- Compatibility with iMac® and MacBook® Pro and Intel® Core™ i5 and i7 processors.
- A revision to the calculation for the S-SMD Soil Moisture Sensor ensuring data is displaying accurately.
- The option to create new files or overwrite existing ones via FTP when using the data delivery feature for HOBO Data Nodes. This allows you to automatically import wireless node CSV data into other applications, such as Microsoft® Excel®.

HOBOware 3.2:

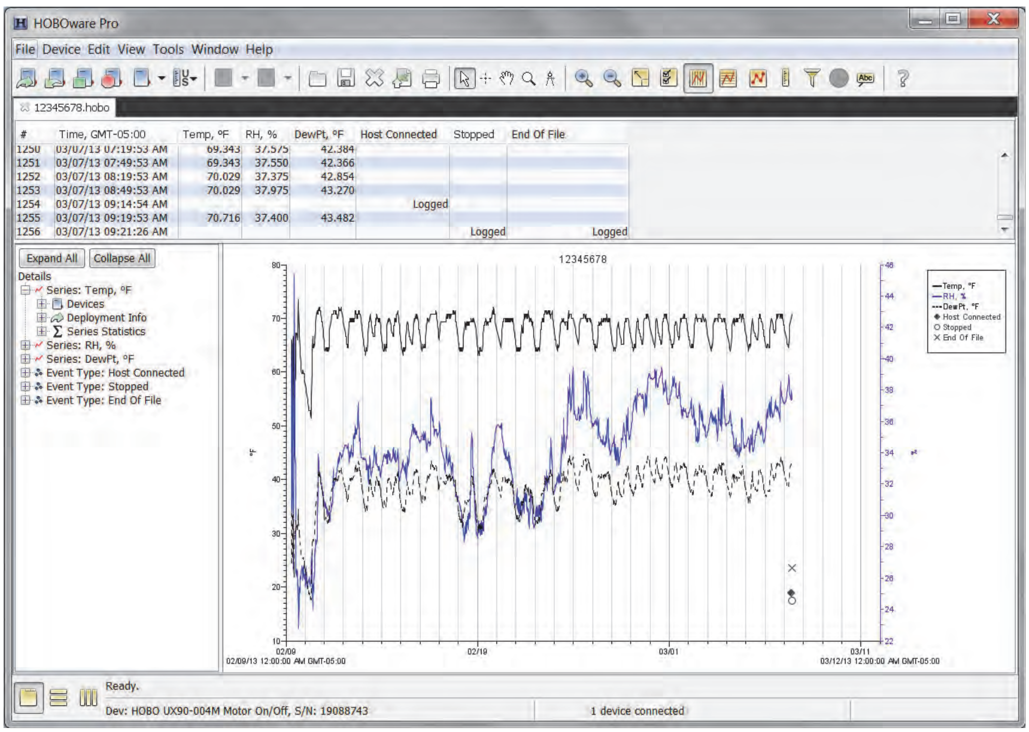
- A redesigned launch window for quick logger configuration and easy sensor setup.
- Faster processing times for opening large data files (512KB and up).
- The ability to configure filtered series when launching the logger, which automatically generates custom series, such as average temperature per day, when you read out the logger and plot data.
- The ability to configure Pulse Scaling, Linear Scaling, and kWh Data Assistant series when launching any logger with applicable external sensors
- Support for the new HOBO 4-Channel Pulse Input Data Logger (UX120-017x), including advanced sensor configuration for setting maximum pulse frequency and lockout times as needed in raw pulse and event channels.

- Support for the new E50B2 Power & Energy Meter (T-VER-E50B2), including single-step configuration with the HOBO 4-Channel Pulse Input Data Logger (UX120-017x) and automatic calculation of numerous additional data series for analysis.
- Support for the new HOBO Conductivity Logger (U24-002).
- The option to disable logging the battery channel by default on some loggers, which can extend battery life and memory space.

Note: Loggers launched in HOBOware 3.2 or later with series created by the Pulse Scaling, Linear Scaling, and kWh Data Assistants or with filtered series cannot be read out in earlier versions of HOBOware.

A Tour of the HOBOware Interface

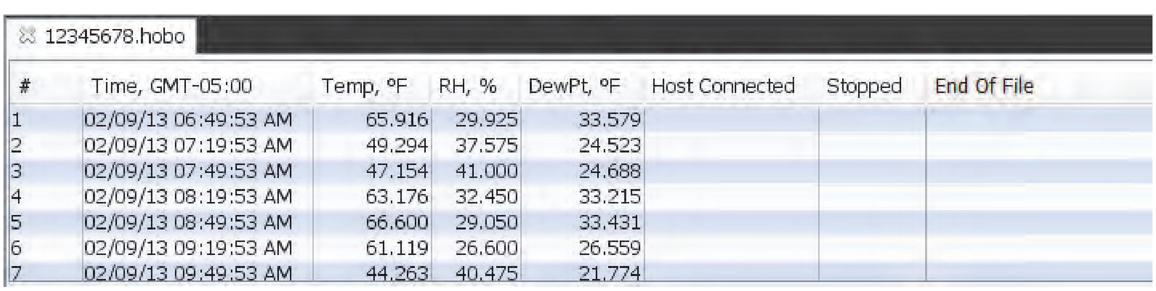
This is the main HOBOware window. Use the menu bar or tool bar to access all the features within HOBOware. The status bar at the bottom of the window shows the current view in place (as selected by the Window menu) as well as the device currently selected or connected, if any.



This example shows a file that has been opened and plotted. There are three components to a plotted datafile: the Points Table, the Details Pane, and the Plot.

The Points Table

The Points Table is a list of data points, or values, and logged events displayed in the plot. The Points Table is linked to the graph: only the data for the series and events on the plot are listed in the Points Table.



12345678.hobo

#	Time, GMT-05:00	Temp, °F	RH, %	DewPt, °F	Host Connected	Stopped	End Of File
1	02/09/13 06:49:53 AM	65.916	29.925	33.579			
2	02/09/13 07:19:53 AM	49.294	37.575	24.523			
3	02/09/13 07:49:53 AM	47.154	41.000	24.688			
4	02/09/13 08:19:53 AM	63.176	32.450	33.215			
5	02/09/13 08:49:53 AM	66.600	29.050	33.431			
6	02/09/13 09:19:53 AM	61.119	26.600	26.559			
7	02/09/13 09:49:53 AM	44.263	40.475	21.774			

The data points are listed chronologically. Each point or event is listed in a single row and each series or event type is displayed in a column. You can resize the columns by clicking and dragging the dividers between the column headers.

Use the arrow keys or scroll bars to move up, down, left, and right in the Points Table. Additionally, as you click the crosshair tool in the plot, the corresponding point is selected in the Points Table. Similarly, if you click a value or event cell in the Points Table, the crosshair will appear on the graph at the time corresponding to that cell.

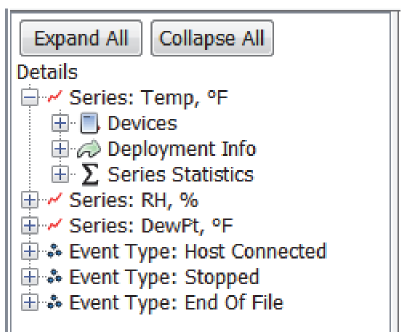
To resize the pane, drag the divider between the Points Table and the plot. To hide the Points Table, select Points Table from the View menu.

If you do not want the Points table to be displayed by default when you plot data, open the Preferences, select Plotting, and then Layout. Disable the "Show the points table when plotting data" checkbox.

The Details Pane

The Details Pane shows information for each series and event displayed in the plot including:

- Information about the devices, such as model and serial numbers.
- Deployment information, such as the launch description, deployment number, start time and time zone, logging interval, and battery voltage at launch.
- Σ Series statistics, such as the total number of sensor samples and events, time of the first and last sample, and the maximum, minimum, average, and standard deviation for each sensor series in the plot.
- Audit trail information for secure files.



Click the + or - button to expand or collapse an entry in the Details Pane. Click the Expand All/Collapse All buttons to expand or collapse the entire details tree.

Click a series node in the details tree to select the corresponding series on the graph and corresponding column in the Points Table.

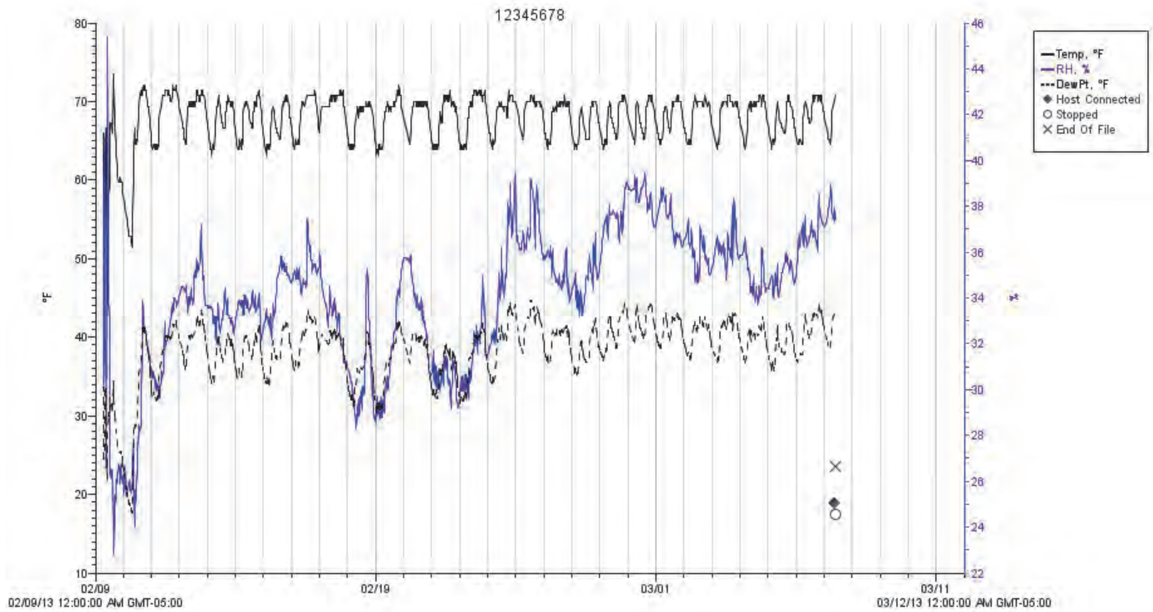
Right-click a series to hide it on the plot and in the Points table. The hidden series will be grayed out in the Details Pane. Right-click a grayed out series to show that series or select Show All Hidden Series to show all series that were previously hidden.

To resize the pane, drag the divider between the Details pane and the graph. To hide the Details Pane, select Details Pane from the View menu.

If you do not want the Points table to be displayed by default when you plot data, open the Preferences, select Plotting, and then Layout. Disable the "Show the details table when plotting data" checkbox.

The Plot

The plot displays the data series and events in a graph. The plot has a time axis (x-axis) and a value axis (y-axis) for each series selected in the Plot Setup window. The title, displayed at the top of the plot by default, is the Description in the Plot Setup window. The legend, displayed to the right of the plot by default, lists the keys for each series (line colors and marker types). If the crosshair tool is in use, it also lists the date, time and point values currently selected by the crosshair. For secure files (.hsec and .dsec), a padlock icon appears in the legend next to the names of the series that were verified as original data.



To show or hide the title or legend, use the View menu. Double-click a plot element (series, axis, title, or legend) to change its properties or right-click the plot and select the item from the menu.

For more details on working with plot, see Reading Out, Plotting, and Analyzing Data.

Working in Secure Mode: 21 CFR Part 11 Compliance

You can create secure files in HOBOware Pro to comply with 21 CFR Part 11, or simply to add a level of security when working with datafiles. When Secure Mode is enabled, HOBOware Pro begins an audit trail in the logger when you launch it and adds an encoded digital signature to the new datafile when you read it out. A digitally signed file, or "secure file," has a filename extension of .hsec (for most U-Series loggers) or .dsec (for station-type loggers).

Notes:

- Issues may arise if you do not always use HOBOware Pro in the Secure Mode, if you sometimes use HOBOware, or if you sometimes use a version of HOBOware prior to 2.3.0. The resulting file issues are described later in this section.
- This feature is not available for use with HOBOnode Manager and its associated ZW series data node files.
- Project (.hproj) and export files are not secure, even if you create them from secure files.

To enable secure mode:

1. From the File menu in Windows or the HOBOware menu in Mac, select Preferences
2. Select General and then select Data Verification.
3. Select the Enable Secure Mode checkbox.
4. Click OK. When Secure mode is enabled, a padlock icon appears in the lower right corner of the main HOBOware Pro window

Opening a Secure File and Data Verification

Secure files can be opened with HOBOware Pro 2.3.0 or greater. You can open .hsec files only with HOBOware 2.3.0 or greater.

Every time you open a secure file – even when you are not in Secure mode – HOBOware verifies the encoded digital signature to detect whether the file has been corrupted or tampered with. When a file is verified as secure, the padlock icon appears in the legend next to the series that were verified as original data.

- Filtered series set up prior to launching or created after readout are not verified.
- Series that were created as a result of user input after readout, such as running a data assistant or entering a constant temperature value for pressure or humidity, are not verified.
- Series retain their verification status (and padlock icon) when copied and pasted into other plots.

In the Details pane, audit trail information is displayed under the Data Verification node for each series. HOBOware Pro automatically obtains the Launch User and Readout User names from your computer's operating system. To save the Launch User name, you must have Secure Mode enabled when you launch the logger.

If the digital signature cannot be verified when you open a file and even a single bit of data has changed since readout, a warning message will appear that verification has failed. This means that the file has been altered or become corrupted since it was originally saved. You may still be able to plot the data from the file, but the padlock icon will not display in the legend or there will be no signing information in the Details pane. You will still be able to perform typical HOBOware functions on the file.

File Compatibility

Depending on the type of logger, the version of HOBOware that launched the logger, and the version of HOBOware that reads out the logger, the resulting datafile may not be compatible with versions of HOBOware prior to 2.3.0 or you may not be able to read out the logger at all. The following files are created when launching and reading out in these scenarios:

- **Launching and reading out in non-secure mode with any version of HOBOware.** A backward-compatible datafile (.hobo or .dtf) is created.
- **Launching in non-secure mode with any version of HOBOware and reading out in secure mode.** A secure file (.hsec or .dsec) is created with an audit trail that lists the readout user, but not the launch user. Secure files are not backward-compatible.
- **Launching in secure mode and reading out in a pre-2.3 version of HOBOware.** Most U-Series loggers cannot be read out. A backward-compatible datafile (.dtf) is created for station loggers.
- **Launching in secure mode and reading out in non-secure HOBOware 2.3.** A datafile (.hobo) is created for U-Series loggers, but it is not backward-compatible. A backward-compatible datafile (.dtf) is created for station loggers.
- **Launching and reading out in secure mode.** A secure file (.hsec or .dsec) is created with a full audit trail. Secure files are not backward-compatible.

Chapter 2
Working with HOBO Data Loggers

Working with HOBO data loggers involves the following basic steps:

1. Connect the logger to the computer for the initial setup and launch.
2. Launch the logger. Enter or select the appropriate parameters for the logger deployment and then launch, or start, the logger.
3. Check the status of the logger. You have the option of checking the current status of the logger and any current readings while it is still connected to the computer. This can be helpful to verify that the launch configuration is as expected.
4. Read out the logger. After deploying the logger, read out all recorded data and save it to a file. Many devices also work with shuttles that allow you to keep the logger in the field, but still read out any recorded data. You can then bring the shuttle back to the office, connect it to the computer, offload and save the files.
5. Plot the data. After reading out the logger and saving the data, you can select and define the data series you wish to plot in a graph. Data Assistants may be available for automatic scaling of certain data when plotting.
6. Analyze the data and customize the plot. There are numerous tools available for working with the data and changing the plot, such as exporting, filtering, merging files, cropping, and more.
7. Save changes to the plot as a project file. Changes to the axis, series, plot, and legend properties as well as any filtering or merging can be saved as an .hproj file.

Connecting Devices

Most HOBO data loggers and shuttles connect to the computer with a USB cable. The HOBO Weather Station, HOBO Micro Station, and HOBO Energy Logger connect to the computer with a serial cable (or to a USB port with a Keyspan™ serial adapter).

Some loggers require an optic USB base station/coupler to connect to the computer. Consult the manual that came with your device for specific information about required base stations/couplers or cables.

Once a device is properly connected to the computer as described below, the device name is listed in the status bar at the bottom of the main HOBOware window.

Notes:

- For instructions on connecting HOBOware compatible shuttles or using the HOBO Waterproof shuttle as a base station, refer to the shuttle's user guide.
- For details on working with HOBO ZW Wireless Data Nodes, see HOBOnode Manager.
- Windows only: If the device has never been connected to this computer before, it may take some time for the computer to detect the new hardware and report that it has connected successfully. One or more messages will appear, indicating that new hardware has been found. You may also hear a chime.
- Windows only: Your computer may tell you to reboot before you can use the device. It is not necessary to reboot.

Connecting a USB logger or Shuttle

To connect a logger or shuttle to HOBOware using a USB cable:

1. Open HOBOware.
2. Plug the large end of the USB interface cable into a USB port on the computer.
3. Plug the small end of the USB interface cable into the port on the device.

For instructions on connecting shuttles or using the HOBO Waterproof Shuttle as a base station, refer to the shuttle’s user guide.

Connecting a Serial Device

To connect a device to a computer using a serial cable:

1. Open HOBOware.
2. Plug the 9-pin end of the serial interface cable into a serial port on the computer or Keyspan adapter.
3. Plug the other end of the serial interface cable into the communications port on the device. (Refer to the diagram and instructions that came with the device if you need help finding the port.)
4. Click the Select Device icon  on the toolbar to ensure that the device is listed in the Select Device window. Click the button next to the device in the window, then click OK.

If you are using a serial port other than COM1 (PC) or Default (Macintosh), you will need to set up HOBOware to use another port. To change the serial port:

1. From the File menu in Windows or the HOBOware menu in Macintosh, select Preferences.
2. Select Communications.
3. Select the serial port you want to use. Note that checking multiple serial ports can take some time, even when no devices are attached.
4. Click OK.

Connecting a Base Station/Coupler

To connect a logger to a base station/coupler:

1. Open HOBOware.
2. Plug the base station/coupler cable into a USB port on the computer. **Important:** Make sure the base/station coupler is the correct model for the logger you want to use. Consult the manual that came with the logger if you are not sure.
3. Attach the logger to the base station/coupler as described in the documentation that came with your logger.

Disconnecting a Device

To disconnect the device, simply unplug the USB or serial cable or unplug the device from the base station/coupler.

To attach another logger via a base station/coupler, remove the logger, leaving the base station/coupler connected and then connect the next logger.

Connecting Multiple Devices

If your computer has multiple USB and serial ports, you can connect multiple devices and work with one at a time. When multiple devices are connected, the Select Device window opens every time you select Launch, Readout, Stop, or Status from the Device menu. Click the button next to a device on the list to select it, then click OK. The selected action will then proceed. The status bar lists the number of devices connected.

To access the Select Device window at any time, click the Select Device icon on the toolbar, or choose Select Device from the Device menu.

Click the Blink Device Light button in the Select Device window to verify that you have selected the appropriate device. This briefly illuminates the light on the devices that you have selected. If the device does not have a light, or if the light is not visible when the devices is in the base station/coupler, simply check the serial number (S/N) on your devices to make sure that it matches the one that is selected in this window.

Notes:

- If serial devices are selected in Preferences, it may take some time for HOBOware to scan all the serial ports. You can select the device you want as soon as it is displayed. You do not have to wait for all of the ports to be scanned.
- Serial devices that you have added or removed are not reflected in the device count until you click the Select Device icon on the toolbar to update the device list.
- If you work with multiple U-Series devices frequently and are using HOBOware Pro, you can set the Default Action in the Device menu to Launch and enable Launch Time-Saving Options to work more efficiently.

Launching Devices

To set up a logger to record data, you must specify several parameters and launch, or start, the logger.

Tip: Check that the time on the computer is correct before configuring a launch. If it is not correct, close HOBOware, update your computer's clock manually or synchronize it with an online time server (if available) and then reopen HOBOware.

To launch a logger:

1. Connect the logger to the computer.
2. Click the Launch icon on the toolbar, or select Launch from the Device menu.
3. Different messages may appear depending on the state of the logger. Answer each of the prompts accordingly. A warning appears if the logger has already been launched. Click Yes to continue or click No to cancel.
4. Select the options for the launch in the Launch Logger window.
5. Click the Start button when you are finished choosing the launch settings. Note that the text on the Start button varies depending on when you chose logging to begin. HOBOware displays the progress of the launch and warns you not to unplug the logger while it is being configured.

Once the logger begins logging, it will continue logging until the memory is full (if the logger is configured to stop logging when the memory fills), it is stopped, or the battery runs out. **Note:** Any data stored in the logger from a previous launch will be erased once the logger is relaunched.

Launch Logger Window

Use the Launch Logger window to set up your logger to record data. The Launch Logger window is divided into the following three panes:

- **Logger Information.** The model of the logger currently selected appears at the top of this pane, which also includes the serial number, deployment number, and current battery level.

  Use the Name field to type up to a 40-character name for the logger deployment. The name you enter here will be used as the default file name when you read out the logger and save the data. It will also be the default title on the plot. For new loggers, the name defaults to the logger serial number.

  Click the Status button in this pane to see the current status of the logger and the settings used on the previous launch.

  A User Notes button may also appear for some loggers. Click it to enter more extensive notes about the deployment.

- **Sensors.** This pane displays a list of the sensors available for the logger. Choose the sensors, or channels, that you wish to log in this deployment, select any external sensors you may be using, and type labels for sensors as desired. Note that labels may not be applied to some calculated or derived channels, such as filtered series. This pane also displays any utilities available for your logger, such as Alarms, Scaling, and Filters. For the HOBO Plug Load logger (UX120-018) logger, you also have the option of configuring statistics for each channel in this pane.

- **Deployment.** Use this pane to select the logging interval (the rate at which you want the logger to record data) and to choose when the logger should begin recording data. Loggers can be configured to start logging immediately or on a specific date/time. Some loggers also can be configured to start at an interval or start with push button/coupler start. The coupler start (also known as a triggered start) involves removing the logger from its coupler or base station and then taking it to the deployment location. When you are ready for logging to begin, insert the logger in the coupler without the base station for three seconds. Refer to the logger manual for details.

This pane also displays the logging duration, which is the approximate time it will take to fill the logger memory based on the logging interval, sensors, and other settings currently selected. For some loggers, you can also set a sampling interval, choose when to stop logging, and select other options in this pane.

When you are done choosing the launch settings, click the button in the lower right-hand corner of the window to send the settings to the logger. Note that the button text changes based on when you chose to start logging.

HOBOware Pro Tip: If you will be using the same launch settings for multiple deployments of the same logger type, select the Skip Launch Window Next Time checkbox to bypass this window the next time you launch a device. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in Launch Time-Saving Options subcategory of the General preferences.

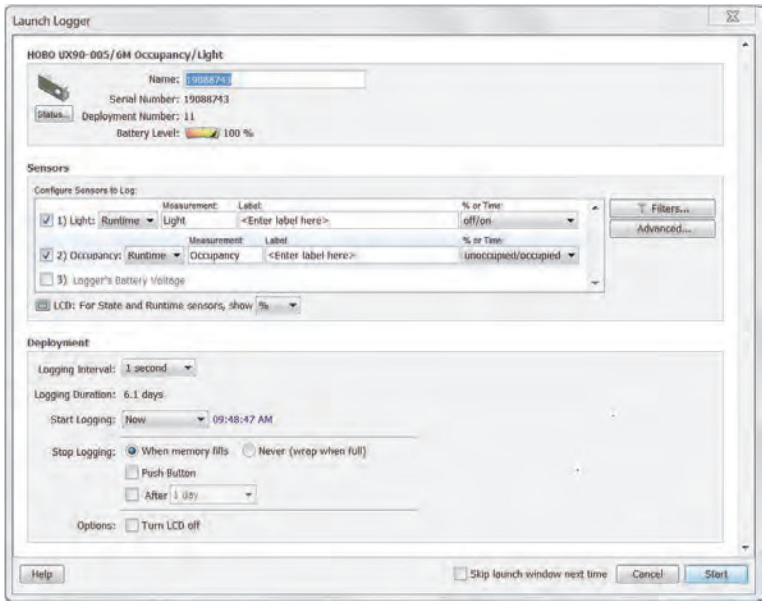
The options available in the Logger Launch window vary depending on the type of logger you are using. For more details about launching your particular device, refer to the following topics:

- Launch Options for HOBO UX90 Series Loggers
- Launch Options for the HOBO UX100 Series Loggers and the HOBO 4-Channel Thermocouple Logger (UX120-014M)
- Launch Option for the HOBO 4-Channel Analog Logger (UX120-006M)
- Launch Options for the HOBO 4-Channel Pulse Input Logger (UX120-017x)
- Launch Options for the HOBO Plug Load Logger (UX120-018)
- Launch Options for the HOBO MX CO_2 Logger (MX1102)
- Launch Options for Other U-Series Loggers

- Launch Options for the HOBO U30 and Other Station Loggers

Launch Options for HOBO UX90 Series Loggers

The following launch options are available for HOBO UX90 series data loggers. Note that the Launch Logger window may vary from the example shown below.



Logger Information

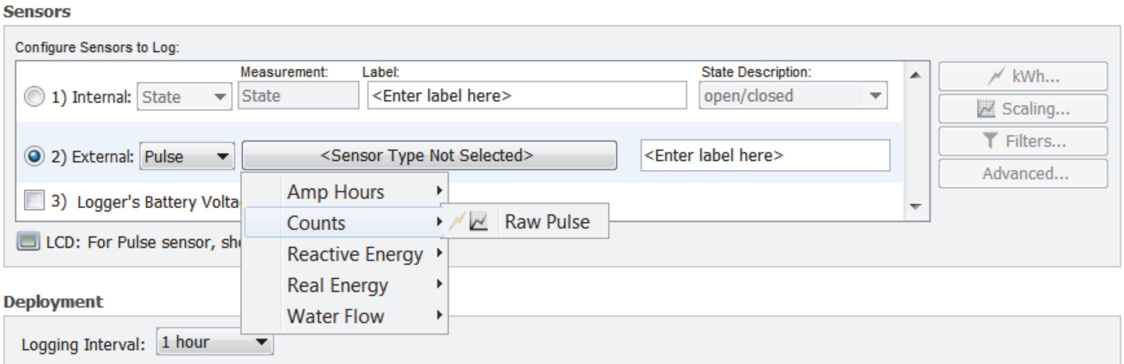
- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger. Note that some external sensors or devices also have serial numbers, which are not listed here.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level.** This shows the current battery level in the logger.
- **Status.** Click the Status button to check the logger settings from the previous launch.

Sensors

The Sensors List displays all internal and external sensors available for recording data. Choose the sensors, or channels, that you wish to log in this deployment. To configure a sensor:

1. Select the sensor(s) you wish to log.
2. Choose the measurement to log (e.g. State, Runtime, etc.) from the drop-down list.
3. Type a label for the sensor, if desired.
4. Complete additional details for the sensor. This will vary depending on what the logger will be measuring. For most sensors, type a name and select a description pair from the drop-down list. For external Pulse channels, click the button for the corresponding channel in the sensor list to select the sensor type as shown below. If you select Raw Pulse for the sensor type, you can use Data Assistants to set up kWh (HOBOware Pro only) and pulse scaling information as necessary, which will also display

on the logger LCD screen. Note that sensors that support Data Assistants at launch time display the kWh and/or scaling icon next to their name.



5. Repeat steps 1 through 4 if your logger supports multiple sensors.
6. Set the units that display on the logger's LCD screen. When the sensor is configured to log State or Runtime, choose either:
   - "Time" to show the total amount of time the switch has been closed or on since logging began, ranging from seconds to days; or
   - "%" to show the percentage of time the switch has been closed or on since logging began.

When the sensor is configured to log Pulse or Event, the LCD will display the units in three characters. Accept either the default units or type your own three-character units.

Notes on configuring sensors:

- Click the Filters button to create additional filtered series for any of the channels you configured. The filtered series will then be automatically calculated when you read out the logger and plot the data.
- Click the Advanced button to access the following settings specific to the logger: Pulse Frequency and Lockout Time, Occupancy, and Calibration.
- When setting up a pulse sensor, consider setting up the launch for a delayed or push button start and then connect the sensors/devices later before logging begins. **Important:** Sensors that are connected after logging begins may not log accurate data.
- The Occupancy/Light logger (UX90-005x/-006x) also automatically generates additional series upon reading out the logger to give you combined statistics, such as how long the lights were left on while the room was unoccupied. These series will be available in the Plot Setup dialog when opening the datafile.
- You have the option to record the logger's battery voltage at each sample time; this is the last channel in the sensors list. Like the other data channels, logging the internal battery channel consumes some of the logger's memory. Unless you suspect abnormal battery performance, you do not need to log the battery voltage. You can also hide the battery channel with Series preferences (in Preferences, select Display, then Series).
- Note that labels do not apply to calculated or derived channels, such as filtered series.

Deployment

- **Logging Interval.** Select how often the logger will record data (only available for sensors configured to log Pulse or Runtime). You can choose either one of the preset logging intervals or specify a custom logging interval. The minimum logging interval is one second and the maximum for most loggers is 18 hours, 12 minutes, and 15 seconds. The shorter the logging interval, the more quickly memory fills and battery power is consumed. See also Multiple Logging Intervals and Fast Logging Intervals.

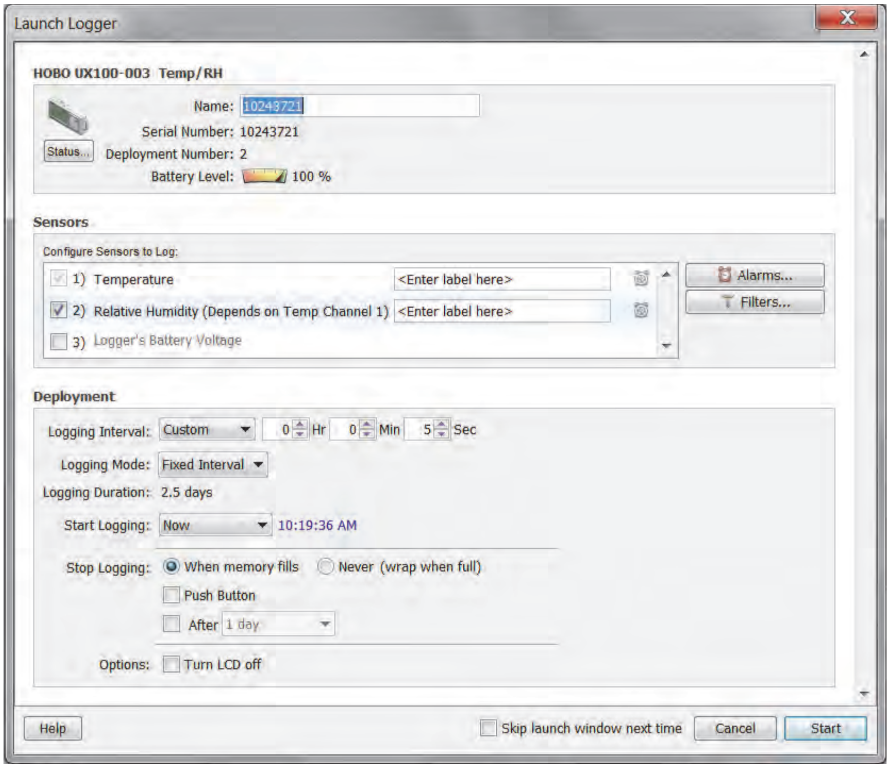
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval and sensors currently selected. This is a theoretical estimate only; battery life and frequent state and event logging will affect your deployment. This estimate is only available when the sensors are configured to log Pulse or Runtime. For estimates with State and Event logging, refer to the logger documentation, also available at http://www.onsetcomp.com/support/manuals.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch this logger:
  - Now. Logging begins as soon as you click the **Start** button in the Launch Logger window.
  - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose. This option is only available when the sensors are configured to log Pulse or Runtime.
  - Push Button. Logging will not start until you press the Start/Stop button on the logger and hold it down for at least three seconds. The LCD screen on the logger will display "Start" until you press the button.
  - On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present. The LCD screen will count down to that start date/time and then logging will begin.
- **Stop logging.** Select when you want the logger to stop logging. You can choose:
  - When memory fills or Never (wrap when full). If you select "When memory fills," then the logger will stop recording data once the memory is full. If you select "Never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data. When wrapping, the memory segment on the logger LCD screen will blink.
  - Push button. When this option is selected, the logger will stop recording data when you press the Start/Stop button on the logger itself for 3 seconds. The LCD screen on the logger will display "Stop" when this option has been selected.
  - Specific stop date. Select the date you want the logger to stop recording data. Choose either a preset time or set your own custom date and time.
- **Options.** Select "Turn LCD off" if you want the logger to operate in "stealth mode" with the LCD screen turned off. You can override this temporarily by pressing the Start/Stop button on the logger. The LCD will then remain illuminated for 10 minutes.

Skip launch window next time (HOBOware Pro)

Check this box if you would like to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in Launch Time-Saving Options subcategory of the General preferences.

Launch Options for HOBO UX100 Series Loggers and the HOBO 4-Channel Thermocouple Logger (UX120-014M)

The following launch options are available for HOBO UX100 series data loggers and the HOBO 4-Channel Thermocouple Logger (UX120-014M). Note that the Launch Logger window may vary from the example shown below.



Logger Information

- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger. Note that some external sensors or devices also have serial numbers, which are not listed here.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level.** This shows the current battery level in the logger.
- **Status.** Click the Status button to check the logger settings from the previous launch.

Sensors

The Sensors List displays all sensors available for recording data. Choose the sensors, or channels, that you wish to log in this deployment. If connecting a thermocouple, select the appropriate type from the drop-down list. Type a label for the sensor, if desired.

Notes:

- Click the Alarms button to set an alarm for this logger. Note that the Logging Mode must be set to Normal or Statistics to configure an alarm. For thermocouple loggers (UX100-014M and UX120-014M models), alarms can only be configured on thermocouple channels; they are not available on the internal 10K thermistor (temperature) channel.

- Click the Filters button to create additional filtered series for any of the channels you configured. The filtered series will then be automatically calculated when you read out the logger and plot the data.
- You have the option to record the logger's battery voltage at each sample time; this is the last channel in the sensors list. Like the other data channels, logging the internal battery channel consumes some of the logger's memory. Unless you suspect abnormal battery performance, you do not need to log the battery voltage. You can also hide the battery channel with Series preferences (in Preferences, select Display, then Series).
- Note that labels do not apply to all calculated or derived channels, such as filtered series channels.

Deployment

- **Logging Interval.** Select how often the logger will record data. You can choose either one of the preset logging intervals or specify a custom logging interval. The minimum logging interval is one second and the maximum for most loggers is 18 hours, 12 minutes, and 15 seconds. The shorter the logging interval, the more quickly memory fills and battery power is consumed.
- **Logging Mode.** Select the type of logging mode you wish to use: Fixed Interval, Burst Logging, or Statistics. With Burst Logging mode, you can configure the logger to use a different logging interval when specific conditions are met. With Statistics mode, you can configure the logger to calculate maximum, minimum, average, and standard deviation for all enabled sensors (except battery voltage) during logging at a sampling interval you specify. Keep in mind that the more statistics you record, the shorter the logger duration and the more memory is required. Once you launch the logger, the selected statistics will be displayed on the logger LCD. After you set up Burst or Statistics logging, there will be an Edit button next to Logging Mode in the Launch Logger window to make additional changes as necessary. Note that Fixed Interval or Statistics mode is required if you want to set up alarms for the logger. On thermocouple loggers, burst logging and statistics are only available on thermocouple channels and not on the internal temperature channel.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval, logging mode, and sensors currently selected. This is a theoretical estimate only; battery life and other factors will also affect the deployment.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch this logger:
  - Now. Logging begins as soon as you click the Start button in the Launch Logger window.
  - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.
  - On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present. The LCD screen will count down to that start date/time and then logging will begin.
  - Push Button. Logging will not start until you press the Start/Stop button on the logger and hold it down for at least three seconds. The LCD screen on the logger will display "Start" until you press the button.
- **Stop Logging.** Select when you want the logger to stop logging. You can choose:
  - When memory fills or Never (wrap when full). If you select "When memory fills," then the logger will stop recording data once the memory is full. If you select "Never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data. When "Never (wrap when full)" is

selected, a wrap indicator icon will display on the logger LCD screen. **Note:** You cannot select "Never (wrap when full)" on UX100 series loggers if Burst is selected for the Logging Mode.

  - Push button. When this option is selected, the logger will stop recording data when you press the Start/Stop button on the logger for three seconds. The LCD screen on the logger will display "Stop" when this option has been selected.
  - Allow button restart. This setting is available when "Push button" is selected as a "Stop Logging" option. If you select this option, you can resume logging on the next even logging interval on a stopped logger by pressing the Start/Stop button for three seconds. For example, press the Start/Stop logging button on the logger once to stop logging. Then, a few minutes, hours, or even days later when you are ready to continue logging, press the Start/Stop button on the logger again and logging will resume at the next even logging interval (i.e. if the logging interval is set at 1 hour and you press the button at 10:15 AM, logging will not resume until 11:00 AM, which is the next even interval based on the 1-hour logging interval). You can then continue to start and stop logging as often as you'd like during this same deployment. Any gaps between when you stopped and restarted logging during this deployment will be reflected on the plotted data when you read out the logger. Once you relaunch the logger, a new deployment and datafile will begin. The data from the previous deployment will not be carried over to the new one.
  - Specific stop date. Select the date you want the logger to stop recording data. Choose either a preset time or set your own custom date and time. **Note:** If you select a specific stop date and also have the logger configured to resume logging on the next button push, then the logger will stop logging at the date you select regardless of how many times you stop and restart the logger with the Start/Stop button.

- **Options.** Select "Turn LCD off" if you want the logger to operate in "stealth mode" with the LCD screen turned off. You can override this temporarily by pressing the Start/Stop button on the logger. The LCD will then remain illuminated for 10 minutes.

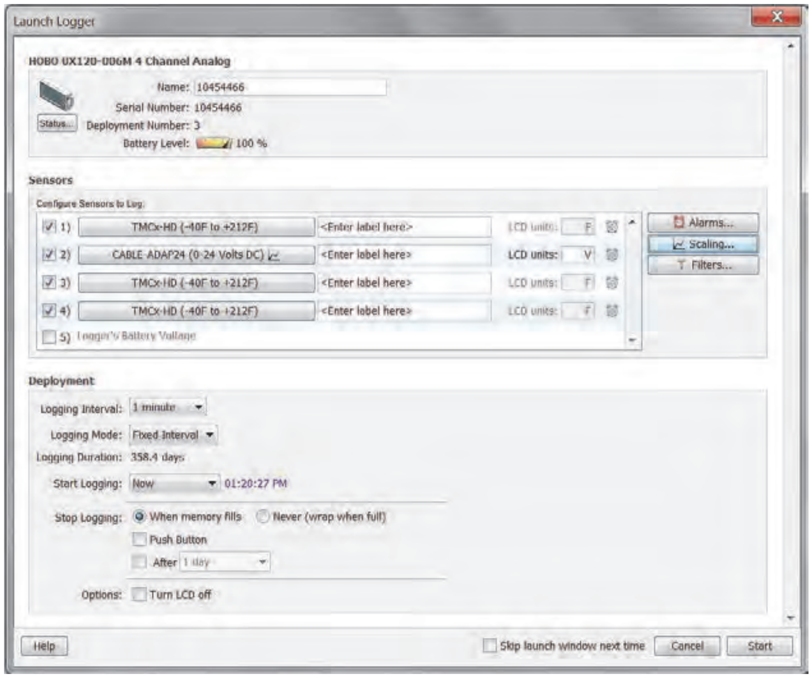
Skip launch window next time (HOBOware Pro)

Check this box to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Important: After you choose the launch settings in this window and click Start, the settings are then loaded into the logger. The LCD screen on the logger will display "LOAD" during this process. If you disconnect the logger from the USB cable before this process is finished, "Err" will appear on the LCD screen instead. If you see "Err" at any point during launch configuration, check the USB connection between the computer and the logger, reopen the Launch Logger window and click Start again.

Launch Options for the HOBO 4-Channel Analog Logger (UX120-006M)

The following launch options are available for the HOBO 4-Channel Analog logger (UX120-006M). Note that the Launch Logger window may vary from the example shown below.



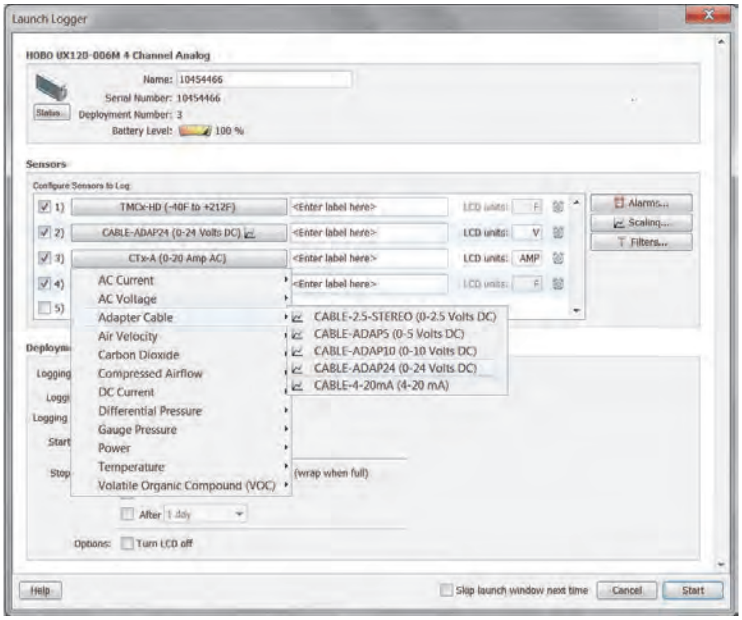
Logger Information

- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger. Note that some external sensors or devices also have serial numbers, which are not listed here.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level.** This shows the current battery level in the logger.
- **Status.** Click the Status button to check the logger settings from the previous launch.

Sensors

The Sensors list displays all internal sensors and external channels available for recording data. Choose the sensors, or channels, that you wish to log in this deployment. To configure a sensor:

1. Select the checkbox next to the channel number to enable the sensor.
2. Select the type of sensor or cable that will be connected to that channel on the logger as shown in the following example.



3. Type a label for the sensor, if desired.
4. Type a 3-character description for the units that the LCD will display for that sensor or use the default units.
5. Set up scaling for the sensor, if applicable. Click the Scaling button and enter the scaled values and units as recommended in the sensor documentation.
6. Repeat steps 1 through 5 for each sensor you wish to configure.

Notes on configuring sensors:

- Although it is helpful to see the connected sensors/devices when setting up the launch, it is not required that you physically connect them while selecting sensor type options. You may set up the launch for a delayed or push button start, then connect the sensors/devices later, before logging begins. Be sure to connect each sensor into the correct numbered jack based on you configured the corresponding channel. Important: Sensors that are connected after logging begins may not log accurate data.
- Click the Filters button to create additional filtered series for any of the channels you configured. The filtered series will then be automatically calculated when you read out the logger and plot the data.
- You have the option to record the logger's battery voltage at each sample time; this is the last channel in the sensors list. Like the other data channels, logging the internal battery channel consumes some of the logger's memory. Unless you suspect abnormal battery performance, you do not need to log the battery voltage. You can also disable the battery channel with Series preferences (in Preferences, select Display, then Series).Note that labels do not apply to calculated or derived channels, such as filtered series.
- Although it is possible to set up more than one scaling value for each sensor, only the first scaling value for that sensor will be used.

Deployment

- **Logging Interval.** Select how often the logger will record data. You can choose either one of the preset logging intervals or specify a custom logging interval. The minimum logging interval is one second and the maximum for most loggers is 18 hours, 12 minutes, and 15 seconds. The shorter the logging interval, the more quickly memory fills and battery power is consumed. If you did not select any channels to log, this field will be disabled.

- **Logging Mode.** Select the type of logging mode you wish to use: Fixed Interval, Burst Logging, or Statistics. With Burst Logging mode, you can configure the logger to use a different logging interval when specific conditions are met. With Statistics mode, you can configure the logger to calculate maximum, minimum, average, and standard deviation for all enabled sensors (except battery voltage) during logging at a sampling interval you specify. Keep in mind that the more statistics you record, the shorter the logger duration and the more memory is required. Once you launch the logger, the selected statistics will be displayed on the logger LCD. After you set up Burst or Statistics logging, there will be an Edit button next to Logging Mode in the Launch Logger window to make additional changes as necessary. Note that Fixed Interval or Statistics mode is required if you want to set up alarms for the logger.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval and sensors currently selected. This is a theoretical estimate only; battery life and other factors will affect your deployment.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch this logger:
  - Now. Logging begins as soon as you click the Start button.
  - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.
  - Push Button. Logging will not start until you press the button on the logger and hold it down for at least three seconds. The Waiting LED will blink on the logger until you press the Start/Stop button.
  - On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present. The LCD screen will count down to that start date/time and then logging will begin.
- **Stop logging.** Select when you want the logger to stop logging. You can choose:
  - When memory fills or Never (wrap when full). If you select "When memory fills," then the logger will stop recording data once the memory is full. If you select "Never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data.
  - Push button. When this option is selected, the logger will stop recording data when you press the Start/Stop button on the logger itself for 3 seconds. If you also configured a Push Button start, then you must wait 5 minutes after logging begins before you can use the button to stop logging.
  - Allow button restart. This setting is available when "Push button" is selected as a "Stop Logging" option. If you select this option, you can resume logging on the next even logging interval on a stopped logger by pressing the Start/Stop button for three seconds. For example, press the Start/Stop logging button on the logger once to stop logging. Then, a few minutes, hours, or even days later when you are ready to continue logging, press the Start/Stop button on the logger again and logging will resume at the next even logging interval (i.e. if the logging interval is set at 1 hour and you press the button at 10:15 AM, logging will not resume until 11:00 AM, which is the next even interval based on the 1-hour logging interval). You can then continue to start and stop logging as often as you'd like during this same deployment. Any gaps between when you stopped and restarted logging during this deployment will be reflected on the plotted data when you read out the logger. Once you relaunch the logger, a new deployment and datafile will begin. The data from the previous deployment will not be carried over to the new one.
  - Specific stop date. Select the date you want the logger to stop recording data. Choose either a preset time or set your own custom date and time.

- **Options.** Select "Turn LCD off" if you want the logger to operate in "stealth mode" with the LCD screen turned off. You can override this temporarily by pressing the Start/Stop button on the logger. The LCD will then remain illuminated for 10 minutes.

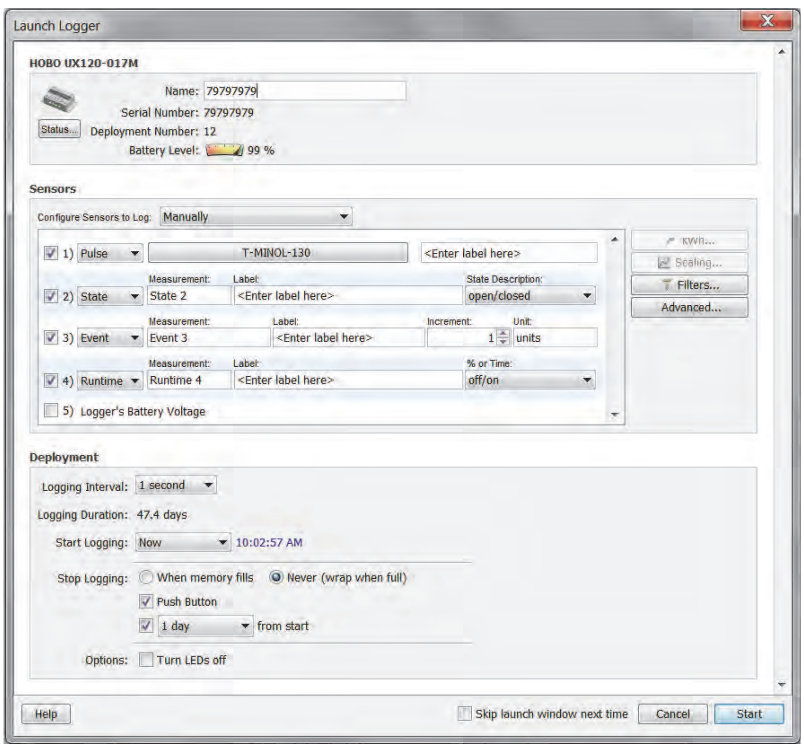
Skip launch window next time (HOBOware Pro)

Check this box if you would like to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Important: After you choose the launch settings in this window and click Start, the settings are then loaded into the logger. The LCD screen on the logger will display "LOAD" during this process. If you disconnect the logger from the USB cable before this process is finished, "Err" will appear on the LCD screen instead. If you see "Err" at any point during launch configuration, check the USB connection between the computer and the logger, reopen the Launch Logger window and click Start again.

Launch Options for the HOBO 4-Channel Pulse Input Logger (UX120-017x)

The following launch options are available for the HOBO 4-Channel Pulse Input Data Logger (UX120-017x). Note that the Launch Logger window may vary from the example shown below.



Logger Information

- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger. Note that some external sensors or devices also have serial numbers, which are not listed here.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.

- **Battery Level.** This shows the current battery level in the logger.
- **Status.** Click the Status button to check the logger settings from the previous launch.

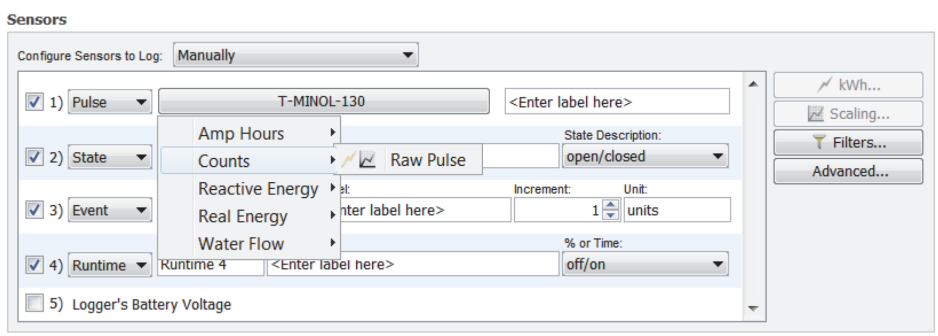
Sensors

The Sensors List displays all internal sensors and external channels available for recording data. Choose the sensors, or channels, that you wish to log in this deployment. To configure a channel:

1. If you are using the logger with an E50B2 Power & Energy Meter, then select "for E50B2 Power & Energy Meter" in the Configure Sensors drop-down list at the top of the Sensors pane. This will automatically preselect the appropriate channels and pulse scaling factors, which you can then customize further in the following steps.

   For all other sensors/devices, select "Manually" in the Configure Sensors drop-down list.

2. Make sure the checkbox is enabled for the external channel you wish to log.
3. Choose either Pulse, State, Event, or Runtime from the drop-down list.
4. For Pulse channels, click the button for the corresponding channel in the sensor list to select the sensor type as shown below. If you select Raw Pulse for the sensor type, you can use Data Assistants to set up kWh (HOBOware Pro only) and pulse scaling information as necessary. You can also adjust maximum pulse frequency and lockout time by clicking the Advanced button. Note that sensors that support Data Assistants at launch time display the Scaling and/or kWh icon next to their name.



   For State and Runtime channels, type a name and select a description.

   For Event channels, type a name, adjust the increment, and type a unit description (or accept the default "units" for the description).

5. Type a label for the sensor, if desired.
6. Repeat steps 1 through 5 for each channel you wish to configure.

Notes on configuring sensors:

- Although it is helpful to see the connected sensors/devices when setting up the launch, it is not required that you physically connect them while selecting sensor type options. You may set up the launch for a delayed or push button start, then connect the sensors/devices later, before logging begins. **Important:** Sensors that are connected after logging begins may not log accurate data.
- Click the Filters button to create additional filtered series for any of the channels you configured. The filtered series will then be automatically calculated when you read out the logger and plot the data.
- You have the option to record the logger's battery voltage at each sample time; this is the last channel in the sensors list. Like the other data channels, logging the internal battery channel consumes some of the logger's memory. Unless you suspect abnormal battery performance, you do not need to log

the battery voltage. You can also disable the battery channel with Series preferences (in Preferences, select Display, then Series).

- Note that labels do not apply to calculated or derived channels, such as filtered series.

Deployment

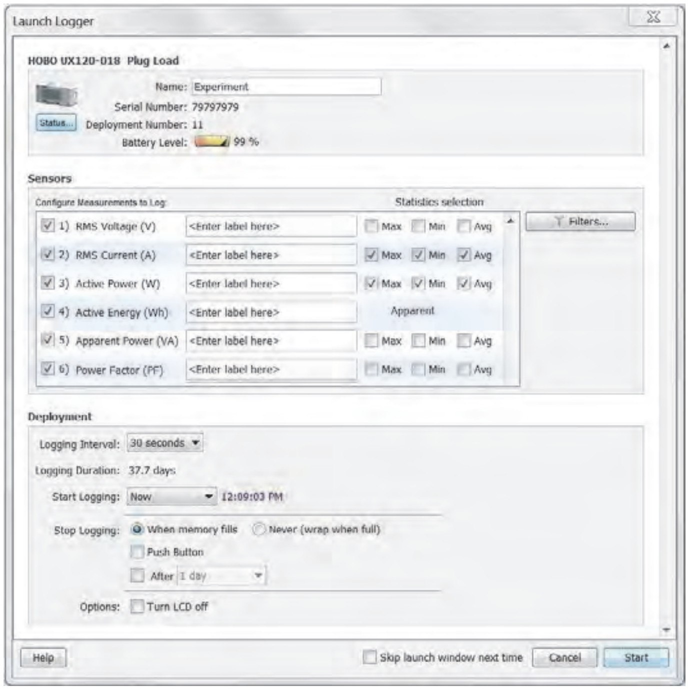
- **Logging Interval.** Select how often the logger will record data. You can choose either one of the preset logging intervals or specify a custom logging interval. The minimum logging interval is one second and the maximum for most loggers is 18 hours, 12 minutes, and 15 seconds. The shorter the logging interval, the more quickly memory fills and battery power is consumed. If you did not select any channels to log, this field will be disabled.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval and sensors currently selected. This is a theoretical estimate only; battery life and frequent state and event logging will affect your deployment. If you are logging only state changes and events, no estimation is possible.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch this logger:
    - Now. Logging begins as soon as you click the **Start** button.
    - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.
    - Push Button. Logging will not start until you press the button on the logger and hold it down for at least three seconds. The Waiting LED will blink on the logger until you press the Start/Stop button.
    - On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present. The Waiting LED will blink on the logger until logging begins on the selected date/time.
- **Stop logging.** Select when you want the logger to stop logging. You can choose:
    - When memory fills or Never (wrap when full). If you select "When memory fills," then the logger will stop recording data once the memory is full. If you select "Never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data.
    - Push button. When this option is selected, the logger will stop recording data when you press the Start/Stop button on the logger itself for 3 seconds. If you also configured a Push Button start, then you must wait 5 minutes after logging begins before you can use the button to stop logging.
    - Specific stop date. Select the date you want the logger to stop recording data. Choose either a preset time or set your own custom date and time.
- **Options.** Select "Turn LEDs off" if you want the logger to operate in "stealth mode," which disables the Logging LED on the logger. The Waiting LED and the Test button/Activity lights will still remain operational when this option is selected.

Skip launch window next time (HOBOware Pro)

Check this box if you would like to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Launch Options for the HOBO Plug Load Logger (UX120-018)

The following launch options are available for the HOBO Plug Load logger (UX120-018). Note that the Launch Logger window may vary from the example shown below. This logger also has the ability to operate in meter mode without logging data. For details on that capability, refer to the logger manual.



Logger Information

- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level.** This shows the current battery level in the logger.
- **Status.** Click the Status button to check the logger settings from the previous launch. You can also check status on the logger LCD (see the logger manual for details).

Sensors

The Sensors list displays all measurements available to log with this logger. To configure measurements:

1. Select the checkbox next to each measurement you want to log. The available measurements to log are:
    - **RMS Voltage (V).** RMS is root mean square. True RMS is the real or effective value of AC voltage for a circuit.
    - **RMS Current (A).** True RMS is the real or effective value of current for a circuit.
    - **Active Power (W).** The capacity of the circuit for performing work in a particular time (also known as real power).
    - **Active Energy (Wh or kWh).** A watt-hour (Wh) is a unit of energy equivalent to one watt (1 W) of power expended for one hour (1 h) of time. kWh is a unit of energy equal to 1,000 watt-hours.
    - **Apparent Power (VA).** The product of the current and voltage of the circuit.

- **Power Factor (PF).** The ratio of the active or real power flowing to the load to the apparent power in the circuit. It is a dimensionless number between 0 and 1.

2. Type a label for each enabled measurement, if desired.
3. Select the Max, Min, or Avg checkboxes (if available) to log statistics for each enabled measurement. The logger will calculate maximum, minimum, and average values at each logging interval based on the logger's fixed single-cycle sampling rate of 60 Hz or 16.67 mS. For example, at a 1-minute logging interval, the statistics would be based on 3,600 samples (60 Hz x 60 seconds). This will result in up to three additional series per channel that record the following information at each logging interval:

   - The maximum, or highest, sampled value,
   - The minimum, or lowest, sampled value, and
   - An average of all sampled values.

   Statistics are not available for Active Energy (kWh).

Notes on configuring measurements:

- If statistics were configured, press the Next/Clear button on the logger for 1 second to cycle through the maximum and minimum values (as applicable) on the LCD screen. Average is not available for viewing on the LCD screen. Note that the maximum and minimum values displayed are not the values recorded at the logging interval. They are based on samples taken every 16.67 mS during the entire logging period. To reset the starting point used to determine the maximum and minimum values shown on the LCD screen, press and hold the Next/Clear button for 3 seconds. See the logger manual for more details.
- Statistics are not available in the HOBOware Status window. You can plot the statistics series once you read out the logger.
- Click the Filters button to create additional filtered series for any of the measurements you configured. The filtered series will then be automatically logged and available when you read out the logger and plot the data.
- You have the option to record the logger's battery voltage at each sample time. Logging the internal battery channel consumes some of the logger's memory. Unless you suspect abnormal battery performance, you do not need to log the battery voltage. You can enable or disable the battery channel with Series preferences (in Preferences, select Display, then Series).
- Note that labels do not apply to calculated or derived series, such as filtered series.

Deployment

- **Logging Interval.** Select how often the logger will record data. The shorter the logging interval, the more quickly memory fills and battery power is consumed. If you did not select any channels to log, this field will be disabled.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval and sensors currently selected. This is a theoretical estimate only; battery life and other factors will affect your deployment.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch this logger:
  - Now. Logging begins as soon as you click the Start button.
  - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.

- Push Button. Logging will not start until you press the button on the logger and hold it down for at least three seconds. The Waiting LED will blink on the logger until you press the Start/Stop button.
- On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present. The LCD screen will count down to that start date/time and then logging will begin.

- **Stop logging.** Select when you want the logger to stop logging. You can choose:
  - When memory fills or Never (wrap when full). If you select "When memory fills," then the logger will stop recording data once the memory is full. If you select "Never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data.
  - Push button. When this option is selected, the logger will stop recording data when you press the Start/Stop button on the logger itself for 3 seconds. If you also configured a Push Button start, then you must wait 5 minutes after logging begins before you can use the button to stop logging.
  - Allow button restart. This setting is available when "Push button" is selected as a "Stop Logging" option. If you select this option, you can resume logging on the next even logging interval on a stopped logger by pressing the Start/Stop button for three seconds. For example, press the Start/Stop logging button on the logger once to stop logging. Then, a few minutes, hours, or even days later when you are ready to continue logging, press the Start/Stop button on the logger again and logging will resume at the next even logging interval (i.e. if the logging interval is set at 1 hour and you press the button at 10:15 AM, logging will not resume until 11:00 AM, which is the next even interval based on the 1-hour logging interval). You can then continue to start and stop logging as often as you'd like during this same deployment. Any gaps between when you stopped and restarted logging during this deployment will be reflected on the plotted data when you read out the logger. Once you relaunch the logger, a new deployment and datafile will begin. The data from the previous deployment will not be carried over to the new one.
  - Specific stop date. Select the date you want the logger to stop recording data. Choose either a preset time or set your own custom date and time.
- **Options.** Select "Turn LCD off" if you want the logger to operate in "stealth mode" with the LCD screen turned off. You can override this temporarily by pressing the Start/Stop button on the logger. The LCD will then remain illuminated for 10 minutes.

Skip launch window next time (HOBOware Pro)

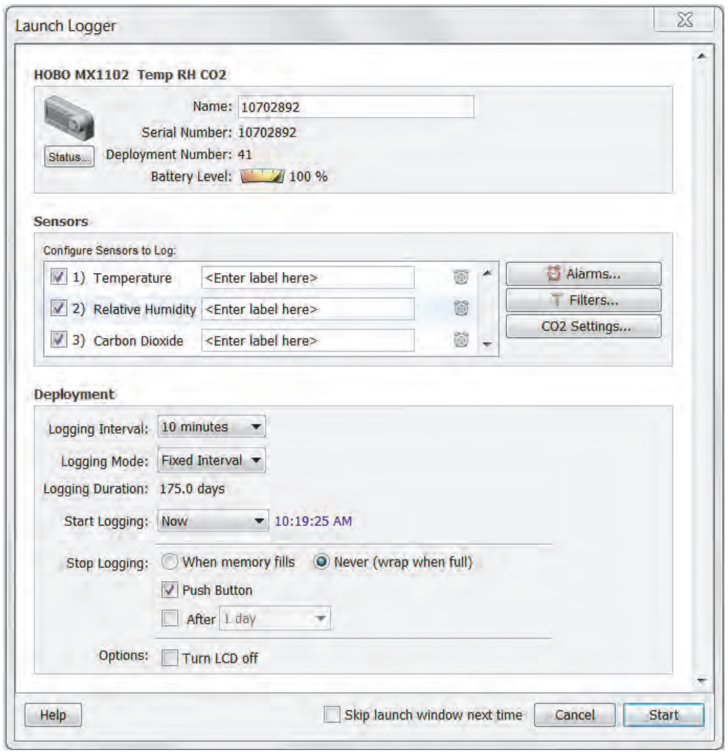
Check this box if you would like to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Important: After you choose the launch settings in this window and click Start, the settings are then loaded into the logger. The LCD screen on the logger will display "LOAD" during this process. If you disconnect the logger from the USB cable before this process is finished, "Err" will appear on the LCD screen instead. If you see "Err" at any point during launch configuration, check the USB connection between the computer and the logger, reopen the Launch Logger window and click Start again.

Launch Options for the HOBO MX CO_2 Logger (MX1102)

The following launch options are available for the HOBO Temp/RH/CO_2 logger (MX1102). Note that the Launch Logger window may vary from the example shown below. This logger can be used with both HOBOware and the HOBOmobile app. See the HOBOmobile User's Guide for details on that software.

Important note on battery life: Battery life for this logger is less than 6 months when logging CO_2 and selecting a logging interval or statistics sampling interval faster than 5 minutes. It is recommended that you select logging and sampling intervals of 5 minutes or greater when the CO_2 sensor is enabled to prolong battery life. If you select intervals faster than 5 minutes, you will need to replace the batteries more frequently. If you require faster longer intervals, you can also power the logger via USB cable. For specifications and complete logger details, refer to the product manual at www.onsetcomp.com/manual/mx1102.



Logger Information

- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level.** This shows the current battery level in the logger.
- **Status.** Click the Status button to check current settings.

Sensors

The Sensors list displays all sensors available for recording data. Choose the sensors, or channels, that you wish to log in this deployment and type a label if desired.

Notes:

- Click the Alarms button to set an alarm for this logger. Note that the Logging Mode must be set to Fixed Interval or Statistics to configure an alarm.
- Click the Filters button to create additional filtered series for any of the channels you configured. The filtered series will then be automatically calculated when you read out the logger and plot the data.
- Click the CO_2 Settings button to select calibration and altitude compensation settings for the carbon dioxide sensor. See Carbon Dioxide Sensor Settings for more details.
- Labels do not apply to all calculated or derived channels, such as filtered series channels.

Deployment

- **Logging Interval.** Select how often the logger will record data. You can choose one of the preset logging intervals or specify a custom logging interval. The minimum logging interval is one second and the maximum is 18 hours, 12 minutes, and 15 seconds. The shorter the logging interval, the more quickly memory fills and battery power is consumed. Note: Battery life for this logger is less than 6 months when logging CO_2 and selecting a logging interval faster than 5 minutes. It is recommended that you select a logging interval of 5 minutes or slower when the CO_2 sensor is enabled to prolong battery life.
- **Logging Mode.** Select the type of logging mode you wish to use: Fixed Interval, Burst, or Statistics. With Fixed Interval logging, the logger records data points for enabled sensors at each logging interval. With Burst logging mode, the logger can use a different logging interval when specific conditions are met. With Statistics mode, the logger can calculate maximum, minimum, average, and standard deviation for all enabled sensors during logging at a sampling interval you specify. Keep in mind that the more statistics you record, the shorter the logger duration and the more memory is required. It is recommended that you select a sampling interval of 5 minutes or slower when the CO_2 sensor is enabled to prolong battery life. Once you launch the logger, the selected statistics will be displayed on the logger LCD. After you set up Burst or Statistics logging, there will be an Edit button next to Logging Mode in the Launch Logger window to make additional changes as necessary. Note that Fixed Interval or Statistics mode is required if you want to set up alarms for the logger.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval, logging mode, and sensors currently selected. This is a theoretical estimate only; battery life and other factors will also affect the deployment.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch this logger:
  - **Now.** Logging begins 15 seconds after you click the Start button in the Launch Logger window.
  - **At Interval.** Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.
  - **On Date/Time.** Logging will begin at a date and time you specify, up to approximately six months from the present. The LCD screen will count down to that start date/time and then logging will begin.
  - **Push Button.** Logging will begin 15 seconds after you press the Start/Stop button on the logger for 3 seconds. The LCD screen on the logger will display "Start" until you press the button.
- **Stop Logging.** Select when you want the logger to stop logging. You can choose:
  - **When memory fills or Never (wrap when full).** If you select "When memory fills," then the logger will stop recording data once the memory is full. If you select "Never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data. When "Never (wrap when full)" is selected, a wrap indicator icon will display on the logger LCD screen.
  - **Push button.** When this option is selected, the logger will stop recording data when you press the Start/Stop button on the logger for three seconds. The LCD screen on the logger will display "Stop" when this option has been selected.
  - **After a specific stop date.** Select the date you want the logger to stop recording data. Choose either a preset time or set your own custom date and time.
- **Options.** Select "Turn LCD off" if you want the logger to operate in "stealth mode" with the LCD screen turned off. You can override this temporarily by pressing the Start/Stop button on the logger. The LCD will then remain illuminated for 10 minutes.

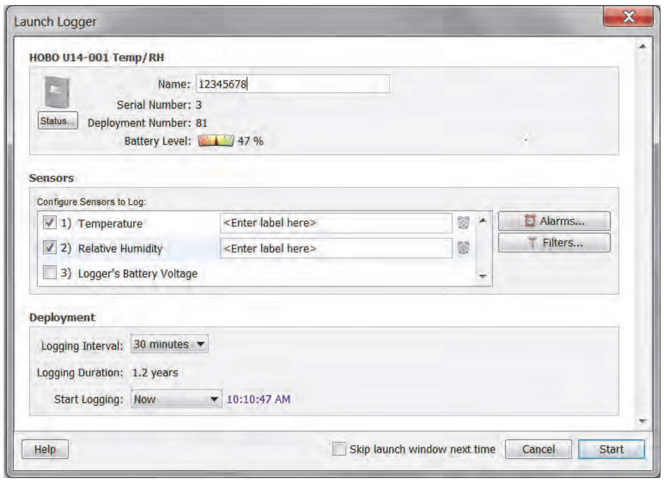
Skip launch window next time (HOBOware Pro)

Check this box to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Important: After you choose the launch settings in this window and click Start, the settings are then loaded into the logger. The LCD screen on the logger will display "LOAD" during this process. If you disconnect the logger from the USB cable before this process is finished, "Err" will appear on the LCD screen instead. If you see "Err" at any point during launch configuration, check the USB connection between the computer and the logger, reopen the Launch Logger window and click Start again.

Launch Options for Other U-Series Loggers

The following launch options are available for USB U-Series loggers other than the UX90, UX100, and UX120-017x. Note that the Launch Logger window may vary from the example shown below.



Logger Information

- **Description.** Enter a description for the launch, up to 40 characters, in this field. This description is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger. Note that some external sensors also have serial numbers, which are not listed here.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level or State.** This shows the current battery level in the logger or whether the battery state is good or bad (depending on the logger model).
- **Status.** Click the Status button to check the logger settings used in the previous launch.

Sensors

The Sensors List displays all internal sensors and external channels available for recording data. Choose the sensors, or channels, you wish to log in this deployment. To configure an external sensor:

1. Make sure the checkbox is enabled for the external channel you wish to configure.
2. Click the button for the corresponding channel in the sensor list to select the sensor type as shown below. If the external sensor has not been configured, the button reads <Sensor Type Not Selected>. Otherwise, the previous sensor type selected will be displayed on the button.

3. Select the measurement category and then the specific sensor part number and range (if applicable). Note that the sensor part number must match the part number listed on the shrink tube on the sensor cable to record accurate data.
4. Type a label for the sensor, if desired.
5. Repeat steps 1 through 4 for each additional external sensor you wish to configure.

Notes on configuring sensors:

- Although it is helpful to see the connected sensors when setting up the launch, it is not required that you connect the sensors during launch set-up. You may set up the launch for a delayed or push button start, then connect the sensors later, before logging begins. **Important:** Sensors that are connected after logging begins will not log any data. Alternatively, if you select an external channel, but do not plug the sensor in, false data will be recorded for that channel.
- Some loggers with RH or pressure sensors require that you also select the internal temperature sensor to log relative humidity or pressure. The dependency may be noted in the sensors list (see Relative Humidity channel in the example above). Refer to the manual that came with your logger for additional information.
- When both the internal temperature and RH sensors are selected, dew point will be calculated automatically.
- If external events or states are available for your logger, you can enter names to identify the event and state channels that are in use. You can also rename the Open and Closed descriptions for each state, and enter increments and units for each event channel.
- Data Assistants let you create new data series by combining data recorded by the logger with additional data. When you use a Data Assistant from the Launch Logger window, the parameter set is saved and applied to data every time you read out a logger or open the resultant data file. The derived data is also shown when you check the latest readings in the Status window. Click the Scaling button to access the Data Assistants window and choose the Linear Scaling or Pulse Scaling Assistant. Click the Create button to run the assistant. After you enter values, click Save. Sensors that support Data Assistants at launch time display the Scaling icon next to their name.
- Some loggers have alarm functionality. Click the Alarms button, if available, to set alarms as desired. Sensors that have alarm functionality display the Alarms icon next to their name.
- Click the Filters button to create an additional filtered series, such as average temperature per day, automatically when you read out the logger and plot the data.
- You have the option to record the logger's battery voltage at each sample time; this is the last channel in the sensors list. Like the other data channels, logging the internal battery channel consumes some of the logger's memory. Unless you suspect abnormal battery performance, you do not need to log the battery voltage. You can also disable the battery channel with Series preferences (in Preferences, select Display, then Series).
- Note that labels do not apply to calculated or derived channels, such as filtered series.

Deployment

- **Logging Interval.** Select how often the logger will record data. You can choose either one of the preset logging intervals or specify a custom logging interval. The shorter the logging interval, the more quickly memory fills and battery power is consumed. If you did not select any channels to log, this field will be disabled. See also Multiple Logging Intervals and Fast Logging Intervals.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval and sensors currently selected. This is a theoretical estimate only; battery life and

frequent state and event logging will affect your deployment. If you are logging only state changes and events, no estimation is possible.

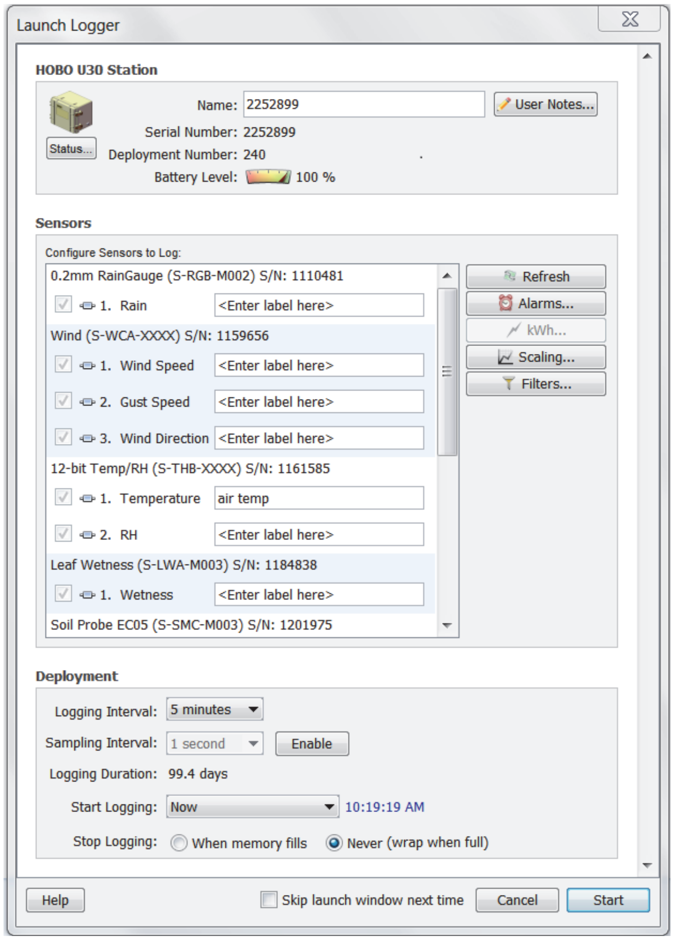
- **DO Sensor Cap Expires (HOBO U26 Dissolved Oxygen logger only).** If a DO sensor cap is installed on the U26 logger, the date the cap expires is listed. The logger will not collect any data after the cap expires. For more details on the DO sensor cap, see Working with the HOBO U26 Dissolved Oxygen Logger.
- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). For U-Series loggers, you can choose to launch the logger:
  - Now. Logging begins as soon as you click the **Start** button.
  - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.
  - Push Button/Using Coupler. (Available only on certain loggers.) Logging will not start until you press the button on the logger and hold it down for at least three seconds, or return the logger to the coupler without the base station for at least three seconds (refer to your logger manual for more information). If the logger has a light, it will flash quickly when logging begins.
  - On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present.

Skip launch window next time (HOBOware Pro)

Check this box if you would like to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Launch Options for the HOBO U30 and Other Station Loggers

The following launch options are available for Station loggers, which connect to the computer via serial cable instead of USB cable. Note that the Launch Logger window may vary from the example shown below.



Logger Information

- **Name.** Enter a name for the launch, up to 40 characters, in this field. This name is used as the default file name when you read out and save the data recorded by the logger. It is also the default title of the plot.
- **Serial Number.** This is the serial number for the logger. Note that some external sensors also have serial numbers, which are listed in the Sensors pane.
- **Deployment Number.** This is the number of times (including this time) the logger has been launched. Each time you start a new launch, the deployment number increases by one.
- **Battery Level.** This shows the current battery level in the logger.
- **User Notes.** Click this button to type up to 2000 characters of information about the deployment. This text will be displayed in the Details pane after you read out the logger and plot the data.
- **Status.** Click the Status button to check the logger settings from the previous launch.

Sensors

Only the sensors that are currently plugged in or built into the logger are listed. **Sensors are listed in ascending order by serial number, regardless of their physical position in the logger.** If you add or remove sensors, click the Refresh button to make sure your changes are seen by the logger and displayed in this list.

You can assign a name to each sensor (up to 30 characters). This is helpful if you want to specify a location where the sensor will be placed or if you need to differentiate multiple sensors of the same type.

Sensors must be connected prior to launching if you will be entering a name for the sensor or configuring FlexSmart modules or Analog Sensor Ports (use the Configure button to the right of the Label field). Otherwise, sensors do not have to be connected when setting up the launch. You may set up the launch for a delayed or push button start, then connect the sensors later before logging begins.

Notes about configuring sensor channels:

- Do not attach more than 15 channels of sensors. The logger cannot accommodate more than 15 channels.
- In addition to logging up to 15 channels, the HOBO Energy Logger and HOBO U30 Station can record their internal battery channel (other sensors must be attached; the logger cannot log battery alone). When enabled, the logger's battery voltage is recorded at each interval. The battery voltage is logged by default for the U30-GSM, U30-WIF, and U30-ETH and is an option for other logger models.
- Always enable the logger's internal battery channel when logging with excitation power. This will help you determine whether and when excitation power was turned off during a deployment.
- HOBOware Pro Data Assistants let you create new data series by combining data recorded by the logger with additional data. When you use a Data Assistant from the Launch Logger window, the parameter set is saved and applied to data every time you read out a logger or open the resultant data file. The derived data is also shown when you check the latest readings in the Status window. You can use the following Data Assistants from the Launch window (others can only be used from the Plot Setup window): Pulse Scaling, Linear Scaling, and kWh (HOBOware Pro only). This feature is available for the HOBO U30, the HOBO H21 (Weather Station and Micro Station) and the HOBO H22 (Energy Logger) loggers. Click the kWh or Scaling button to access the Data Assistants window. Select the desired assistant and click the Create button to run the selected assistant. After you enter values, click Save. Sensors that support Data Assistants at launch time display the Scaling and/or kWh icon next to their name.
- Click the Filters button to create an additional filtered series, such as average temperature per day, automatically when you read out the logger and plot the data.
- Note that labels do not apply to calculated or derived channels, such as filtered series.

Deployment

- **Logging Interval.** Select how often the logger will record data. You can choose either one of the preset logging intervals or specify a custom logging interval. The minimum logging interval is one second and the maximum for most loggers is 18 hours, 12 minutes, and 15 seconds. The shorter the logging interval, the more quickly memory fills and battery power is consumed. Some sensors (specifically, the FlexSmart TRMS modules) require a logging interval of two seconds or greater. If you choose a faster logging interval, erroneous data will be logged on these channels.
- **Sampling Interval.** The sampling interval allows you to take multiple measurements within the logging interval, then average them together to create a single logged measurement. The sampling interval is optional and is valid only for sensors that support measurement averaging. Refer to the sensor's user manual to determine whether measurement averaging is available on the sensor. If you have at least one sensor that supports measurement averaging, click the Enable button, then set the sampling interval at less than or equal to the logging interval (up to four minutes). Rapid sampling (faster than one minute) will reduce the logger's battery life. If you do not have any sensors with measurement averaging or wish to turn off the sampling interval, click the Disable button.
- **Logging Duration.** This lists the approximate time it will take to fill the logger memory based on the logging interval and sensors currently selected. This is a theoretical estimate only; battery life and frequent state and event logging will affect your deployment. If you are logging only state changes

and events, no estimation is possible. If you add or remove sensors while viewing the Launch window, click the Refresh button to get an updated Logging Duration.

- **Start Logging.** Select when to launch the logger. This defaults to the setting for the logger's previous launch (you can change this in HOBOware Pro with the Launch Time-Saving Options subcategory of the General preferences). You can choose to launch the logger:
  - Now. Logging begins as soon as you click the **Start** button. If you do not have at least one sensor attached, the logger will not launch.
  - At Interval. Logging will begin at an exact interval (for example 9:00:00 rather than 8:47:00 when you choose a one-hour logging interval). The exact start time depends on the logging interval you choose.
  - Push Button. Logging will not start until you press the button on the logger and hold it down for at least three seconds. If the logger has a light, it will flash quickly when logging begins. This is not available for the U30 Station.
  - On Date/Time. Logging will begin at a date and time you specify, up to approximately six months from the present.
  - Save Settings in Logger. Logging will not start, but the launch settings will be saved so that you do not have to re-enter them when you are ready to launch at a later time. The next time you view the Launch window for this logger, the settings you entered will still be in place.
- **Stop Logging.** There are two options for stopping the logger: either "when memory fills" or "never (wrap when full)." If you select "when memory fills," then the logger will stop recording data once the memory is full. If you select "never (wrap when full)," the logger will record data continuously until either the logger battery runs out or you stop it. Once the logger is full, the newest data will overwrite the oldest data.

Skip launch window next time (HOBOware Pro)

Check this box if you would like to bypass the Launch Window the next time you choose Launch from the Device menu or click the Launch icon. This will cause the next logger to be launched with either the previous launch settings or the current logger settings as set in the Launch Time-Saving Options subcategory of the General preferences.

Note: For additional details on launching the HOBO U30 Station, see Working with the HOBO U30 Station.

Multiple Logging Intervals

Some loggers can be configured with multiple logging intervals, which allow you to define separate intervals for different phases of the deployment.

To configure multiple logging intervals:

1. From the Device menu, select Launch.
2. In the Launch Logger window, click the Add New Interval button for each interval you wish to add (the maximum number of intervals allowed varies by logger model). If there is no Add New Interval button, then the logger does not support multiple logging intervals.
3. Set the hours, minutes, and seconds for each interval, and the number of samples you want the logger to record at each interval.
4. Use the Start and End times in the Duration column to decide how many samples to record at each interval. **Note:** Because internal logger events, such as coupler events, do take up some of the logger's memory, the number of samples and end times are only estimates. Frequent events will cause the logger to fill up sooner.

5. Set any other launch options and click Start.

To delete an interval, click the Remove button next to the interval in the Launch Logger window.

Fast Logging Intervals

Some loggers can be configured with fast logging intervals, which allow you to log more than once per second, up to 100 measurements per second (hertz).

To use fast logging intervals:

1. From the Device menu, select Launch.
2. In the Launch Logger window, click the Fast button. If there is no Fast button, then the logger does not support fast logging intervals.
3. Choose a logging frequency from the Hertz drop-down list or enter the logging interval in decimal form in the Sec field.
4. Set any other launch options and click Start.

Notes:

- A logger cannot communicate with a computer or shuttle while it is logging at a fast interval. The logger will stop logging if you connect the logger to a computer, base station, or shuttle while it is logging in fast interval mode.
- Be aware that a fast logging interval typically means a very short logging duration. Make sure the logger will run long enough to collect the data you need. Disabling unnecessary channels can extend the logging duration and help to compensate for decreased duration while operating in fast interval mode.
- Because fast logging deployments are so brief, the logger must be launched with a coupler or button start. Follow the instructions that came with your logger for a trigger (coupler or button) start. If the logger has a light, it will flash quickly when logging begins.

Setting a Default Action on Multiple U-Series Devices

By default, HOBOware does not take any action when you connect a device. You can change this behavior by setting a default action to Launch, Readout, or Get Status. This can save you time when working with multiple loggers of the same type. **Note:** This feature is only available with HOBOware Pro and U-Series loggers.

To set a default action:

1. From the Device menu, select Default Action.
2. Select Launch, Readout, or Get Status.

If you set the default action to launch, you can also change the preferences to automatically populate the Launch Logger window with the same settings as the previous launch. This is helpful if you are launching numerous loggers of the same type with the same settings. To set this preference:

1. Select Preferences from the File menu in Windows or the HOBOware menu in Macintosh.
2. Select General and then select Launch Time-Saving Options.
3. For the "Fill launch window with contents of" setting, select Previous Launch.
4. Click OK.

When a device is connected, the default action you set will take place automatically. For example, if you chose Readout, HOBOware Pro will read out the logger immediately. You can then disconnect that logger, connect another logger, and the next logger will be read out automatically. If you connect a shuttle, the shuttle's new files will be offloaded automatically. Similarly, if you chose Launch for the Default Action, the Launch Logger window will open automatically when you connect the logger. The next time you connect a logger of the same time, the Launch Logger window will open automatically and be populated with the previous launch settings if you configured the Launch Time-Saving Options in the Preferences. A note will appear in the Launch Logger window when this preference is in use.

Important Note for Windows: The first time you connect a device, the Default Action may not be triggered. After the device has been connected to the computer and disconnected at least once, the Default Action should then be triggered.

Using Launch Utilities

There are several utilities available from the Launch Logger window for setting up customized data series, configuring alarms, and setting advanced logger options. These utilities vary depending on the type of logger you are using. They include:

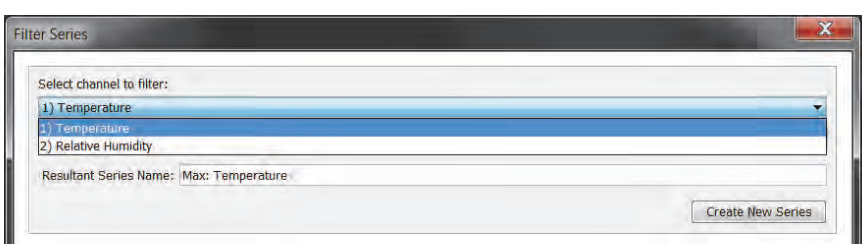
- Scaling
- Filters
- Alarms
- Advanced Sensor Properties: Pulse Frequency and Lockout Time
- Advanced Sensor Properties: Calibration
- Advanced Sensor Properties: Occupancy
- Statistics: Maximum, Minimum, Average, and Standard Deviation
- Filtered Series vs Statistics Logging
- Burst Logging

Filter Series at Launch

As part of the launch setup, you can create a filtered series that automatically calculates additional values, such as maximum, minimum, average, or total, for a set interval upon readout of the logger. The filtered series is saved as an additional series in the datafile so it is always available when plotting your data. This saves you the time of manually filtering data for each series after readout using the regular HOBOware filter tool, although this tool is still available should you need to further filter data later.

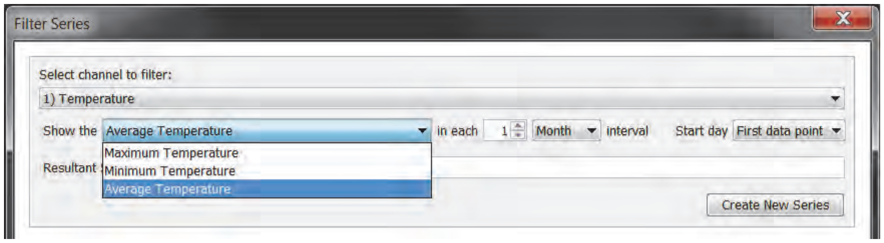
To set up a filtered series at launch:

1. Select the channel, or sensor type, you wish to filter.

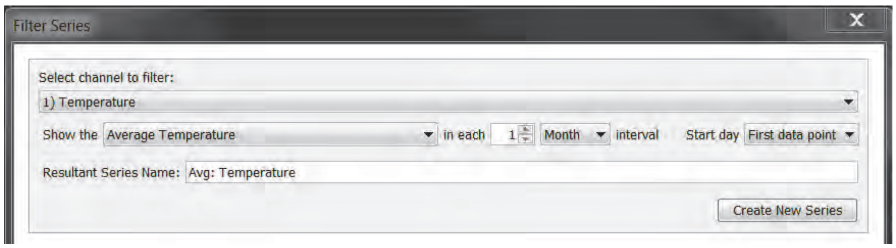


2. Select the type of filter and the interval you wish to use. If you select an interval of week or month, select "First data point" for the filter to start on the date and time of the first logged data point or select the day of the week or month you want the filter to start (the filter will start at midnight on the

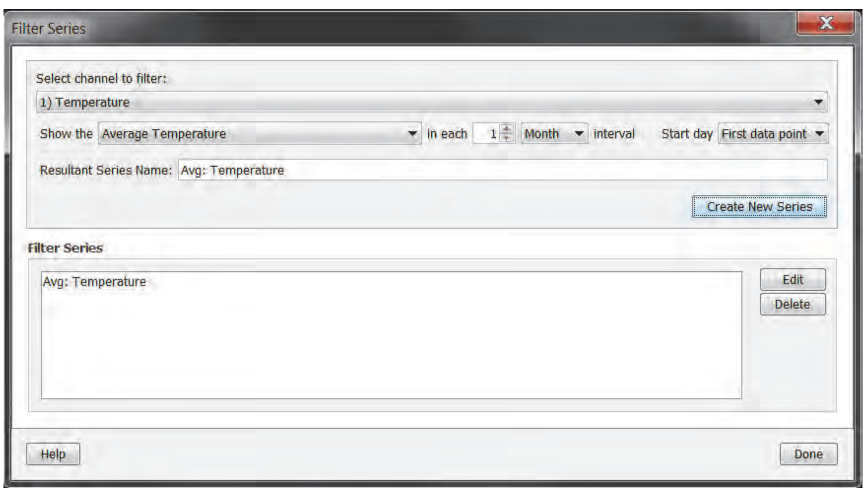
day selected). In this example, the type of filter is "Average Temperature" in each month starting with the first data point. Note that filters vary depending on the channel's measurement type.



3. Edit the Resultant Series Name as desired. Click Create New Series.



4. The newly created series is added to the Filtered Series list as shown below. To make a change to a filtered series, either double-click the series name or select the series name and click Edit. To delete a filtered series, select the series name and click Delete.



5. Repeat steps 1 through 4 to create additional filtered series. Not only can you create filtered series for all channels, but you can also create multiple filtered series on a single channel (for example, you can show the maximum, minimum, and average temperature for a single temperature channel).

6. Click Done when finished. The number of filtered series that you created is displayed on the Filter button in the Logger Launch window.

7. After you launch the logger and read it out, the filtered series will automatically be listed in the Plot Setup dialog, from which you can select the series you wish to plot. **Note:** If you change the GMT offset for the filtered series, the data points will not reflect that change. They will continue to be filtered based on times within the original GMT offset at launch.

Notes:

- Loggers launched in HOBOware 3.2 with series created by the Pulse Scaling, Linear Scaling, and kWh Data Assistants or with filtered series cannot be read out in earlier versions of HOBOware.

- Filtered series created at launch time are not available for use with the Barometric Compensation, Grains Per Pound, Conductivity, or Dissolved Oxygen Data Assistants.

See also:

- Filtered Series vs. Statistics Logging

Data Assistants Window (Scaling)

When you run a Data Assistant from the Launch Logger window, you can create a derived series, which is an additional data series automatically calculated each time you read out the logger. The Data Assistants window lists only those assistants available for the currently selected sensor and logger at launch time. There may be other Data Assistants available for use after reading out the logger.

To set up a derived series with a Data Assistant:

1. Select the Data Assistant you wish to use and click Create.
2. Select the information, or scaling parameters, you want the series to contain and click Save.
3. The new series appears in the My Derived Series list. Create additional series as desired.

   To make a change to a derived series, either double-click the derived series name or select it and then click Edit.

   To delete a derived series, select the series and then click Delete.

4. After you have finished creating or editing the derived series, click Done. Depending on the type of logger you are using, the total number of derived series created appears on the kWh and/or Scaling buttons in the Launch Logger window. Derived series are also listed in the Status window.

After you launch the logger and read it out, the derived series will automatically be listed in the Plot Setup dialog, from which you can select the series you wish to plot.

Notes:

- Loggers launched in HOBOware 3.2 with series created by the Pulse Scaling, Linear Scaling, and kWh Data Assistants or with filtered series cannot be read out in earlier versions of HOBOware.
- When setting up kWh or scaling for UX90 series loggers, the scaled series information will appear on the LCD screen on the logger. In addition, only the Energy series appears on the LCD screen when configuring kWh. Average power and cost series will not display on the screen; they are available in HOBOware only.
- Although it is possible to set up more than one scaling value for each sensor on the HOBO 4-Channel Analog logger (UX120-006M), only the first scaling value for that sensor will be used.

Configure Alarms

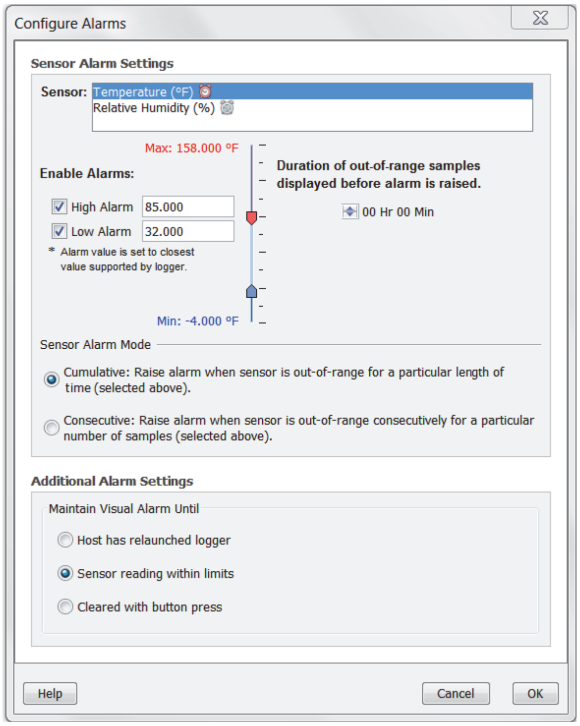
You can set an alarm to trip when a sensor reading rises above or falls below a specified value on certain logger models. **Note:** The U30 Station also has alarms capability; see Setting Alarms on a HOBO U30 Station for more details.

To set an alarm:

1. If the Alarms window is not already open, click the Alarms button from the Launch Logger window. If there is no Alarms button, then the logger does not have alarm capability. If the Alarms button is disabled, be sure you have enabled logging on a sensor that supports alarms. If the Alarms button is disabled for MX, UX100, or UX120 series loggers, make sure the Logging Mode is not set to Burst.

Alarms are not available for these loggers when the Logging Mode is set to Burst in the Launch Logger window.

2. In the Alarms window, select the sensor that you want to have an alarm. **Note:** The example below is for a UX100 series logger. Any differences for other logger models are noted in these steps.



3. Select the High Alarm checkbox if you want an alarm to trip when the sensor reading rises above the high alarm value. Type the reading next to the High Alarm checkbox or drag the red upper slider. In this example, we've set an alarm to trip when the temperature rises above 85°F.

4. Select the Low Alarm checkbox if you want an alarm to trip when the sensor reading falls below the low alarm value. Type in the reading next to the Low Alarm checkbox or drag the blue lower slider. In this example, we've set an alarm to trip when the temperature falls below 32°F.

   Note: The actual values for the high and low alarm limits are set to the closest value supported by the logger. For example, the closest value to 85°F that the UX100 series logger can record is 84.990°F and the closest value to 32°F is 32.043°F. In addition, alarms can trip or clear when the sensor reading is within the logger specifications of 0.02°C resolution. This means the value that triggers the alarm may differ slightly than the value entered. For example, if the High Alarm is set to 75.999°F, the alarm can trip when the sensor reading is 75.994°F (which is within the 0.02°C resolution).

5. Set the duration for out-of-range samples before an alarm is tripped.

6. Select either Cumulative or Consecutive for the Sensor Alarm Mode (select logger models only). If you select Cumulative, then the alarm will trip when the time the sensor is out of range over the course of the deployment is equal to the selected duration. If you select Consecutive, then the alarm will trip when the time the sensor is continuously out of range is equal to the selected duration. For example, the high alarm for temperature is set to 85°F and the duration is set to 30 minutes. If Cumulative is selected, then an alarm will trip once a sensor reading has been at or above 85°F for a total of 30 minutes since the logger was configured; specifically, this could be 15 minutes above 85°F in the morning and then 15 minutes above 85°F again in the afternoon. If Consecutive is selected, then an alarm will trip only if all sensor readings are 85°F or above for a continuous 30-minute period.

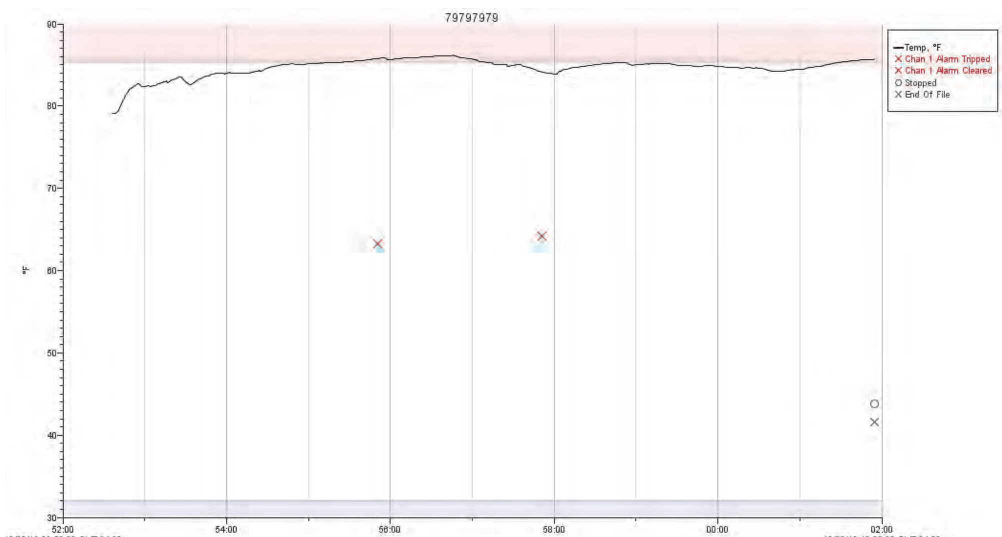
7. Choose how long the logger should maintain the sensor or visual alarm once it has tripped (select logger models only). Select "Host has relaunched logger" if you want the alarm to remain visible on the LCD until the next time you relaunch the logger. Select "Sensor reading within limits" if you want the

alarm to clear once the sensor reading returns to the normal range between the high and low alarm limits. Select "Cleared with button press" if you want the alarm to remain on and visible on the LCD until you press the Alarm button on the logger (select logger models only).

8. U14-00x loggers only: You can set the Relay Contacts to Normally Open or Normally Closed as described in the logger manual. Click the Test Set Alarm button to test the relay switches. Deselect the "Set Alarm on Low Battery" checkbox if you do not want an alarm to trip when the logger's battery is running low.
9. MX1102 loggers only: You can select Use Audible Alarm if you want a beep to sound on the logger every 30 seconds when the sensor alarm trips. The beeping will continue until the alarm is cleared from the software, a button on the logger is pressed, or 7 days have passed. Battery life will be slightly reduced when this setting is enabled. It is recommended that you only enable this feature if you have regular access to the logger so that you can easily turn off the beeping.
10. Click OK to save the alarm settings and return to the Launch Logger window.

Once the logger is launched, alarms will trip as determined by these settings. For UA-001 loggers, a "high" or "low" LED will blink when an alarm is tripped; alarms are checked at every logging interval. For other models, logger alarms will display on the LCD screen. The alarm limits are checked when the logger's LCD screen refreshes. See the logger manual for details on LCD screen refresh rates.

When you read out the logger, high and low alarm levels will be displayed on the plot. In the example below, the temperature rose above 85°F so those readings are in the red, or high alarm, portion of the plot. The temperature never fell below the low alarm limit, which is the blue portion at the bottom of the plot. Some logger models also display alarm events showing when the alarm tripped (and cleared if applicable). In this example, there are "Chan 1 Alarm Tripped" and "Chan 1 Alarm Cleared" events showing when the temperature alarm tripped and cleared. The "Chan 1 Alarm Cleared" event contains the value that was furthest out of range for the sensor before the alarm cleared (see the Points table for the actual value).



Advanced Sensor Properties: Pulse Frequency and Lockout Time

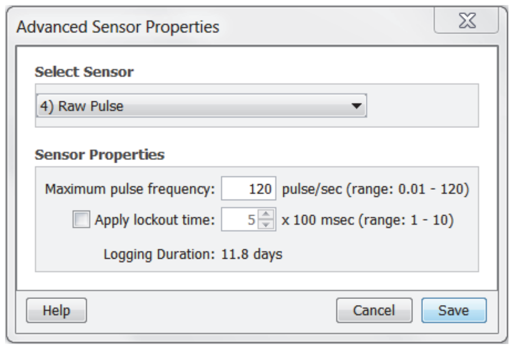
Use the Advanced Sensor Properties window to set the maximum pulse frequency for raw pulse channels and to specify a lockout time for raw pulse and event channels, which prevents false readings from mechanical sensors as their relay state changes.

Setting maximum pulse frequency is not required, but it can help optimize logging duration. The maximum pulse frequency, multiplied by the logging interval, determines the maximum count of pulses possible within each interval. The logger then can use this value to adjust the amount of memory (bits) used to log each data point. This means the logger uses memory as efficiently as possible, which in turn maximizes logging duration.

To configure maximum pulse frequency and lockout time:

1. Select the sensor that corresponds with the pulse channel you wish to configure.

2. Set the maximum pulse frequency, which controls how many pulses per second can be processed by the logger on a single pulse channel. The option to set the maximum pulse frequency is only available for raw pulse channels (sensors for which you have selected Raw Pulse as the sensor type in the Launch Logger window). Refer to the specifications in your sensor or device documentation for recommended maximum pulse frequency values. In general, the larger the maximum pulse frequency, the shorter the logging duration will be for the deployment. Note that the pulse frequency ranges in this window vary depending on the logger model.



3. Click the "Apply lockout time" checkbox if you wish to specify a time period when pulses will be ignored. Select the lockout time value from 1 to 10. On sensors with both pulse frequency and lockout time settings, lockout time will affect the maximum pulse frequency: the higher the lockout time, the lower the maximum pulse frequency will be.

Notes:

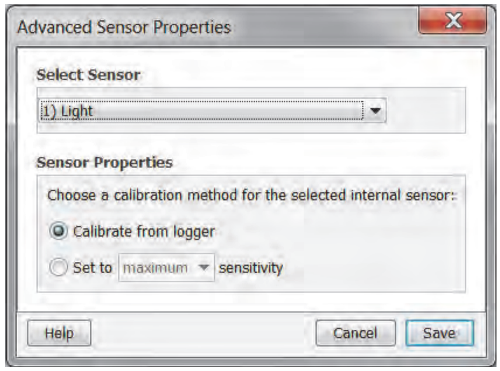
- If the logger has multiple sensors, then all sensors will have the same lockout time. This means if you are using multiple sensors with different lockout time requirements, this may result in lost pulses or false pulses.
- Lockout time is only available for raw pulse channels and event channels.
- When lockout time is enabled, you can specify a value from 1 to 10 (with a default of 5), which is then multiplied by 100 milliseconds for a range of 0.1 to 1 second. The available range for the maximum pulse frequency is automatically recalculated based on the lockout time. For example, if the lockout time is set to 2, the maximum pulse frequency range changes to 0.01 to 5 Hz. The maximum pulse frequency also varies depending on the logger model. Refer to the specifications in the logger documentation for maximum pulse frequency (documentation is also available at http://www.onsetcomp.com/support/manuals).

4. Click Save. Note that the selections will not take effect in the logger until you launch it.

Advanced Sensor Properties: Calibration

Use the Advanced Sensor Properties window to set the calibration method used for internal light or motor sensors in UX90 series data loggers. The default calibration method is to "calibrate from logger," which is an auto-calibration procedure using the Calibrate button on the logger. Alternatively, you can set the calibration method to a maximum or minimum sensitivity level as defined by HOBOware. To change the calibration method:

1. Select the sensor that corresponds with the internal light/motor channel you wish to configure.
2. Select "Calibrate from logger" to use auto-calibration or select "Set to maximum or minimum sensitivity" to use HOBOware for calibration. See below for more details on both procedures.

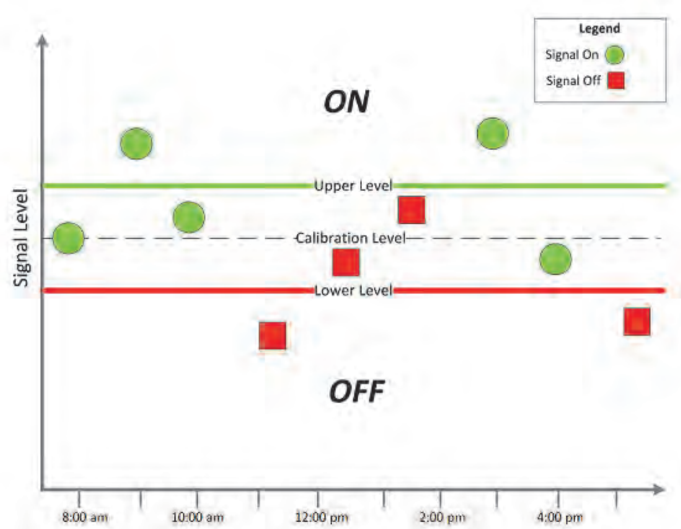


3. Click Save. Note that the selections will not take effect in the logger until you launch it.

Calibrate from Logger

Calibrating from the logger with the calibration button, also called auto-calibration, is used to calibrate the ON and OFF threshold of the logger to achieve reliable readings in an environment where motor or light levels are unknown prior to deployment or where logger light levels are variable. In the auto-calibration process, the light level or the AC magnetic field for a motor sensor is measured via a built-in analog-to-digital converter and the resulting value is used to generate a calibration threshold.

The logger has a built-in hysteresis level of approximately 12.5% for the light sensor and 6.25% for the motor sensor to prevent the sensor from toggling between ON and OFF when the signal level is near the calibration threshold. This plot shows how the logger handles hysteresis. The logger interprets the signal as ON until it drops below the lower level of the calibration threshold. Once it switches to off, the signal will not switch back to ON until it bypasses the upper limit of the calibration level.



When auto-calibrating from the logger (button calibrating):

1. Deploy the logger near the light/motor to be monitored. Turn the light or motor on.
2. Press the Calibrate button for 1 second. The LCD screen will display the signal strength of the light/motor. The signal strength should ideally be at least 3 bars. Orient the logger as necessary to increase the signal strength. The signal strength indicator will remain on the display for ten minutes or until calibration is complete.
3. Press the Calibrate button for 3 seconds while "HOLD" appears on the LCD screen. For the light sensor, move your hand away from the logger to prevent shadowing. The logger will count down to the auto-calibration and then display either "PASS" or "FAIL" after calibration is complete.

4. If the auto-calibration fails, point the sensor directly at the light or position it closer to the motor source and then repeat these steps.

Set to Maximum/Minimum Sensitivity

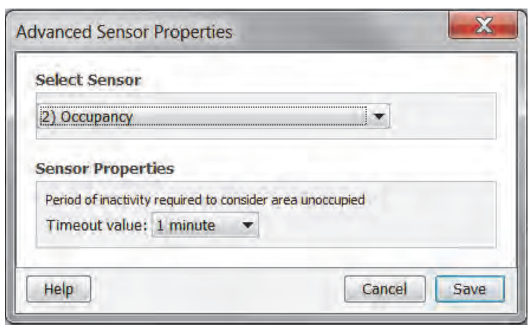
If you cannot manipulate the light source or access the motor, you can set the calibration level in this window. The lower the light/magnetic field level, the higher the sensitivity needs to be to record changes between ON and OFF conditions. For light sensors, the maximum sensitivity is approximately 100 lux (for rooms with low light levels, such as residential environments) and the minimum sensitivity is approximately 500 lux (for rooms with high light levels, such as retail environments). For motor sensors, the maximum sensitivity is approximately 40 mG (for a weak magnetic field) and the minimum sensitivity is set to approximately 100 mG (for a strong magnetic field).

Advanced Sensor Properties: Occupancy

Use the Advanced Sensor Properties window to set the timeout value for an occupancy sensor (UX90-005x/006x models). The timeout value is the period of inactivity required for the sensor to consider the area unoccupied. The timeout value is set to 1 minute by default. You can change this to one of the preset values or enter a custom value.

To change the timeout value for an occupancy sensor:

1. Select the sensor that corresponds with the occupancy channel you wish to configure.
2. Select a preset timeout value as shown in the example below or select Custom and enter your own value in minutes and seconds.



3. Click Save. Note that the selections will not take effect in the logger until you launch it.

Statistics: Maximum, Minimum, Average, and Standard Deviation

You can configure UX100 series and some UX120 series loggers to calculate maximum, minimum, average, and standard deviation statistics for all enabled sensors during logging at each logging interval based on samples taken at a rate you specify. This will result in up to four additional series per sensor that record the following information at each logging interval:

- The maximum, or highest, sampled value,
- The minimum, or lowest, sampled value,
- An average of all sampled values, and
- The standard deviation from the average for all sampled values.

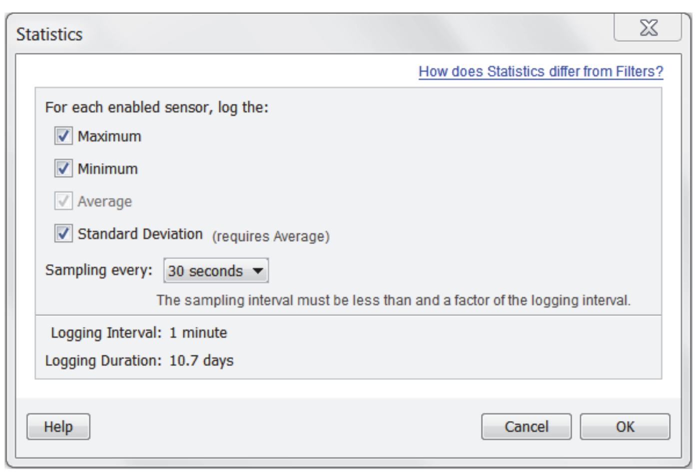
For example, let's say both the temperature and RH sensors have been enabled, the logging interval is set to 5 minutes and the sampling interval is set to 30 seconds (with maximum, minimum, average, and standard deviation all enabled). Once logging begins, the logger will measure and record the actual temperature and RH sensor values every 5 minutes. In addition, the logger will take a temperature and RH sample every 30 seconds and temporarily store them in memory. The logger will then calculate the maximum, minimum, average, and standard deviation using the samples gathered over the previous 5-minute period and log the resulting value(s). When reading out the logger, this would result in 10 data series (not including any derived series, such as dew point): two sensor series (with temperature and RH data logged every 5 minutes) plus eight maximum, minimum, average, and standard deviation series (four for temperature and four for RH with values calculated and logged every 5 minutes based on the 30-second sampling).

Notes:

- Statistics are not available for logging if Normal or Burst has been chosen as the Logging Mode in the Launch Logger window.
- On thermocouple loggers, statistics are only available on thermocouple channels and not on the internal temperature channel.
- Maximum, minimum, and average statistics can be logged for a HOBO Plug Load logger (UX120-018), but they are configured differently than the following steps for the UX100 series and other UX120 series loggers. In addition, average statistics are not displayed on the LCD screen for this logger. The maximum and minimum values displayed are based on the entire deployment. See Launch Options for a HOBO Plug Load logger (UX120-018) for details.

To configure statistics:

1. If the Statistics window is not already open, select Statistics from the Logging Mode drop-down menu in the Launch Logger window. Or, if Statistics has already been configured, click the Edit button.
2. Click the Maximum, Minimum, Average, and Standard Deviation checkboxes for each of the statistics you want to calculate during logging. Note that Average is automatically selected when selecting Standard Deviation. **Important:** Statistics apply to all enabled sensors; every selected statistic will be calculated for all sensors (except battery voltage). For example, if both the temperature and RH sensors have been selected in the Launch Logger window and you select Average, then the average will be calculated for both temperature and RH. In addition, the more statistics you record, the shorter the logger duration and the more memory is required. **For MX1102 loggers:** You can also select Current Reading if you want to log the sensor readings at each logging interval.
3. Set the sampling interval, which must be less than and a factor of the logging interval. Choose either a preset sampling interval or select Custom and enter your own sampling interval. Keep in mind that the more frequent the sampling rate, the greater the impact on battery life.



4. Click OK when done. This will return you to the Launch Logger window. Click the Edit button next to Logging Mode in the Launch Logger window to make additional changes.

Once logging begins, press the Alarm/Stats button on the logger for 1 second to cycle through the current maximum, minimum, average, and standard deviation data (as applicable) on the LCD screen (it is not available in the HOBOware Status window). You can plot the statistics series once you read out the logger.

Filtered Series vs. Statistics Logging

Some logger models support filtered series and statistics logging, both of which involve calculating maximum, minimum, and average values that you can plot after the logger is read out. Both are accessed from the Launch Logger window (for filtered series, click the Filters button; for statistics logging, select Statistics as the Logging Mode or for a UX120-018 logger, select the Max, Min, and Avg checkboxes for each sensor). However, there are some key differences between the two features. Essentially, statistics logging is performed at the sampling interval of the logger while filters include data accumulated from a series of logged data points.

The following table compares filtered series to statistics logging so that you can choose the best solution for your deployment. **Note:** There is also another filtering option available after you read out the logger, which is available from the Filter button on the toolbar. This allows you to create filtered series based on the data in the plotted datafile. For more information on filtering after reading out a logger, see Filtering a Series.

	Filtered Series	**Statistics Logging**
What logger models work with this feature?	All logger models.	Only UX100, MX, and some UX120 series loggers.
Which sensors does this apply to?	Only those that you select; you must set up individual filters for each sensor.	Automatically calculated for all enabled sensors (each sensor selected in the Launch Logger window except for Battery if applicable) except for UX120-018 loggers, which require selecting Max, Min, or Avg for each sensor.
Which measurement types are compatible?	All measurement types, including state, event, pulse, and runtime.	Those supported by the individual logger.
Can I view the data on the logger's LCD screen (if available)?	No, filtered series are only available after the logger is read out.	Yes, you can press a button on the logger to cycle through each of the enabled statistics.
What kind of data can be calculated with this feature?	Maximum, minimum, and average; standard deviation is not available.	Maximum, minimum, average, and standard deviation (the UX120-018 does not support standard deviation).
How often can data be calculated?	By day, hour, minute, or second using samples taken at the logging interval. The filter interval should be greater than the logging interval. It is also recommended that it is a multiple of the logging interval so that every filter interval has an equal number of samples.	For UX100, MX, UX120-006M, and UX120-014M: Data is calculated at each logging interval using samples taken at the sampling interval. The sampling interval must be less than and a factor of the logging interval (i.e., if the logging interval is set to 10 minutes, statistics cannot be calculated every hour; the sampling interval would have to be less than and a factor of 10 minutes). For UX120-018: Data is sampled at an internal logger rate of 16.67 mS and statistics are logged at each logging interval.

	Filtered Series	Statistics Logging
Can I select different intervals for each calculated series?	Yes, you can select a different interval for each filter you set up.	No, the intervals apply to all selected statistics.
How is the data recorded?	Sensor data is recorded at every logging interval and filtered data points are calculated at the rate you specified (for example, the average temperature is calculated every hour). This requires more memory as every sample is recorded.	For UX100, MX, UX120-006M, and UX120-014M: The logger takes a sample at every sampling interval, but only records statistics data at the logging interval. This requires less memory as every sample is not recorded. For UX120-018: Data is sampled at an internal logger rate and statistics are logged at each logging interval.

Burst Logging

Burst logging is a logging mode available for UX100, MX, and some UX120 series loggers that allows you to set up more frequent logging when a specified condition is met. For example, let's say the logger is recording data at a 5-minute logging interval and burst logging is configured log every 10 seconds when the temperature goes above 85°F (the high limit) or falls below 32°F (the low limit). This means the logger will record data every 5 minutes as long as the temperature remains between 85°F and 32°F. Once the temperature reaches 90°F, for example, the logger will switch to the faster logging rate and record data every 10 seconds until the temperature falls back below the high limit (or 85°F in this case). At that time, logging then resumes every 5 minutes at the normal logging interval. Similarly, if the temperature falls to 30°F, for example, then the logger would switch to burst logging mode again and record data every 10 seconds. Once the temperature rises back to 32°F, the logger will then return to normal (fixed interval) mode, logging every 5 minutes.

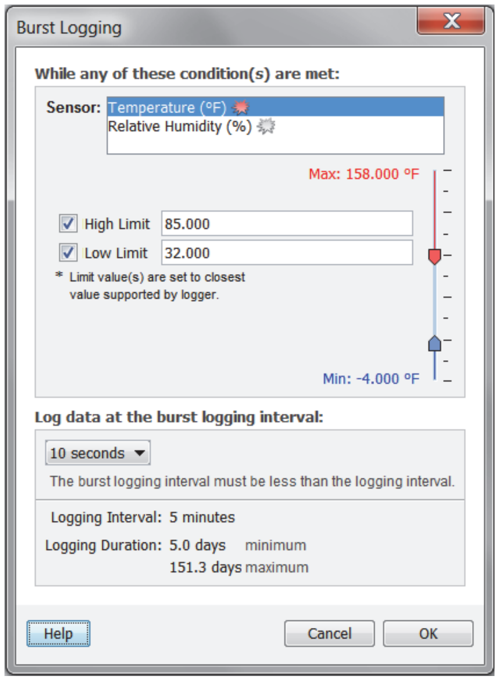
Notes:

- Burst logging is not available if alarms have been enabled for the logger.
- The Stop Logging option "Never (wrap when full)" is not available when burst logging is configured.
- The actual values for the burst logging limits are set to the closest value supported by the logger. For example, the closest value to 85°F that the logger can record is 84.990°F and the closest value to 32°F is 32.043°F.
- Burst logging mode can begin or end when the sensor reading is within the logger specifications of 0.02°C resolution. This means the value that triggers burst logging may differ slightly than the value entered. For example, if the High Limit for a temperature alarm is set to 75.999°F, burst logging can start when the sensor reading is 75.994°F (which is within the 0.02°C resolution).
- Once the high or low condition clears, the logging interval time will be calculated using the last recorded data point in burst logging mode, not the last data point recorded in normal or fixed interval mode. For example, let's assume the logger has a 10-minute logging interval and logged a data point at 9:05. Then, the high limit was surpassed and burst logging began at 9:06. Burst logging then continued until 9:12, when the sensor reading fell back below the high limit. Now back in normal (fixed interval) mode, the next logging interval will be 10 minutes from the last burst logging point, or 9:22 in this case. If burst logging had not occurred, the next data point would have been at 9:15.
- A New Interval event will appear on the plot (if you select events for plotting in the Plot Setup window) each time the logger enters or exits burst logging mode.
- On thermocouple loggers, burst logging is only available on thermocouple channels and not on the internal temperature channel.

To set up burst logging:

1. If the Burst Logging window is not already open, select "Burst logging" from the Logging Mode drop-down menu in the Launch Logger window. Or, if Burst logging has already been configured, click the Edit button.
2. Select the sensor you want to configure for burst logging.
3. Select the High Limit checkbox if you want to set up a condition in which burst logging will occur when the sensor reading rises above the high limit value. Type in the value or drag the red upper slider.
4. Select the Low Limit checkbox if you want to set up a condition in which burst logging will occur when the sensor reading falls below the low limit value. Type in the value or drag the blue lower slider.

In this example, both the high and low limits were selected. You may choose only one if you wish.



5. Set the burst logging interval, which must be less than the logging interval. Select either a preset burst logging interval or select Custom and enter your own interval. Keep in mind that the more frequent the burst logging rate, the greater the impact on battery life and the shorter the logging duration.
6. Click OK when done. This will return you to the Launch Logger window. Click the Edit button next to Logging Mode in the Launch Logger window to make additional changes.

Once the logger is launched, the high and low burst logging levels are only checked when the logger's LCD screen refreshes once every 15 seconds. Therefore, if you set the logging interval to less than 15 seconds and the sensor reading falls outside the levels, the burst logging will not log until the next 15-second refresh cycle.

Important: If high and/or low limits have been configured for more than one sensor, then burst logging will begin when any high or low condition goes out of range. Burst logging will not end until all conditions on all sensors are back within normal range.

Carbon Dioxide Sensor Settings

The CO_2 sensor in the HOBO MX CO_2 logger (MX1102) requires altitude compensation and regular calibration to ensure accurate readings are being taken in the location where it is deployed. Both auto and manual calibration are selected by default when first configuring the logger. Altitude compensation should be used if you are monitoring CO_2 at elevations above or below 305 meters (1,000 feet). A manual calibration immediately after logging begins is recommended for best accuracy.

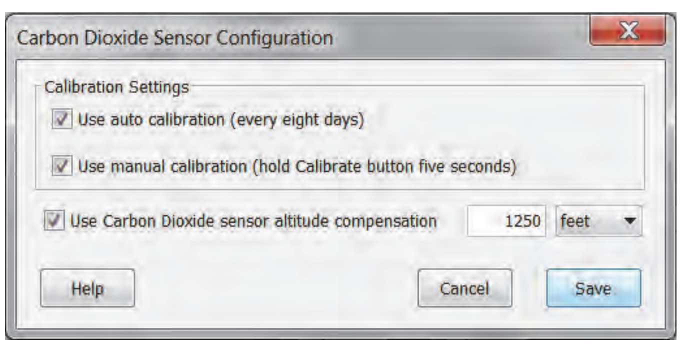
The following CO_2 settings are available:

- **Use manual calibration.** Manual calibration is the best way to calibrate your logger. Select this option if you want to manually calibrate the logger to 400 ppm using the Calibrate button on the logger. This requires taking the logger outside in fresh air on a dry day or to an indoor location that is unoccupied and has no connection to a ventilation system for five minutes on a regular basis. This is recommended if the logger is deployed in a building that is always occupied, if you want the logger to be calibrated more frequently than every eight days (the normal auto calibration schedule), or if you want to calibrate the logger immediately after logging begins. Note: Once a manual calibration is performed, the 24-hour auto calibration is canceled and an auto calibration will be performed eight days from the time the manual calibration occurred. (Relaunching the logger resets the 24-hour/8-day auto calibration routine).

- **Use auto calibration.** Select this option if you want the logger to automatically calibrate within the first 24 hours after logging begins and then every eight days thereafter. The logger will be calibrated based on the average of the three CO_2 measurements that follow the lowest CO_2 value identified during the 24-hour or 8-day time period as applicable. **Important:** Accurate auto calibration requires the building or location where the logger is deployed to be empty at least once during the eight-day period (for example, an empty office building during the weekend or overnight will typically have background CO_2 levels of 400 to 450 ppm).

  If the logger is deployed in an area where the CO_2 level does not go down to 400 ppm during the eight-day time period, then manual calibration should be performed regularly instead or inaccurate CO_2 readings will be reported. If you plan on using auto calibration but the building will be occupied during the first day after logging begins, then you can use the manual calibration option as well. You can manually calibrate the logger immediately after logging begins and use auto calibration thereafter. Note: Every time the logger is launched, auto calibration will occur after 24 hours and then again after eight days unless a manual calibration is performed first.

- **Use Carbon Dioxide sensor altitude compensation.** Select this option if the logger is deployed at a location above or below 305 meters (1,000 feet). Type the altitude above or below sea level in either meters or feet. In normal use, the CO_2 measurement will vary by approximately 0.135% of the reading for each mbar change in barometric pressure (the sensor is calibrated at 1,013 mbar). Use altitude compensation when deploying the logger for the best CO_2 accuracy possible.



After you have selected the carbon dioxide sensor settings, click Save. The settings will take effect once the logger is launched.

Notes:

- If both auto calibration and manual calibration are selected, the logger will automatically calibrate within 24 hours after logging begins unless a manual calibration occurs during that time period. In addition, when both calibration settings are selected, the eight-day calibration cycle will be reset any time a manual calibration is performed.

- When the logger is calibrated, a Manual Calibration or Automatic Calibration event is logged and available in the data file for plotting with a date and time stamp of when the calibration took place.

How to manually calibrate the logger:

1. Take the logger outside in fresh air on a dry day where the carbon dioxide level is 400 ppm. You can also use an indoor location for manual calibration if it is unoccupied and is not exposed to a ventilation system.
2. Press the Calibrate button on the logger for 5 seconds until it beeps. The logger will then calibrate for 5 minutes. The CO_2 and Calibrate symbols on the LCD will flash while the calibration is underway. A time- and date-stamped manual calibration event is logged in the data at the end of the 5-minute calibration sequence.
3. Once the Calibration process is complete, return the logger to its deployment location. Repeat this process at least once every eight days for best accuracy.

For information about launching the logger, see Launch Options for the HOBO MX CO_2 Logger (MX1102).

For specifications and complete logger information, including additional details on calibration, refer to the product manual at www.onsetcomp.com/manual/mx1102.

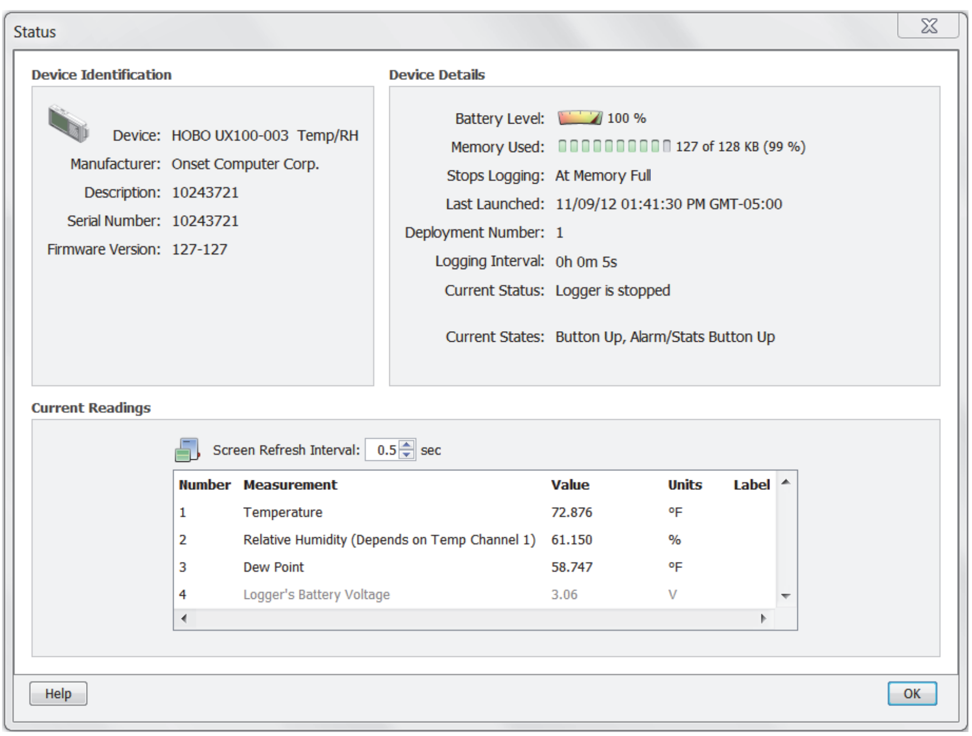
Checking Device Status

The Status window displays real-time information about the attached logger, including the current state of the logger, logging start time, current readings, and memory used. You can check the status for a logger whether it is waiting for logging to begin, actively logging (unless it is logging at a fast logging interval), or stopped.

To check the status of a logger:

1. Connect the logger to the computer.
2. Click the Status icon  on the toolbar, or select Status from the Device menu. You can also check the status by clicking the Status button on the Launch window, but this will show details from the previous launch.

This is an example of the Status window. The information displayed varies depending on the logger that is connected. See Status window for details on the type of information displayed.



Important: Battery power is drained more rapidly while checking status. Keep this in mind when frequently checking status during a deployment. You can significantly reduce the demand on the battery by adjusting the Screen Refresh Interval to five seconds or higher (not available on all loggers).

The Status Window

The Status window displays the current status of the logger. If you clicked Status from the Launch Logger window, then details from the previous launch is displayed. The Status window is divided into three panes: Device Identification, Device Details, and Current Readings.

Device Identification

The Device Identification pane shows the logger selected for status. It lists the device name and model number, description entered when the logger was last launched (which is also used as the default file name and title in the plot), serial number, and firmware number.

Device Details

The Device Details pane shows detailed information about the logger deployment including the following items. Note that not all of these items are displayed for every logger model.

- **Battery Level/Battery State.** This is the condition of the battery. Consult the logger documentation for specifics on battery capacity.
- **Memory Used.** This is the percentage of logger memory used so far in the deployment. Consult the logger documentation for specifics on memory capacity. Note that if the battery died during logging, the Memory Used will be 100% even if only a small amount of the memory was used.
- **Stops Logging.** This displays the date/time or the condition under which the logger will stop logging.
- **Last Launched.** This is the date and time, including the offset to Greenwich Mean Time (GMT), when the logger was last launched. This is not necessarily the time when the first sample was recorded; it is the time all the launch settings were loaded in the logger.
- **Delayed Start (if applicable).** If the logger has been launched, but is waiting to start on a particular date/time or at the next interval, the scheduled start time is shown here in local time.
- **Deployment Number.** This is the number of times the logger has been launched, including the most recent launch.
- **Logging Interval (if applicable).** This is the rate at which the logger was set up to record data. If multiple logging intervals are available, the interval currently in use (if the logger is logging) will be shown in bold.
- **Sampling Interval (if applicable).** This is the rate at which sensors are sampling data in between the logging interval.
- **DO Sensor Cap Information (HOBO U26 Dissolved Oxygen logger only).** For HOBO U26 Dissolved Oxygen loggers, the DO sensor cap expiration date, initialization date, and manufactured date is shown. For more details about the DO sensor cap, see Checking Dates for the HOBO U26 Dissolved Oxygen Logger Sensor Cap.
- **Current Status.** This is a message that describes the state of the logger. Messages include:
  - **Awaiting Button/Coupler Start.** The logger has been launched with a coupler or push button start (if available). Press and hold down the button on the logger for three seconds to begin logging, or follow the instructions that came with your logger if it offers a triggered (coupler) start but does not have a button.

  - **Awaiting Delayed Start.** The logger will begin recording data at a specific time because the logger was configured to start on a specific date/time or at the next interval.
  - **Launched, Logging.** The logger has been launched is actively recording data.
  - **Logger Is Full.** The logger has reached its memory capacity and is no longer recording data.
  - **Logger Is Stopped.** The logger is not logging, is not full, and is not awaiting a start.
  - **On Hold for Later Launch.** The logger has been launched with a Save Settings start (if available). Logging is not scheduled to begin, but the launch settings have been entered and saved.
  - **Relay is open/Relay is closed.** For the HOBO U30 Station, the current state of the relay is also displayed.

- **Current States, if applicable.** This is the current condition of the logger button(s). Refer to the logger documentation for details on logger operation, buttons, and interval events.

Current Readings

The Current Readings pane lists the latest measurement for each data series. Sensors that measure state changes do not show current readings. To change the order of series displayed in the Status window, go to the Preferences and select Display and then Series.

You can also set the Screen Refresh Interval for some loggers. This is the frequency the current readings are updated, up to 3,600 seconds (one hour). A higher number results in less drain on the logger's battery.

A Contact HOBOlink button also appears at the bottom of the Status window for the HOBO U30 Station only. Click this button when you want the HOBO U30 Station to connect to HOBOlink. When you click Contact HOBOlink, a confirmation message is displayed. Once you click Yes, the Status screen will close and then the HOBO U30 Station will attempt to connect to HOBOlink within 30 seconds. A warning may appear in the event that a live connection with HOBOlink is already underway.

Notes:

- Readings are displayed for all available sensors, even if they are not being logged. Sensors not being logged are dimmed.
- If a logger has channels for external sensors, a description and reading will be given for the external channels even if no sensors are plugged in.
- For event loggers, the event count displayed in Current Readings will always start at zero, even if many events have already been logged.
- Sensor labels (if applicable) are displayed following the sensor name.
- For station loggers, the location (if defined) is displayed next to the reading.
- If a HOBO U30 Station has an Analog Sensor Port, readings for one or both channels are displayed.
- When a Station logger is logging, the last sample taken by the logger at the last interval will be displayed.
- The RSSI (Signal Level) is displayed for the HOBO U30/GSM Station. This helps you determine if there is enough signal strength in the current location for the HOBO U30 Station to contact a cellular tower for connecting with HOBOlink. Signal level is measured on a scale of 0 to 10, with 0 being no signal, 1 being a weak signal, and 10 being a strong signal
- Battery voltage is displayed for some loggers.
- For acceleration loggers only, color-coded tilt meters display X, Y, and Z-axis tilt graphically (relative to vertical, assuming that the only acceleration force on the logger is gravity).

Stopping a Device

A logger automatically stops recording data when the memory is full (unless it has been configured to never stop logging) or when the battery runs down. Depending on the launch settings selected, you can also press the Start/Stop Logging button to stop logging on certain logger models. In addition, you can use HOBOware to stop the logger manually at any time.

To stop a logger:

1. Connect the logger to the computer.
2. Click the Stop icon  on the toolbar, or select Stop from the Device menu.

After the logger has been stopped, the data remains in the logger until the next launch. Be sure to read out the logger before setting up the next launch.

Chapter 3
Reading Out, Plotting, and Analyzing Data

After a logger has recorded data, you can then do the following:

- Read out the data from the logger
- Plot the data
- Modify the plot if desired
- Use Data Assistants
- Export the data
- Import data

Reading Out Data

To retrieve data recorded by a logger, you must read out the logger. Reading out the logger copies data from the logger to your computer, allowing you to save the data and plot it. During readout, the logger continues to record data unless you have stopped it or it is full.

You can also read out many logger types to a shuttle and then offload the datafiles from the shuttle to your computer. See Offloading and Saving Shuttle Files for more details.

To read out a logger to the computer:

1. Connect the logger to the computer.
2. Click the Readout icon  on the toolbar or select Readout from the Device menu. If the logger is still logging, confirm whether to stop the logger. Click either Don't Stop or Stop as desired.
3. A progress bar displays while the data is being read out. Once the readout is complete, choose a location and/or a new filename or accept the default location and name to save the data. The default location is:

    - C:\Documents and Settings\<user>\My Documents\HOBOware
    (for Windows XP)
    - C:\Users\<user>\Documents\HOBOware
    (for Windows 7, Windows 8, or Windows 10)
    - Users/<user>/Documents/HOBOware
    (for Macintosh OS X)

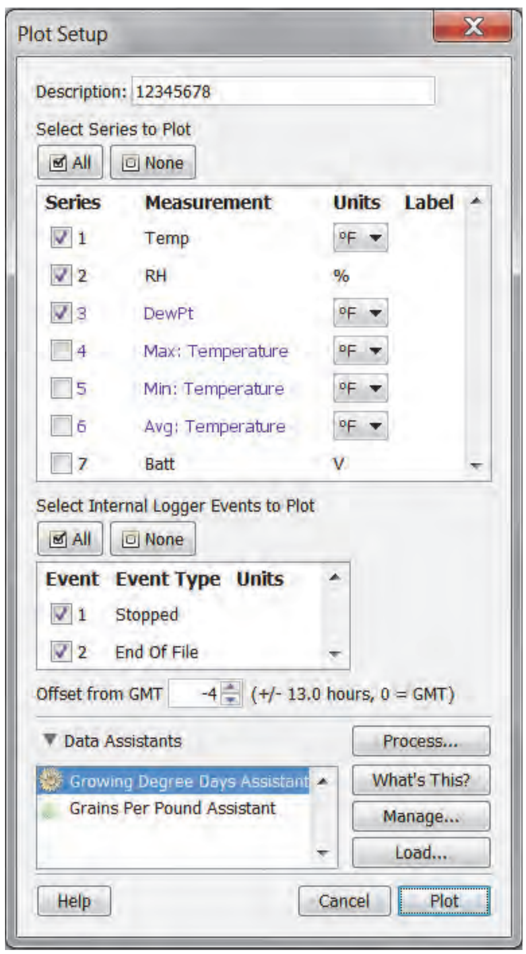
    If you save the file to a different folder, that folder will be the new default save location for future readouts.
4. Click Save. Most datafiles have a .hobo extension, but station loggers have a .dtf extension. If you are using HOBOware Pro in secure mode, the file extensions will be .hsec (U-Series loggers) or .dsec (Station loggers).
5. After saving the data, select the sensors and/or events you wish to display in a graph and click Plot. See Plotting Data for more details on the options available when plotting.

Notes:

- If you elected to not save the data upon reading out, you can still plot the data. However, this plotted data will not be saved automatically. You will be prompted to save the datafile upon closing the plot if desired. Or, select Save Datafile from the File menu if you now want to save the data.
- Once a logger is read out, the data will remain in the logger memory until the next time the logger is launched. Logger memory will automatically be erased once the logger is launched again.
- You can read out some U-Series loggers when the batteries are low if the logger can be powered by a USB cable. In this case, a warning appears before the readout begins indicating the battery is very low and that you may experience communications problems. Once the readout is complete, be sure to replace the batteries as suggested.
- You can bypass the Save window during the readout process by setting the Readout Time-Saving Options in the General subcategory of Preferences.

Plotting Data

After you read out a logger or open a saved file, you can plot the data with the Plot Setup window like the following example.



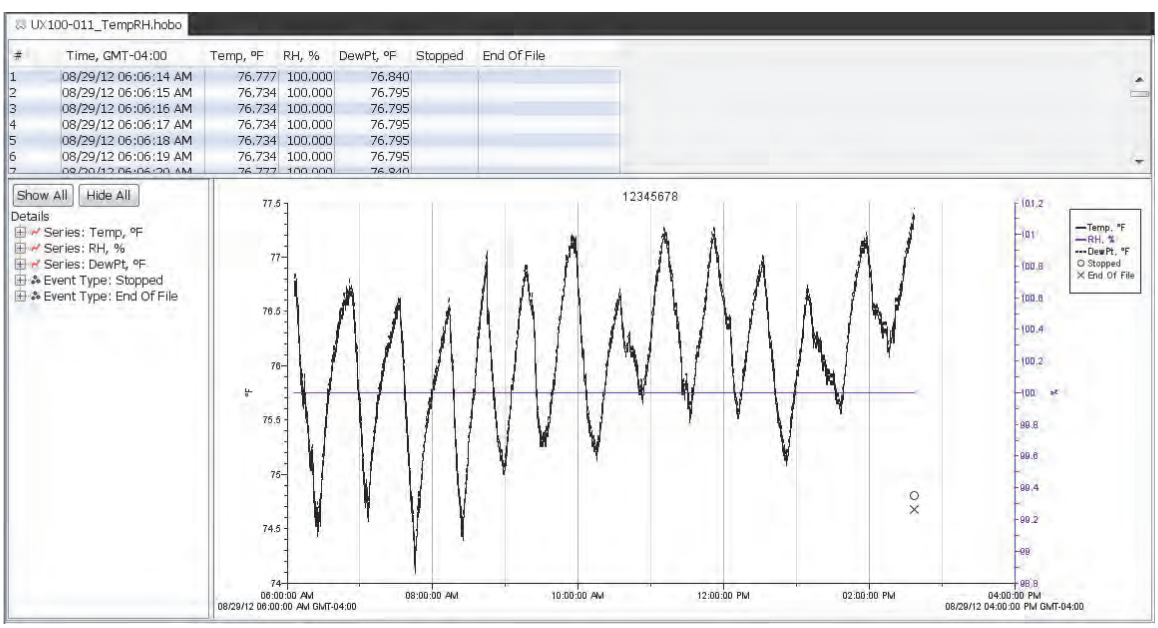
To plot the data:

1. Use the existing description or type a new one. The default description matches the one used when launching the logger and will be used for the plot title.

2. Select the series you wish to view on the plot. Click the All or None button to select or deselect all series, or click the checkboxes to select or deselect individual series. Series types can include:

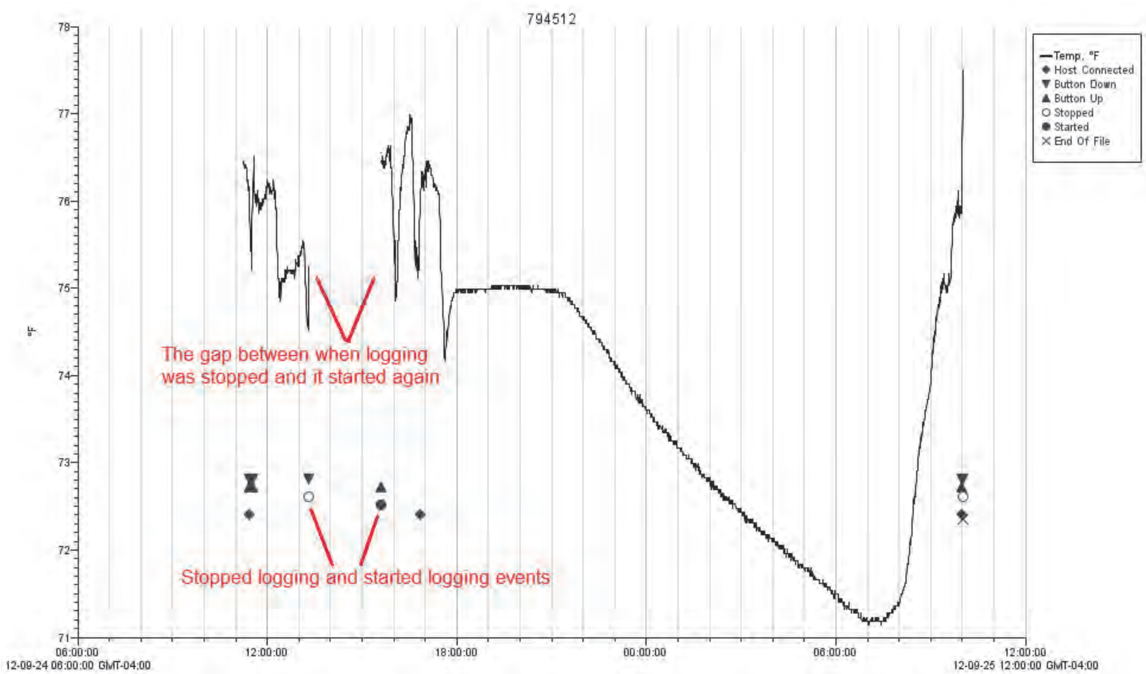
   - Logged data series, which is a series containing the sensor measurements, state changes, or statistics (select loggers only) recorded by the logger.
   - Derived series, which is a series calculated based on one or more logged data series. This could be an automatically generated series for a measurement type, such as Dew Point when temperature and RH is logged. Or, it could be a filtered or scaled series if you configured a filters or scaling with a data assistant in the Launch Logger window (select loggers only).
   - Battery voltage, which lists the logger battery voltage recorded at each logging interval.

3. Change the default units for selected series if desired. You can also change the units for a series after it is plotted.
4. Select the internal logger events to view on the plot. Click the All or None button to select or deselect all events, or click the checkboxes to select or deselect individual events. Internal logger events are individually logged occurrences that can be recorded at any time during deployment, regardless of the logging interval. These events can include started or stopped logging, low battery, or an alarm trip. Refer to the logger manual for a complete list of internal events if applicable.
5. Adjust the time zone offset, if necessary. By default, data is shown in the offset used to launch the logger with HOBOware (not a shuttle). To select a different offset, enter the hours offset from GMT (UTC) in decimal form. You may find this useful if you logged in multiple time zones, or if you took the logger to a different time zone after launching it.
6. If data assistants are available, you can use them to create additional series. Select an assistant from the list and click Process to create a new series.
7. Click the Plot button to generate a plot. The plot is drawn and includes a title, a time axis (x-axis), one or more value axes (y-axis), and a legend. The data for each series are listed in a points table above the plot. Details about each series, such as the type of logger and deployment information are listed in the Details pane to the left of the plot. You can show or hide these elements using the View menu. To organize several plots, use the Window menu to switch between Tabbed View, Tile Horizontally, or Tile Vertically.



Notes:

- To change the order of series displayed in the Plot Setup window, open the Preferences, select Display and then Series.
- To change the series and events that are selected by default in the Plot Setup window or to control whether four possible Light/Occupancy series are derived on supported loggers, open the Preferences, select Plotting and then Plot Setup.
- To bypass the Plot Setup window when opening a datafile, open the Preferences, select General and then select Open File Time-Saving Options.
- If a pie chart icon appears in the Plot Setup window, this means the data in the file you are plotting can also be plotted in a pie chart. See Viewing a Pie Chart for more details.
- On some loggers, the Started and Stopped internal events can only occur once. However, UX100 series loggers can start and stop logging multiple times in a single deployment (as configured in the Launch Logger window). Multiple stopped and started events in a single file are not only displayed on the plot if selected in the Plot Setup window, but the resulting gap that occurs in the data is also represented in the series. In this example, the logger was stopped at 1:19 and then started again at 2:35; both events are on the plot. The temperature series shows a break between those two times. That represents the gap between when logging was stopped and when it resumed, both using the button on the logger.



Opening Files

HOBOware can open .hobo files from HOBO data loggers, .hproj HOBOware project files, and .dtf files from the HOBO U30 Station, Weather Station, Micro Station, or Energy Logger. The following files can be opened by HOBOware Pro:

- .hsec, which are secure files (21 CFR Part 11 Conformance) from U-Series loggers.
- .hproj, which is HOBOware Project file.
- ..dsec, which are secure files (21 CFR Part 11 Conformance) from Station loggers.

- .txt, .csv, and most ASCII files can be imported.

To open a file:

1. Double-click a compatible file from Windows Explorer or Mac Finder. Or in HOBOware, click the Open icon  on the toolbar or select Open Datafile from the File menu.
2. Select one or more files and click Open.
3. Select the series and/or events you wish to view in the plot and click the Plot button. If you selected multiple files to open, you will be prompted with a Plot Setup window for each file (unless you have set the preference to automatically plot data as described in General Preferences).

To open a project file:

1. From the File menu, select Open Project.
2. Select a project (.hproj) file and click Open.

Recently opened files are listed in the File menu. From the File menu, select Recent Files and then choose the file you wish to open. To empty the recent file list, select Recent Files from the File menu and then select Clear Recent Files.

Opening Files from Unsupported Loggers

Although the following loggers cannot be launched or read out using HOBOware, datafiles from these loggers can be opened and plotted. All graphing tools, filters, and Data Assistants can be used with the files and data can be exported to text and project files.

H08 (8-bit)

- H08-001-04
- H08-002-04
- H08-003-04
- H08-004-04
- H08-006-04
- H08-008-04

TBI/WTA

- TBI32-05+37
- TBI32-20+50
- WTA08-05+37
- WTA08-39+75
- WTA32-05+37
- WTA32-39+75

H08 (12-bit)

- H08-030-08
- H08-031-08
- H08-032-08

H20

- H20-001

H06

- H06-001-02
- H06-002-02
- H06-003-02
- H06-004-02

H07

- H07-001-02
- H07-001-04

H14

- H14-001
- H14-002

H12

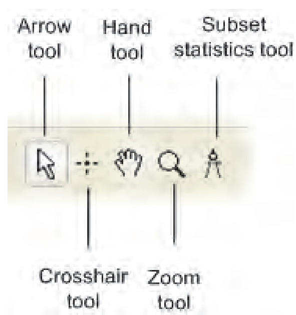
- H12-001
- H12-002
- H12-003

Working with Plots

There are several tools available for working with plots.

Tools

There are five tools available on the toolbar for viewing the plot and isolating data.



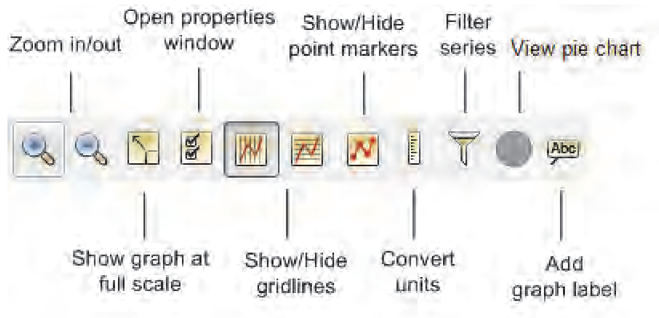
- Use the Arrow tool to point to and select items on the graph to edit their properties (through a right-click menu).
- Use the Crosshair tool to zero in on a specific date and time in the plot and any data points associated with that date and time. Click the Crosshair icon and then place your cursor anywhere on the plot to draw a red vertical line at a particular point.
- Use the Hand Drag tool to move different areas of the graph into view (panning) or adjust the position of one series so it can be viewed more easily. This is particularly useful when you are zoomed into the

graph and want to see another section of the graph without zooming out and then zooming back in on the new location.

- Use the Zoom tool to focus on one area of the graph, allowing you to see more detail.
- Use the Subset Statistics tool to view statistics for a particular time span (HOBOware Pro only).

Actions

Use the Actions buttons on the toolbar to perform a number of actions on a plot or a series.



- Use the Zoom In/Zoom Out buttons to keep the plot centered as you zoom.
- Click the Grow Graph at Full Scale button to return to the original, full-scale version of the plot when the datafile was first opened.
- Click the Open Properties button to open the properties window the plot element that is currently selected, such as axis, series, legend, or title.
- Use the Gridline buttons to toggle all horizontal or vertical gridlines on and off. You can also toggle gridlines on and off for each axis individually. Using the arrow tool, double-click an axis to get the Axis Properties window. Select or deselect the Show Gridlines checkbox to toggle the gridlines for that axis.
- Click the Point Markers button to toggle the point markers for all series on and off. To show or hide markers for an individual series, right-click the series to open the Series Properties window. Select or deselect the Mark Points checkbox to toggle the markers for that series.
- Click the Convert Units button to open the Convert Plot window, which allows you to convert the units on certain series on the plot to other units (for example, from degrees Fahrenheit to degrees Celsius).
- Click the Filter Series button the Filter Series window, which allows you to add a statistical series to the plot.
- Click the Pie Charts button if a pie chart is available for the plot (only available on loggers that support state series)
- Click the Add Graph Label button to open the Graph Label Properties window.

Menus

Use the Edit and View menus to access various controls when working with a plot. You can also right-click an element in the plot to access many of the same options available from the Edit and View menu and to open properties windows.

Using the Arrow Tool

Use the Arrow tool to select items on the plot. Click the Arrow icon  on the toolbar or press A to select the arrow tool.

If you are currently using another tool and do not want to switch tools, press N on your keyboard to select each graph item (including hidden items, such as value axes for states or events) in sequence.

The selected item (if visible) is shaded or boxed. You can then right-click the selected item, double-click it, or press the Enter key on your keyboard to open the Properties window for that item.

To deselect, click an area within the axes that does not have series data. Click the View menu and choose Select None or press D.

Using the Crosshair Tool

Use the crosshair tool to zero in on a specific date and time in the plot and any data points associated with that date and time. To use the crosshair:

1. Click the Crosshair icon -¦- on the toolbar or press C.
2. Click a point on the graph to mark it.
3. Click another point to move the marker.

When you click on a graph, the nearest data point is selected. When series are very close together and the location you click is between two points, it is possible that the nearest point is not on the series you clicked.

You can also mark the point on the graph by clicking the corresponding cell in the Points table. If you are zoomed in and click a point in the Points table that is outside the zoom area, the plot will scroll to that area of the graph. To prevent scrolling in this situation, go to the Preferences, select Plotting and then Points Table & Details Pane. Deselect the "When selected value in table is out of plot range, drag series to that value.

The plot changes in several ways when the crosshair is in use. The Points table shifts to the row that contains the data point. Where the crosshair intersects a data point, a square surrounds the data point. The intersection points are also marked by small color-coded arrows on the left and right value axes.

If the legend is displayed next to the graph, the point values for each series are updated to reflect the crosshair location. Values are listed in the legend differently depending on whether the data is a logged sample, state, or event:

- Values that are not in parentheses are actual data points logged at the time selected by the crosshair.
- Values in parentheses are estimated because there were no exact values for the series at the time selected by the crosshair. Zoom in or move the crosshair to see actual values.
- A value of "…" indicates that there is no series data during the time selected. This is seen most frequently for events. If the time selection falls within an event series, but does not contain an event, parentheses surround the "…" value.
- A value of "logged" indicates an internal logger event happened at the selected time.

The legend must expand in height to list the point values. If your application window is too small to accommodate the expanded height, the values will not be added to the legend. You can still refer to the Points table to find the values of the selected points.

To remove the crosshair from the graph, right-click the plot and select Remove Crosshair or choose remove Crosshair from the View menu.

Zooming, Panning, and Smart Scaling Plots

You can adjust the viewing area of the plot by zooming, panning, and smart scaling.

Zooming

There are two ways to zoom: either by using the zoom tool (or pressing Z) or by selecting Zoom In or Zoom Out from the toolbar or the View menu. Use the zoom tool to zoom anywhere on the plot that you select, clicking the right-mouse button to zoom in or out. Use the Zoom In/Zoom Out icons to keep the plot centered as you zoom.

When zooming:

- Right-click to toggle between zoom in and zoom out.
- Check the symbol inside the zoom tool to determine the direction you are zooming. A plus sign (+) or arrows pointing outward will zoom in, while a minus sign (-) or arrows pointing in will zoom out.
- Click an area on the graph inside the axes to zoom one level (a factor of two). Continue clicking to zoom multiple levels.
- Hold down the left mouse button in one location to zoom continuously. Release the mouse button to stop zooming.
- Hold down the left mouse button while drawing a rectangle around the area you wish to zoom in on, then click inside the rectangle. The area inside the rectangle expands to fill the whole graph.
- To constrain the zoom to horizontal or vertical zooming, place the cursor over the axis you want to zoom and click the mouse button. Hold the mouse button down to continue to zoom. Or, press the X key while zooming to restrict motion horizontally and press the Y key while zooming to restrict motion vertically.
- If you are currently working with the crosshair, arrow, or hand tool, you can click the Zoom In/Out icons on the toolbar to quickly zoom into and out of the middle of the display without changing tools.
- Zooming will not work on an axis that is locked. To unlock an axis, double-click the axis with the arrow tool and deselect the Lock Axis Scaling and Tick Marks in the Axis Properties window.

Panning

Use the hand drag tool or press H to pan the graph, which is dragging the plot viewing area along the x- or y-axis. Panning is especially helpful when you are zoomed into a detailed plot and want to focus on a different area without zooming out. Click within the graph and hold down the left mouse button to pan a different section of the graph into view. The graph follows the movement of the mouse, and the axes are continuously updated in response to the movement. To stop dragging, release the left mouse button.

To limit dragging to horizontal or vertical panning, place the cursor over the axis you want to drag, hold down the mouse button, and drag in the direction you want the plot to move. Or, press the X key will dragging to restrict motion horizontally and press the Y key while dragging to restrict motion vertically. Similarly, click the axis associated with a series and hold down the left mouse button. Only the series connected with the axis will follow the movement of the mouse.

Use the hand tool to move different areas of the graph into view or adjust the position of one series so it can be viewed more easily. This is particularly useful when you are zoomed into the graph and want to see another section of the graph without zooming out and then zooming back in on the new location.

Panning will not work on an axis that is locked. To unlock an axis, double-click the axis with the arrow tool and deselect the Lock Axis Scaling and Tick Marks in the Axis Properties window.

Smart Scaling

When you first display a graph, the numerical bounds of the axes are on tick marks. After you have panned or zoomed, this may no longer be the case. Use smart scaling to correct that. With the hand drag, arrow, or crosshair tool, right-click anywhere on the graph and select SmartScale Graph. This will automatically adjust the axes to end on tick marks.

Note: You can always return to the original plot view by clicking the View at Full Scale from the toolbar or the View menu.

Copying Data Points and the Plot

To copy the data points from the Points Table to paste into other software:

1. Select the data you wish to copy in the Points Table.
2. Press Ctrl+C in Windows or Command-C in Macintosh to copy the data.

   Windows: press Ctrl + C

   Mac: press Command - C
3. Open any text editor, word processor, or spreadsheet software.
4. Press Ctrl+V in Windows or Command-V in Macintosh to paste the data into the other application. Fields are delimited by tabs, and records are separated by paragraph returns.

You can also copy the plot as a bitmap for pasting into other programs and documents. To copy the plot:

1. From the Edit menu, select Copy Graph to Clipboard.
2. Go to the other application and paste the plot.

Closing a Plot

To close a single plot, click the on the tab or toolbar, or choose Close from the File menu. On Macintosh, click the red button in the upper-left corner of the internal frame containing the plot when in Tabbed View. To close all open plots, select Close All from the File menu.

Important: Any changes you made to the plot are not saved when you close the datafile. You must save the plot as a project file to preserve the changes. Either select Save Project from the File menu before closing the plot or close the file and click Save when prompted. If you only want to save an image of the plot, you can paste a bitmap of the graph into another program and save it there.

Note: If you do not want HOBOware to prompt you to save the plot as a project file when you close it, open the Preferences. Select Warnings and then select General. Deselect the "Prompt me if there is any remaining unsaved data when closing plot or application" checkbox.

Viewing a Pie Chart

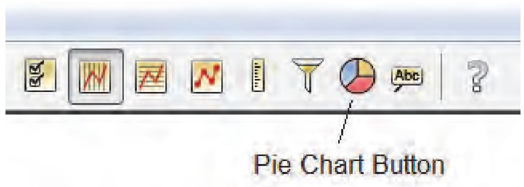
Pie charts are available in HOBOware Pro for plotted state series, such as those from the UX90 data loggers. This provides you with a graphical representation of the data for viewing, saving, and printing in addition to the default line graph. This is particularly useful for the UX90 Occupancy/Light Data Logger (UX90-005x/-006x) because it allows you to quickly compare when the:

- Lights were on and the room was unoccupied
- Lights were on and the room was unoccupied
- Lights were off and the room was occupied
- Lights were off and the room was unoccupied

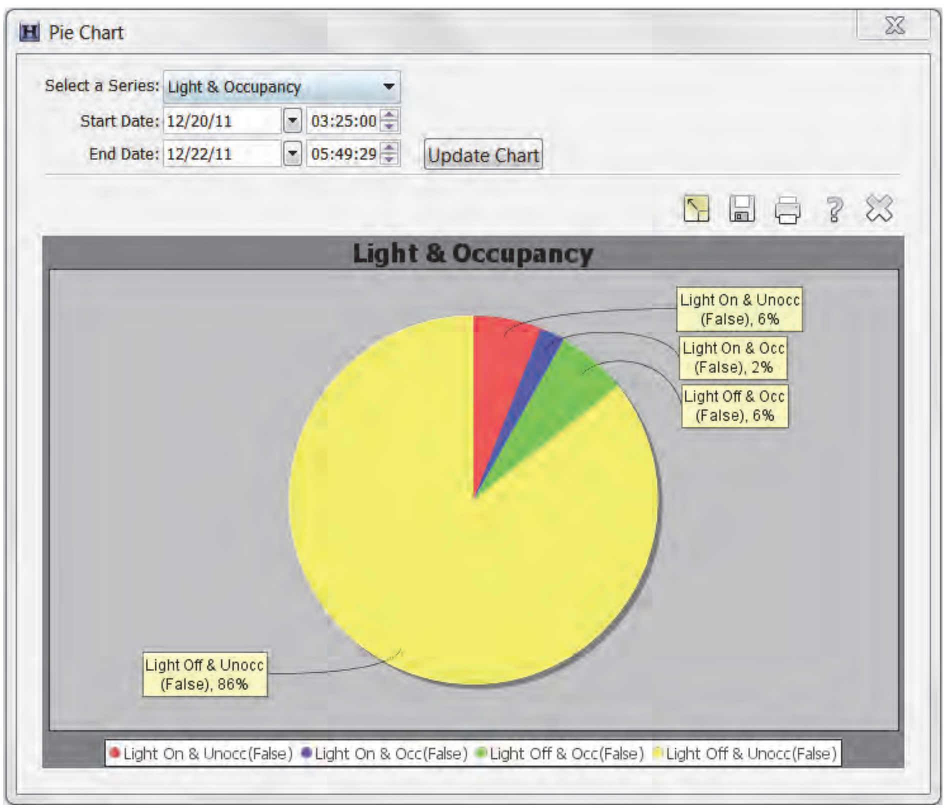
To view a pie chart:

1. Open a file from a logger with state series and plot the state series and derived series (as applicable) that you want to view in the pie chart. Note that a pie chart icon appears in the Plot Setup window if the file you are opening can be plotted in pie chart.

2. Click the Pie Chart button on the toolbar.



3. A pie chart is drawn based on the selected series. In this example, light & occupancy are plotted in the pie chart. The legend at the bottom of the chart indicates what series each piece of the pie represents. Percentages for each pie wedge are shown in the yellow boxes.



- To change the series used to generate the pie chart, click the "Select a Series" drop-down arrow and then click the Update Chart button.
- To change the timeframe used to create the pie chart, change the Start and End Date/Time as necessary and then click the Update Chart button.
- To reset the pie chart to use the Start and End Date/Time for the current selected series, click the Reset/Show at Full Scale  button.
- To save the pie chart as an image (.png file), click the Save  button.
- To print the pie chart, click the Print  button.

4. When you are done viewing pie charts, click the Close button.

Notes:

- The pie chart button on the toolbar will only be enabled when one or more state series is plotted. If you have plotted data and the pie chart button is not enabled as expected, close the plot. Reopen the file and make sure you select the state series from the Plot Setup window. Note that if the sensor channels were configured as runtime instead of state, then pie charts will not be available.
- If you merge datafiles, pie charts may not function properly if the time overlaps between merged series. If you are having difficulty viewing a pie chart for a merged file, try returning to the original separate files to view the individual pie charts from each file.
- If you are working with a plot that has two series, such as Light and Occupancy and you crop one of those series, the time range for the pie chart data will be constrained to the shorter of the two series.
- If you paste a new state series into the plot, it will also be available from the Select a Series pull-down list. You will need to select the series to view it in a pie chart; it will not display automatically.

Printing Plot Elements

Printing a Graph

You can simply print the graph, or you can set up the page and preview it before printing.

To set up the paper for printing the graph:

1. From the File menu, choose Page Setup.
2. Change the paper type, orientation, and margins as necessary and click OK.
3. From the File menu, choose Print Preview.
4. Zoom as necessary.
5. Click the Print icon to print directly from Print Preview. Or, click Close to exit the preview window without printing.

To print the graph:

1. From the File menu, select Print or click the Print icon on the toolbar.
2. Select the appropriate printer, if applicable, and click OK.

Printing Points and Details

You can print all the data in the Points or Details panes. From the File menu, select Print Points (available only with Java 1.5 or higher) or Print Details.

If you highlight a selection of points with your mouse before choosing Print Points, you will also be given the option to print only the selected points.

Chapter 4
Modifying a Plot

Once data is plotted, there are many things you can do to further refine the plot. This includes:

- Setting Properties for Plot Elements
- Adding a Graph Label
- Selecting a Subset of the Plot (Subset Statistics Tool)
- Moving a Series from Front to Back on a Plot
- Filtering a Series
- Cropping a Series
- Hiding/Showing or Removing a Series from the Plot
- Copying a Series to Another Plot
- Merging Files
- Converting Units
- Undoing or Redoing Plot Changes
- Saving Project Files

Setting Properties for Plot Elements

You can set the properties for all the plot elements, including the axes, series, title, and legend. You can access the properties window for a plot element by selecting the Arrow tool and then right-clicking that element. Or, right-click anywhere on the plot and select Other Graph Items and then choose a particular item.

- Setting Axis Properties
- Setting Series Properties
- Setting Legend Properties
- Setting Title Properties
- Setting View Properties

There are also plotting preferences that control the global properties for all plots. To modify these settings, open the Preferences and select Plotting. With Plotting preferences, you can:

- Show or hide the Points table by default
- Show or hide the Details pane by default
- Include the sensor label in the Points table and Details pane by default
- Customize series lines for specific measurement types
- Set default minimum and maximum values for specific series types on the Value Axis

- Enable auto-scrolling to keep marked points in view while zooming
- Automatically select all data series and/or events
- Automatically label the time axis
- Mark all points in a plot by default
- Include the sensor label in the legend
- Control whether horizontal and/or vertical gridlines are displayed automatically
- Set the font style and point size used in plots
- Enable or disable the undo/redo feature

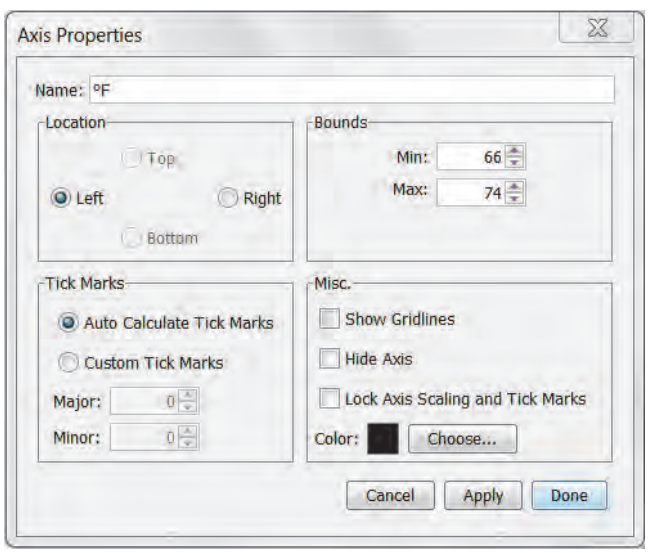
You can also use the Display preferences to set the default unit types and date/time format.

Setting Axis Properties

You can change the appearance of the time axis (x axis) and the value axis (y axis) on the plot. You can customize the axis name, change the location, bounds, tick marks, color, and more.

To change the axis properties:

1. Double-click the axis in the plot with the arrow tool, or select the axis and click the Properties icon  to open the Axis Properties window.



2. In the Name field, enter up to a 40-character name for the axis. The default name for a value axis is the unit type (for example, "°F" is the name for a temperature axis and "%" is the name for an RH axis). The time axis does not have a default name. To add "Time" as the default name for this axis, open Preferences. Select Plotting and then select Other Options. Enable the "Label the time axis" checkbox.
3. Change the location of the axis. The value axis can be located on the left or right while the time axis can be located at the top or bottom
4. By default, tick marks are auto-calculated. Numbers or values are listed next to major tick marks and minor tick marks are not numbered. To change the default tick marks, select Custom Tick Marks and then choose the values for Major and Minor tick marks as desired.

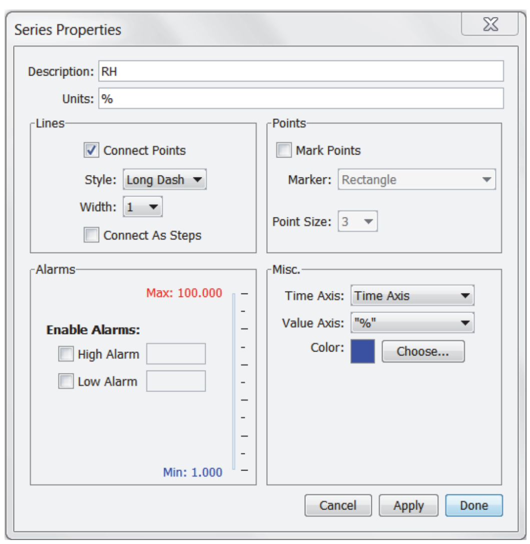
5. Change the default bounds used on each axis. For the time axis, select the dates and times you want the axis to display. For the value axis, type the minimum and maximum value you want the axis to display.
6. You can also modify the appearance of the axis with these options:
    - **Show Gridlines.** This toggles whether gridlines are displayed in the background. Gridlines are shown by default for the time axis, but not for the value axis.
    - **Hide Axis.** This controls whether the axis is displayed or temporarily hidden.
    - **Lock Axis Scaling and Tick Marks.** This controls whether the axis and associated tick marks remain in their original position when zooming or navigating with the hand tool. Locking the axis and tick marks helps to avoid inadvertently zooming or navigating to an area on the graph without data.
    - **Color.** Black is the default color for the time axis. The color of the value axis matches the series color by default. You can change the color for either axis as desired.
7. Click Apply to update the plot and keep the Axis Properties window open. Click Done to update the plot and close the window.

Setting Series Properties

A series is the group of data points you selected to display in the plot. You can change the appearance of a series on the plot including the line style, point marker, alarm values, associated axes, and color.

To change series properties:

1. Double-click the series you wish to modify or select the series and click the Properties icon  to open the Series Properties window.



2. Change the default description. Type up to a 40-character name for the series. The series name will be updated in the legend, series pane, and details pane to the new name you entered.
3. Change the default units. Enter a different unit type as needed. The unit type will be updated in the legend, series pane, and details pane to the new unit type. Note that if you subsequently convert the units while viewing the plot, your custom unit type will no longer be displayed. For example, let's say you change the unit type for a temperature series from °F to "degrees." Then, while viewing the plot,

you decide to convert the data points to Celsius. The unit type for the temperature series automatically changes to °C instead of the custom "degrees" unit that you had entered.

4. Adjust the appearance of the lines with the following options:

   - Connect Points. This controls whether the plotted data points in the series are connected with a line.
   - Style. This changes the appearance of the line used to connect the points in a series.
   - Width. This changes the width of the line used to connect the points in a series.
   - Connect as Steps. This controls whether the lines between the points in a series are connected as a curve or a step. When this option is selected, the line drawn between points keeps the value of the previous point until the next point in the series. Connecting as steps is useful when plotting state or event series.

5. Set High Alarm and/or Low Alarm thresholds. Enabling alarms will show lines on the plot for the series to indicate a visual threshold over or under which data may be falling (for example, if you want to quickly see how many points fall below 32 degrees). Alarms are available for sensor measurement series only, not for state or event series. Select the High Alarm checkbox and type a value relative to the series where you want the maximum (red) alarm line to appear. Select the Low Alarm checkbox and type a value relative to the series where you want the minimum (blue) alarm line to appear.
6. Select the Mark Points checkbox to add a marker for each data point in the series. To avoid cluttering the plot, this option is only enabled by default for series with event data or that have only one data point. If you enable Mark Points, you can change the shape of the marker and the point size.
7. You can also modify the following:

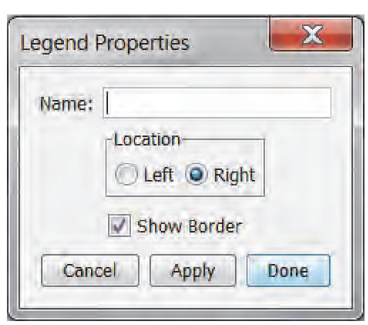
   - Time Axis. This allows you to create an additional time axis for this series. This is useful for comparing data from two different time periods.
   - Value Axis. This changes the axis being used for the series. Choose one of the axes already in view or select New Value Axis from the dropdown list to create your own.
   - Color. This changes the color used for the series.

8. Click Apply to update the plot and keep the Series Properties window open. Click Done to update the plot and close the window.

Setting Legend Properties

You can modify the Legend displayed on the plot. To change the Legend properties:

1. Double-click the Legend or right-click the plot with the arrow tool and select Other Graph Items > Legend Properties.
2. In the Legend Properties window, type a name for the Legend if desired.

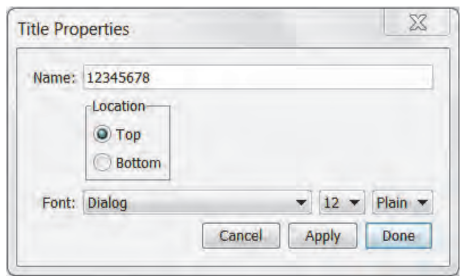


3. Set the location to either the left or right of the plot.
4. Select the Show Border checkbox to have a box around the legend. Deselect this if you do not want the box around the legend.
5. Click Apply to update the plot and keep the Legend Properties window open. Click Done to update the plot and close the window.

Setting Title Properties

You can modify the title displayed on the plot. To change the Title properties:

1. Double-click the plot title or right-click the plot with the arrow tool and select Other Graph Items > Title Properties.
2. In the Title Properties window, change the default name if desired. The name originated from the Plot Setup window.

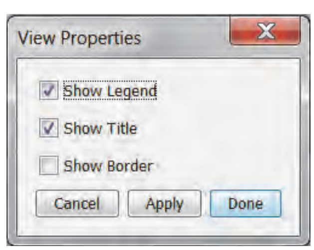


3. Set the location of the title to either the top or bottom of the plot.
4. Adjust the font, point size, and style.
5. Click Apply to update the plot and keep the Title Properties window open. Click Done to update the plot and close the window.

Setting View Properties

You can show or hide certain plot elements. To change the View properties for the plot:

1. Right-click the plot and select View Properties.
2. In the View Properties window, select the Show Legend checkbox if you want the Legend to be displayed on the plot. Deselect this checkbox if you do not want to see the Legend on the plot.

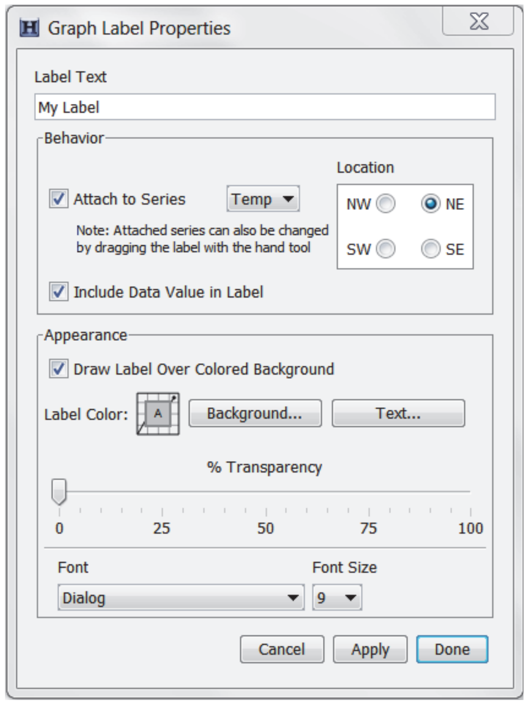


3. Select the Show Title checkbox if you want a title to be displayed on the plot. Deselect this checkbox if you do not want to see a title.
4. Select the Show Border checkbox if you want a border to be drawn around the plot. Deselect this checkbox if you do not want a border around the plot.
5. Click Apply to update the plot and keep the Title Properties window open. Click Done to update the plot and close the window.

Adding a Graph Label

You can add multiple labels to a graph to identify specific points or call attention to a region of the graph. To add a graph label:

1. Right-click the graph at the desired location and choose Add Graph Label from the pop-up menu to open the Graph Label Properties window. Or, select Add Graph Label from the Edit menu. **Note:** To change an existing label, double-click the label or select the label and click the Properties  icon on the toolbar.



2. Type up to a 24-character name for the label.
3. Select the Attach to Series checkbox to attach the label to a point on the series. Choose the name of the series to attach it to from the drop-down list. Select the Include Data Value in Label checkbox to display the value of the point in the label. Select the compass point to described the preferred location of the label relative to the labeled point. **Important:** This indicates the preferred location of the label (space permitting) with respect to the data point it references. This is only available when the label is attached to a series.
4. Adjust the appearance of the label with these options:
    - Draw Label Over Colored Background. Select this option if you want the label to appear in a box with a colored background.
    - Label Color Background. If you chose to give the label a colored background, click this button to select a background color.
    - Label Color Text. Click this button to select a color for the label text.
    - % Transparency. Adjust the label's transparency, which refers to the ability to see the graph through the label. At 0%, the label is opaque and you cannot see the graph through it. At 100%, the label is invisible and only the graph can be seen.
    - Font. Select a font for the label text.

- Font Size. Select a font size for the label text.

5. Click Apply to update the plot and keep the Graph Label Properties window open. Click Done to update the plot and close the window.

Use the hand tool to drag the label to another location if necessary. If the label is attached to a series, you can drag the label to attach it to any other point on the graph. (The hand tool must be close enough to a point to attach the label.) Labels that are attached to a point will move with that point during zooming and panning. Free-floating labels do not move during zooming and panning.

To delete a label from the graph, select the label you wish to remove and press the Delete key, or right-click the label and choose Remove from the menu that appears.

Selecting a Subset of the Plot (Subset Statistics Tool)

The Subset Statistics tool allows you to select a subset, or a range of data, of a graph, and display the maximum, minimum, average, and standard deviation for the measurements in that range (HOBOware Pro only).

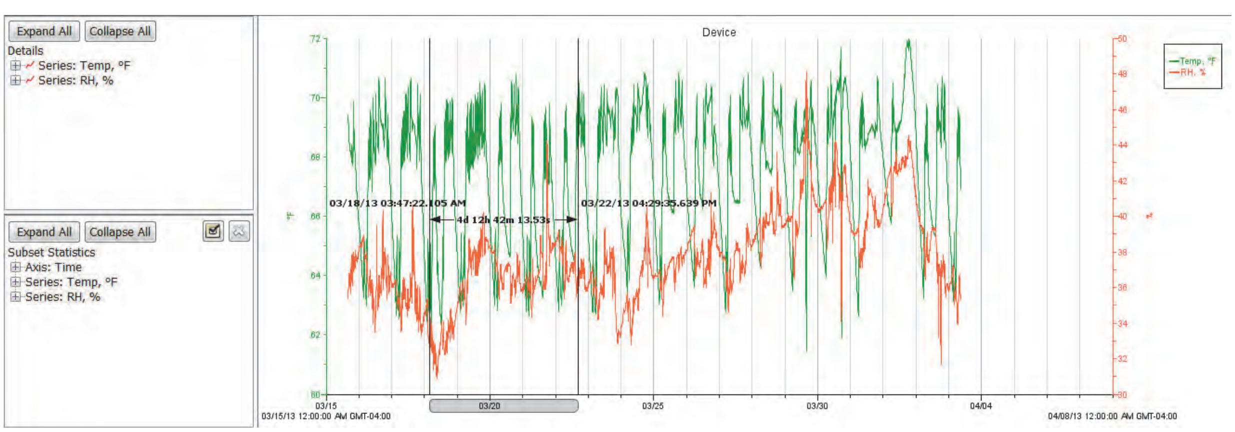
To use the Subset Statistics tool:

1. Select the Subset Statistics tool from the toolbar. The mouse cursor will change to the Subset Statistics Tool icon.
2. Draw the subset on the plot. With the left mouse button, click within the graph to define the start time of the subset and drag to the right. Release the mouse button when you reach the end time of the subset.

The graph subset appears in the graph and the subset statistics pane appears beneath the Details pane as in the example below. Two black vertical indicators appear on the graph to show the range of the subset with date/time labels marking the start and end of the range. To move the vertical indicators and date/time labels, press the up or down arrow keys (make sure the Subset Statistics Tool is selected first).

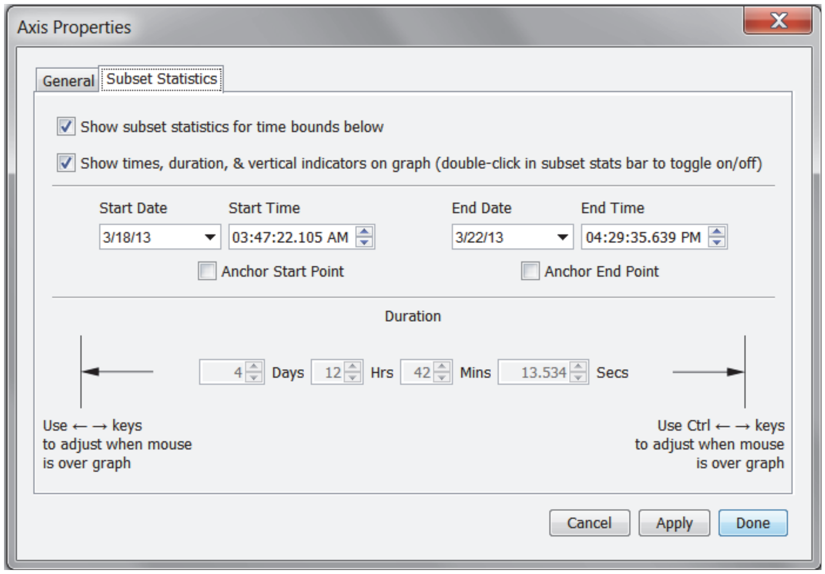
A subset bar is added to the time axis. Double-click this bar to toggle between showing and hiding the vertical indicators and date/time labels. If the plot has one than more time axis, this bar is attached to the one that was created when you first displayed the plot. Click inside the subset bar to drag it to a different time axis.

To quickly adjust the start or end of the subset, click and drag the left or right end of the subset bar on the time axis (make sure the Subset Statistics Tool is selected first). You can also use the arrow keys to move the left boundary and Ctrl+arrow key (or Command-arrow key on Mac) to move the right boundary. Place the cursor in the middle of the subset bar and drag it to move the entire range left or right.



To further refine the subset range:

1. Click the checkmark icon  in the Subset Statistics pane.

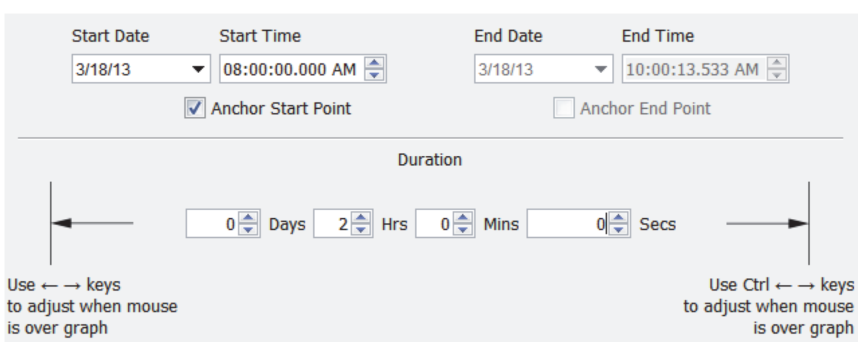


2. The two checkboxes are enabled by default. Deselect "Show subset statistics for time bounds below" if you want to remove the subset from the current time axis. Note that only one time axis can have a subset. If you enable subset statistics for one time axis when another time axis already has a subset, the other time axis's subset will be removed.

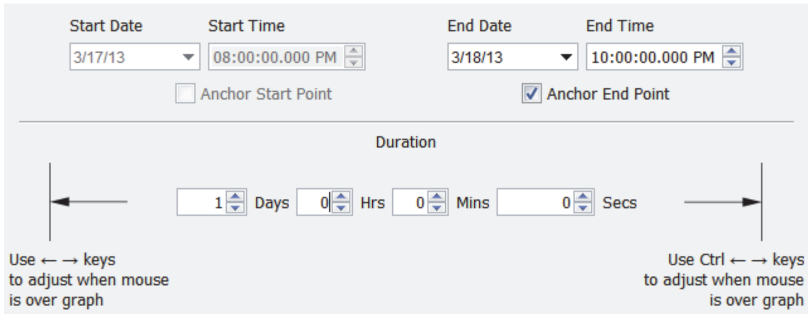
   Deselect the "Show times, duration, & vertical indicators on graph" checkbox to toggle the display of subset indicators and labels on the plot. If you disable this option, the Subset Statistics pane and the shaded subset statistics bar on the time axis will still remain visible.

3. The easiest method to set a range for the subset is to indicate a fixed Start Date/Time or End Date/Time and then indicate the duration. Alternatively, you can enter both a Start Date/Time or End Date/Time without specifying a duration.

   For example, to set a range beginning at 8:00 a.m. on 3/18/13 with a duration of 2 hours, set the Start Date to 3/18/13 and the Start Time to 8:00:00.000 AM. Select the Anchor Start Point checkbox and set the Duration to 2 hours as shown below.



As another example, to set a range of 1 day ending at 10:00 PM on 3/18/13, set the End Date to 3/18/13 and the End Time to 10:00:00.000 PM. Select the Anchor End Point checkbox and set the Duration to 1 day.



To remove the subset and related elements:

- Right-click the plot and select Remove Subset Stats,
- From the View menu, select Remove Subset Stats, or
- Click the X icon in the upper-right corner of the Subset Statistics pane.

Moving a Series from Front to Back on the Plot

You can shuffle the order of series by moving a series to the front or back on the plot. This is helpful if one series is hidden behind another. It also changes the order of series in the Details pane, Points table, and the legend.

To change the order of the series:

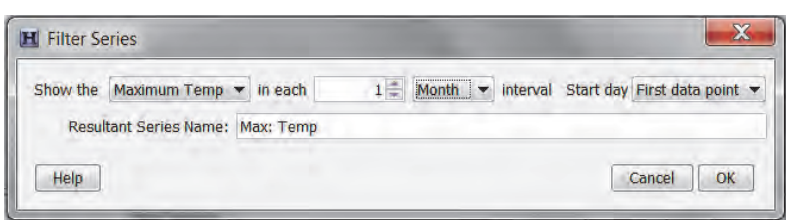
1. Select the arrow tool .
2. Select the series you wish to move.
3. Right-click and select either Bring Series to Front or Send Series to Back.

Filtering a Series

You can filter data from existing series in the plot to create a new statistical series showing calculated data such as average, minimum, and maximum values over a specified period of time. This filter applies to existing data files only; there is an additional filter tool available when launching most loggers.

To filter a series in a plot:

1. Select the series with the arrow tool , right-click it and select Filter Series. Or from the Edit menu, select Filter Series.
2. Select the statistic to use for the filter and the interval. If you select an interval of week or month, select "First data point" for the filter to start on the date and time of the first logged data point or select the day of the week or month you want the filter to start (the filter will start at midnight on the day selected). In the following example, "Maximum Temp" in each month is selected starting with the first data point. Note that the options available vary depending on the series type.

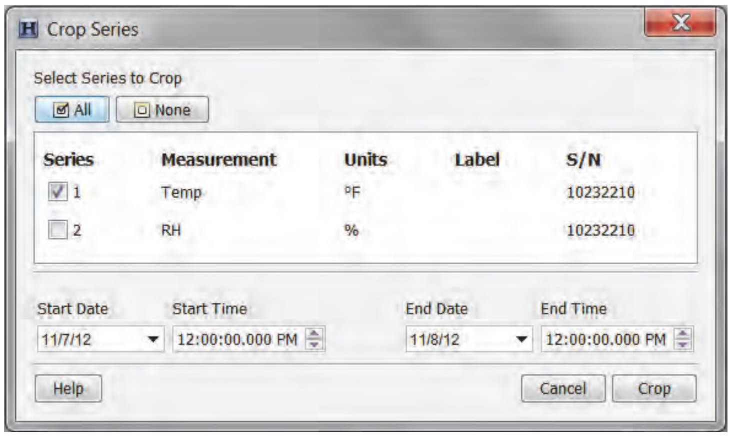


3. Type a Resultant Series Name or use the default name entered based on the filter type.
4. Click OK. The new series is added to the graph, the Details pane, and the Points table. Note that when you apply a filter, the graph rescales to accommodate all the displayed data.

Cropping a Series

You can crop one or more series in a plot to focus on a particular date/time range instead of the default range in HOBOware Pro. To crop a series:

1. With the arrow tool, right-click the series you wish to plot and select Crop Series. To crop multiple series, right-click anywhere in the plot (without a series selected).
2. In the Crop Series window, make sure the series you want to crop is selected. Deselect any series you do not want to crop.



3. Enter the new Start Date/Time and End Date/Time for the series. The boundaries are limited to the minimum and maximum date/time of the Time Axis. If subset statistics have been added to the plot, the start and end points on the subset will be redefined automatically based on how it is affected by cropping.
4. Click the Crop button. The plot displays the cropped series. The Details pane and Points table are both updated to reflect the new cropped series.

Hiding/Showing or Removing a Series from a Plot

You can hide or show a series in the plot and in the Points table. This is helpful if the datafile contains multiple series and you cannot easily view them all together. You can then show or hide each series as you wish.

You can hide a series by:

- Right-clicking the series in the Details pane and selecting Hide Series.
- Selecting the series and then selecting Hide Series from the Edit menu.
- Selecting the series, right-clicking the plot, and then selecting Hide Series.

Press and hold the Shift key while hiding the series to prevent the plot from rescaling.

Once a series is hidden, it is grayed out in the Details pane. You can show the series again by:

- Right-clicking the series in the Details pane and selecting Show Series.
- Selecting the series in the Details pane and then selecting Show Series from the Edit menu.
- Selecting the series in the Details pane, right-clicking the plot, and then selecting Show Series.

To show all previously hidden series, right-click a series in the Details pane, right-click the Plot, or select the Edit menu and then select Show All Hidden Series.

You can also completely remove a series from the Details pane as well as the plot and the Points table. If you remove a series, it can only be recovered by reopening the original datafile or a saved project file that contains that series. To remove a series:

1. Select the arrow tool from the toolbar.
2. Click the series you wish to remove and press the Delete key or select Remove from the Edit menu. You can also right-click the series in the plot and click Remove or right-click the series in the Details pane and select Remove Series.

Copying a Series to Another Plot

To copy a series from one plot to another:

1. Open the source plot (the plot that includes the series you want to copy) and the destination plot (the plot where you want to paste the series).
2. In the source plot, choose the arrow tool and select the series you want to copy. From the Edit menu, select Copy Series or right-click the series and select Copy Series. Or, press Ctrl+C on Windows or Command-V on Macintosh.
3. Switch to the destination plot. From the Edit menu, select Paste Series or right-click the plot with the arrow tool and select Paste Series. Or, press Ctrl+V on Windows or Command-V on Macintosh.

The new series is added to the graph, the Details pane, and the Points pane.

Overlaying Series

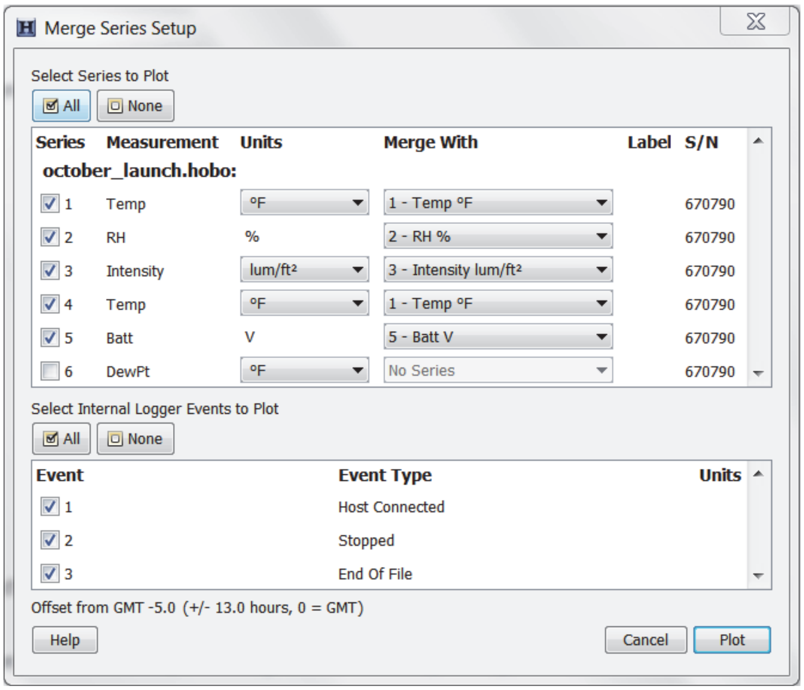
If the series you want to copy to the plot was logged at a different time, you will need to make some adjustments to the plot in order to view the series together.

1. Display the source plot(s) and the destination plot.
2. On the destination plot, choose the arrow tool
3. Double-click the time axis to access the Axis Properties window.
4. In the Axis Properties window, time a unique name in the Name field and click Done.
5. Copy a series from a source plot (right-click the series and select Copy Series).
6. Paste the series into the destination plot (from the Edit menu, select Paste Series).
7. Double-click the new time axis for the pasted series to open the Axis Properties window.
8. Type a unique name in the Name field, different than the name used in step 4, and click Done.
9. Repeat steps 5 through 8 for each series you want to paste.
10. Identify the periods of interest in each series you want to combine and note the times for each. Also, determine which period is the longest; this should be the length of time shown on each axis.
11. Double-click a time axis and adjust its Min and Max bounds. The new bounds should include the period of interest for the series, and be the same length as the longest period identified in the original time axis in the destination plot. Repeat for each time axis.
12. Use the hand tool on each time axis to adjust the series horizontally as needed.

Merging Files

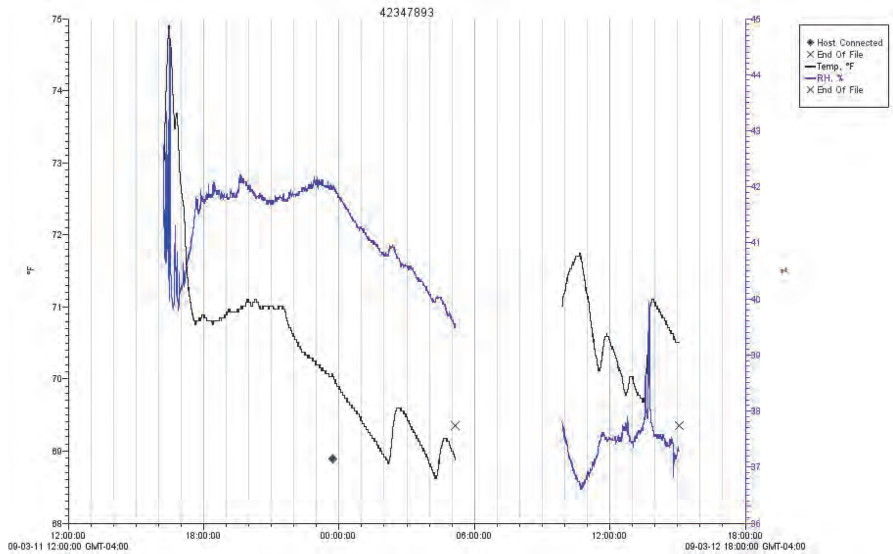
This feature allows you to combine multiple datafiles one file. Note that only series of the same type and name can be merged and there cannot be an overlap in the time in the series.

1. Open the first file (oldest).
2. From the File menu, select Merge Datafile(s).
3. Select the datafiles you want to merge and click Open.
4. Select the series to plot. All series available in the selected datafiles are listed in the Select Series to Plot section. Click the checkbox to add or remove series as necessary, or select the All or None buttons in that section to select all series or no series accordingly.



5. All matching series available in the selected series will be populated with the corresponding series listed in the Merge With column. Each new series can only be merged with the series of the same measurement type and units. If no matching series is available in the plot, the Merge With column will display No Series for that series. If a matching series is found, you can still append the series without merging by choosing No Series from the corresponding drop-down list in the Merge With column. The series will be appended to the plot without being merged with any series.
6. Select any internal logger events to plot, if applicable. Click the checkbox to add or remove each event as necessary, or select the All or None buttons in that section to select all events or no events accordingly.
7. Click the Plot button to merge the selected series with their matching series. Save the new plot as a project file if desired.

There will be a gap between the last sample in the older series and the first sample in the next series as shown here in both the Temperature and RH series.



After the series have been merged, the Details Pane will be regenerated and the Series Statistics will be recalculated. The Points Table will be regenerated and will show samples of both series in one column. The new logger information is added to the Details Pane, showing the specific information about the different loggers that collected the data samples.

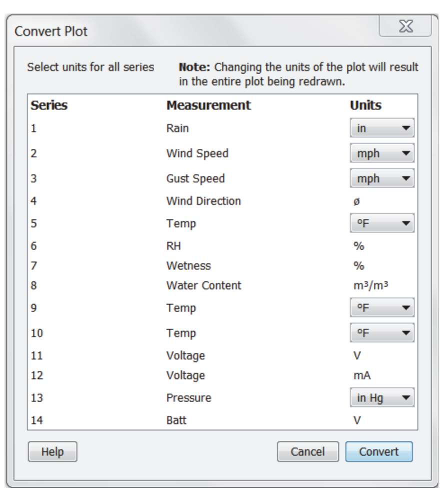
Converting Units

Plots display data points in either SI or US units as defined within the Preferences (select Display and then Default Unit System). You can switch between SI and US units on a single series or an entire plot without changing the overall system preferences.

To change the units for a single series, right-click the series with the arrow tool and select Convert Series Units and then select the unit you want to use.

To change the units for multiple series within the plot, click the Units icon  on the toolbar or select Convert Units from the Edit menu.

If a series can be configured with multiple units, there will be drop-down list in the units field as in the example below. Select the desired units from the drop-down list for all the series you wish to change and then click Convert. This changes the units displayed on the axis, in the legend, in the Details pane, and in the Points table.



1. For each series that supports unit options, select the desired units from the drop-down list
2. Click **Convert**.

This changes the units displayed on the axis, in the legend, in the Details pane, and in the Points table.

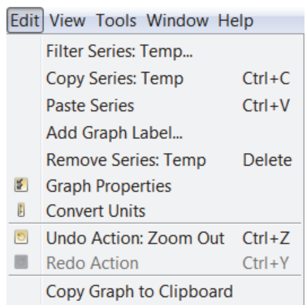
Undoing and Redoing Plot Changes

You can undo and redo changes made to the plot display, including zooming, panning, crosshair placement, graph and axis properties modifications, and more.

To undo the most recent change, click the Undo Action icon on the toolbar or select Undo Action from the Edit menu.

To redo the most recent change that had previously been undone, click the Redo Action icon on the toolbar or select Redo Action from the Edit menu.

When using the Edit menu for Undo or Redo, the most recent change is listed with the menu choice. In the following example, the most recent change that can be undone is to "Zoom Out."



HOBOware keeps track of the changes that you make within each plot window and temporarily stores them as "undoable actions." To see a complete list of all the actions that can be undone or redone, click the down arrow to the right of either icon on the toolbar.

The number of undoable actions stored is set within the plot preferences. You can configure HOBOware to either store a specific number of undoable actions or an unlimited number. In addition, you can enable or disable the feature altogether. Note that storing an unlimited number of actions can impact HOBOware performance on slower computers.

Saving Project Files

A project file (.hproj) is a plot that you have customized using the various features and tools of HOBOware. When you open a project file, the plot appears as it did when you saved the project file and contains all of the same data.

To save your current data with a customized view of the plot, click the Save icon on the toolbar, or choose Save Project from the File menu. To open an existing project file, choose Open Project from the File menu.

Using Data Assistants

With Data Assistants, you can create new series by combining data recorded by the logger with additional data for analysis. For example, the kWh Assistant converts logged pulse data from an energy transducer to kWh, average kW, and energy cost.

When you read out a logger or open a datafile, all available assistants are listed in the Data Assistants section at the bottom of the Plot Setup window. To use a Data Assistant, click the assistant name to select it, and then click the Process button.

For some data loggers, you can also run the Linear Scaling, Pulse Scaling, and kWh Data Assistants from the Launch Logger window to create additional data series that are automatically available each time you read out the logger and open the resultant data file. To use an assistant from the Launch Logger window, click the Scaling or kWh button and then double-click the desired assistant, or select the assistant and click the Create button.

The following Data Assistants are available in both HOBOware and HOBOware Pro:

- **Linear Scaling Assistant.** Use the Linear Scaling Assistant to convert a data series from a compatible sensor to some other measurement. You enter two raw values and their corresponding measurement values. The conversion must be based on a linear relationship. Nonlinear scaling is not available.
- **Pulse Scaling Assistant.** Use the Pulse Scaling Assistant to convert a data series from a compatible sensor to some other measurement. You enter a raw value and its corresponding measurement value. The Pulse Scaling Assistant can be run during Plot Setup or at Launch.

These Data Assistants are available in HOBOware Pro only:

- **Barometric Compensation Assistant.** Use the Barometric Compensation Assistant to compensate for barometric pressure and create a water level or sensor depth series. The BCA uses water pressure data from a HOBO U20 or U20L Water Level logger and additional information you provide.
- **Conductivity Assistant.** Use the Conductivity Assistant to apply compensation to absolute conductance data from a HOBO U24 Conductivity logger.
- **Dissolved Oxygen Assistant.** Use the Dissolved Oxygen Assistant to generate a series adjusted for salinity and a series for percent saturation based on data from a HOBO U26 Dissolved Oxygen logger. Also use this assistant to enter field calibration readings to compensate for fouling.
- **Grains Per Pound Assistant.** Use the Grains Per Pound Assistant to calculate the absolute amount of water in the air, based on temperature, humidity, dew point, and altitude. You can also create an altitude-corrected dew point series.
- **Growing Degree Days Assistant.** Use the Growing Degree Days Assistant to calculate growing degree days based on temperature data spanning at least one full calendar day (midnight to midnight). Growing degree days are used for agricultural and turf management applications, such as estimating harvest time or pest growth.
- **kWh Assistant.** Use the kWh Assistant to convert logged pulse data from a WattNode, Veris, or other energy transducer to kWh, average kW, and energy cost. The kWh Assistant can be run during Plot Setup or at Launch.

Default Settings

The parameters last entered into any given Data Assistant will be the default used the next time the Data Assistant is run, unless it is being used to edit existing series. If you run a Data Assistant at Plot Setup time and then later you run it from the Launch Logger window, the default values are the value you entered at Plot Setup time.

Hiding Assistants

To prevent unwanted assistants from appearing in the Plot Setup window, or to bring back assistants that you have previously hidden, click the **Manage** button. This will open the Preferences window to allow you to change these settings.

Software Updates

If you have an Internet connection, HOBOware can periodically check the Onset website for software updates. This includes updates to your data assistants.

The default is to check once per week, but you can configure HOBOware to check daily or monthly. In Preferences, go to the General pane and select Startup. In the Check for HOBOware Updates drop-down list, select how frequently you want the software to check for updates.

You may also check for updates manually at any time. Choose Check for Updates from the Help menu.

Installing a Data Assistant

Data Assistants are installed automatically. There may also be times when a new Data Assistant is available between HOBOware releases and needs to be installed manually. To do this, click the Load button on the Plot Setup window and select the assistant's .jar file. **Note:** On Windows, you must be an administrator to load a new Data Assistant. To temporarily run HOBOware as an Administrator, right-click the HOBOware icon and select Run as Administrator. Enter the Administrator name and password as prompted.

License Agreement

This software is furnished in accordance with a separate license agreement included with the software, and subject to any restrictions set forth therein. For more information about Onset's licensing terms and policies, contact Onset Customer Service at 1 800 LOGGERS, or visit http://www.onsetcomp.com/corporate/legal.

Linear Scaling Assistant

The Linear Scaling Assistant converts a data series from a compatible sensor to some other measurement when you enter two raw values and their corresponding measurement values. The conversion must be based on a linear relationship. Nonlinear scaling is not supported.

Supported Sensors

This assistant is available for the following sensors:

- CABLE-2.5-STEREO Voltage Input Cable
- CABLE-4-20-mA Input Cable
- CABLE-ADAPx
- S-CIA-xxxx 12-bit 4-20mA Input Adapter
- S-VIA-xxxx 12-bit Voltage Input Adapter
- S-FS-CVIA FlexSmart™ Analog Module
- S-FS-TRMSA FlexSmart TRMS Module
- U30 Analog Sensor Port
- S-LWA-xxxx Leaf Wetness
- S-SMx-xxxx Soil Moisture

The Linear Scaling Assistant can be applied only to logged data from these sensors.

Other Types of Scaling

There are also other types of scaling available that may apply to your configuration:

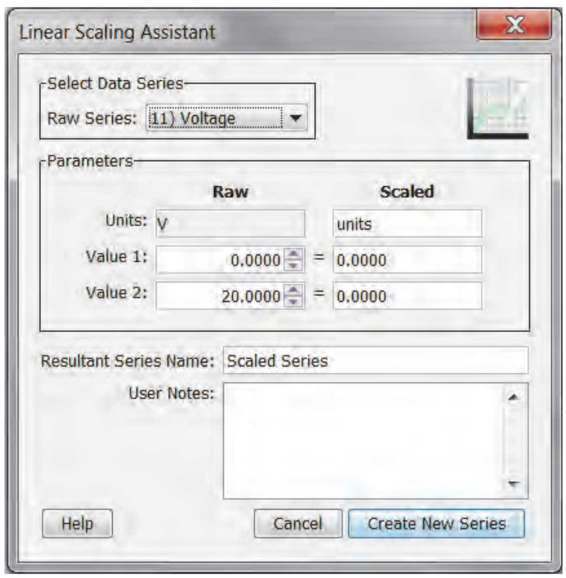
- FlexSmart™ modules are set up for scaling prior to launch, as part of the module configuration process. You can later rescale these scaled series using the Linear Scaling Assistant if you need to create a different measurement. See Configuring an Analog Module/Port.
- The Pulse Scaling Assistant is similar to the Linear Assistant, but only allows scaling of pulse data.

Using the Linear Scaling Assistant

1. **At launch time:** Using a logger with a sensor that supports scaling at launch time, click the Launch icon on the toolbar. Click the Scaling button. Double click the assistant name or select the assistant and click the Create button.

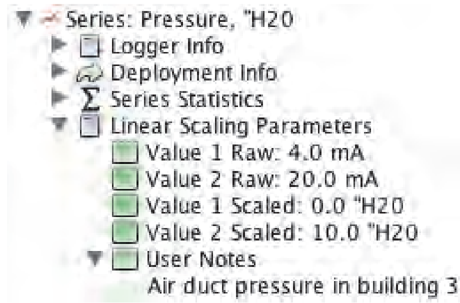
   At plot setup: Read out a logger or open a file that supports linear scaling. Select the Linear Scaling Assistant and click the Process button.

2. In the Linear Scaling Assistant window, choose the data series you want to convert from the Raw Series drop-down list.



3. In the Scaled column of the Parameters panel, type the units name for the scaled series and enter the scaled values in the Scaled column to correspond with the numbers in the Raw column. (The default values in the Raw column are based on the high and low values supported by the sensor, but you may use different values, as long as those values fall within the sensor's range.) These numbers establish a linear relationship between raw and scaled values.
4. In the Resultant Series Name field, keep the default name or type a new one.
5. Type any User Notes concerning the series you are creating (optional).
6. Click the Create New Series button.
7. If you ran the assistant from the Launch window, the Scaling button displays the number of newly created series. If using this assistant while plotting, the new series is listed and selected in the Plot Setup dialog. Click the Plot button to display the series.

8. The scaled series will appear in the plot immediately or when you read out the logger if configuring this at launch time. The settings for the scaled series are listed in the Details pane of the plot:



After the plot is displayed, you may apply minimum, maximum, and average filters to the scaled series as you would for any sensor data series.

Pulse Scaling Assistant

The Pulse Scaling Assistant converts a data series from a compatible sensor to some other measurement when you enter a raw value and its corresponding measurement value. The conversion must be based on a linear relationship. Nonlinear scaling is not supported

The Pulse Scaling Assistant can be run from the Launch window (Pre-set Parameters) or from the Plot Setup window. If you run the assistant from the Plot Setup window, you must run the assistant each time you readout the logger or open a datafile.

Supported Sensors

This assistant is available for the following sensors:

- S-UCA-xxxx and S-UCC-xxxx Electronic Switch Pulse Input Adapter
- S-UCB-xxxx and S-UCD-xxxx Contact Closure Pulse Input
- Raw Pulse sensors connected to HOBO UX series loggers that support pulse logging

Other Types of Scaling

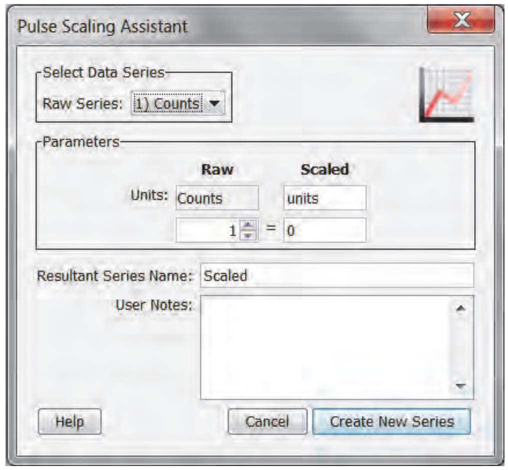
There are also other types of scaling available that may apply to your configuration:

- FlexSmart™ modules are set up for scaling prior to launch, as part of the module configuration process. See Configuring an Analog Module/Port.
- The Linear Scaling Assistant is similar to the Pulse Scaling Assistant, but has slightly different input options and is compatible with a different group of sensors. See the Linear Scaling Assistant for more information.

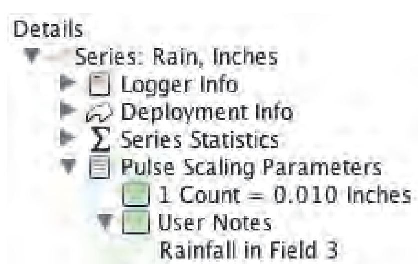
Using the Pulse Scaling Assistant

1. **At launch time:** Using a logger with a sensor that supports scaling at launch time, click the Launch icon on the toolbar. Click the Scaling button. Double click the assistant name or select the assistant and click the Create button.
2. **At plot setup:** Read out a logger or open a file that supports pulse scaling. Select the Pulse Scaling Assistant and click the Process button.

3. In the Pulse Scaling Assistant window, choose the data series you want to convert from the Raw Series drop-down list.



4. In the Scaled column of the Parameters panel, enter the units name for the scaled series and enter a scaled value in the Scaled box to correspond with the number in the Raw box. These numbers establish the relationship between the raw and scaled values.
5. In the Resultant Series Name field, keep the default name or type a new one.
6. Type any User Notes concerning the series you are creating (optional).
7. Click the Create New Series button.
8. If you ran the assistant from the Launch window, the Scaling button displays the number of newly created series. If using this assistant while plotting, the new series is listed and selected in the Plot Setup window. Click the Plot button to display the series.
9. The scaled series will appear in the plot immediately or when you read out the logger if configuring this at launch time. The settings for the scaled series are listed in the Details pane of the plot:



After the plot is displayed, you may apply filters to the scaled series as you would for any other series. In addition to the minimum, maximum, and average filters that are available for most series, the scaled pulse series allows you to create a new series showing totals over a period of time.

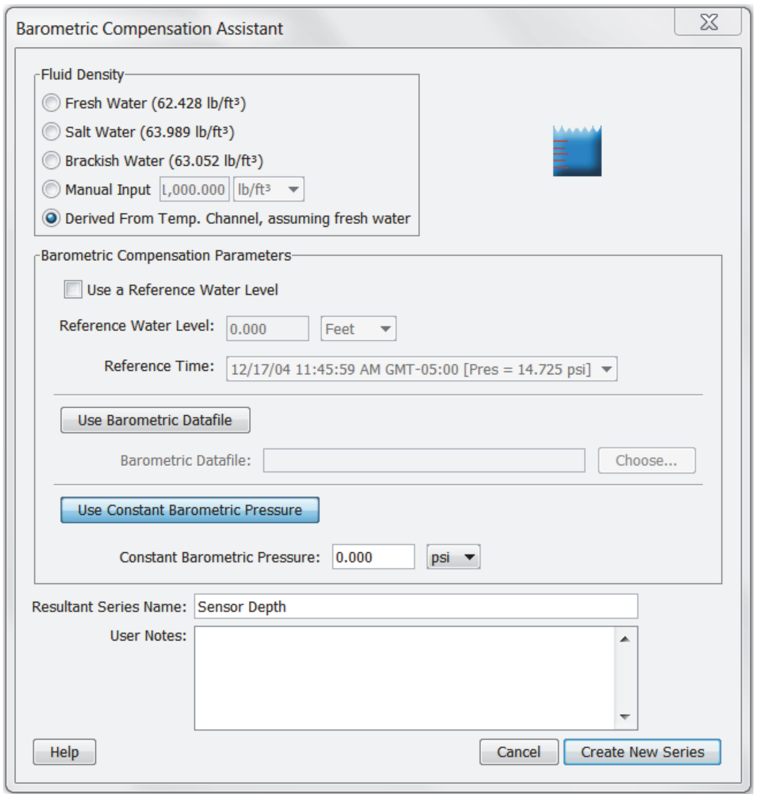
Barometric Compensation Assistant

The Barometric Compensation Assistant uses water pressure data from a HOBO U20 or U20L Water Level Logger and additional information from you to compensate for barometric pressure and create a water level or sensor depth series.

After you use the assistant and display the plot, you may apply filters to the new series.

To create a water level or sensor depth series:

1. Read out a logger or open a datafile that contains water pressure data from a U20 or U20L Water Level Logger.
2. From the Plot Setup window, select Barometric Compensation Assistant and click Process.
3. Provide Fluid Density information by choosing a water type (fresh, salt, or brackish), entering a specific constant value, or using the temperature series (if logged) to use temperature-compensated density assuming fresh water.



4. To enter a reference water level, check the Use a Reference Water Level box, enter the water level, and indicate whether it is in feet or meters.

   - Enter the water level as a *positive number* if it is measured upward from a reference point below the water's surface, such as the water's height above sea level.
   - Enter the water level as a *negative* number if it is measured downward from a reference point above the water's surface, such as a well cap.

Then, from the drop-down, select the logged time and value that is closest to the time when you measured the water level.

   - When selecting a logged value and time to link to the reference level, make sure the logger readings have stabilized. When a logger is first deployed in water, it takes some time for its temperature to reach equilibrium. You will get the best accuracy if you link your reference reading to a stabilized logger reading.
   - When using a reference water level, the resulting series data will contain water level values relative to this reference level. If you do not use a reference water level, the resulting series data will contain values for absolute sensor depth.

5. You can either use a barometric data file from another source, or enter a fixed barometric pressure. For the most accurate water level results, use a reference water level and a barometric data file. The barometric data can come from another HOBO U20 or U20L or U20L Water Level Logger in air; a HOBO

Weather Station, HOBO Micro Station, HOBO U30, or HOBO Energy Logger; or a text file from another source.

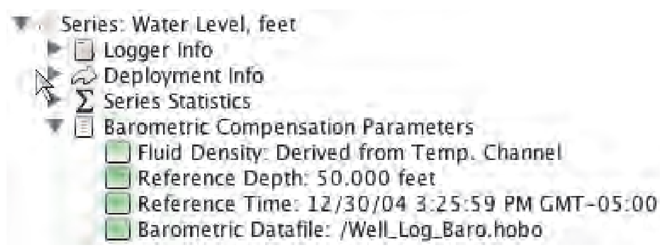
- To use another file to provide barometric information, click the Use Barometric Datafile button and enter (or browse to) the name of a .hobo, .hsec, .dtf, .dsec, .csv, or .txt file that contains a barometric pressure series from an overlapping time period. You will have the option to display this series on the plot. **Important**: Text files must follow specific requirements as described in Import Text Files Requirements.
- To use a constant pressure value, click the Use Constant Barometric Pressure button. Enter the constant value and indicate whether it is in psi or kPa. (You cannot use a constant pressure value in combination with a reference water level.)

6. Keep the default Resultant Series Name, or enter a new one. You may also enter User Notes concerning the series you are creating.

   Note: Your settings are retained, so you do not need to re-select your density and barometric file each time you use the Barometric Compensation Assistant as long as they still apply to the new water level data set.

7. Click Create New Series. The new series is listed and selected in the Plot Setup window. You can click Process on the Plot Setup window again to create another series using different barometric compensation parameters.

8. Click the Plot button. The scaled series will appear in the plot and the settings for the scaled series are listed in the Details pane:



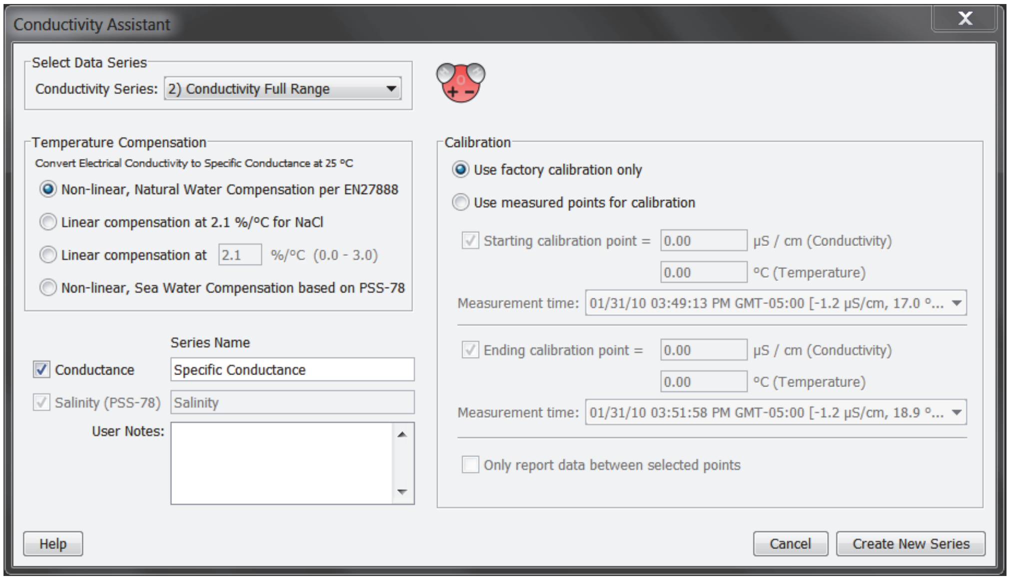
After the plot is displayed, you may apply minimum, maximum, and average filters to the new water level or sensor depth series as you would for any sensor data series in HOBOware Pro.

Conductivity Assistant

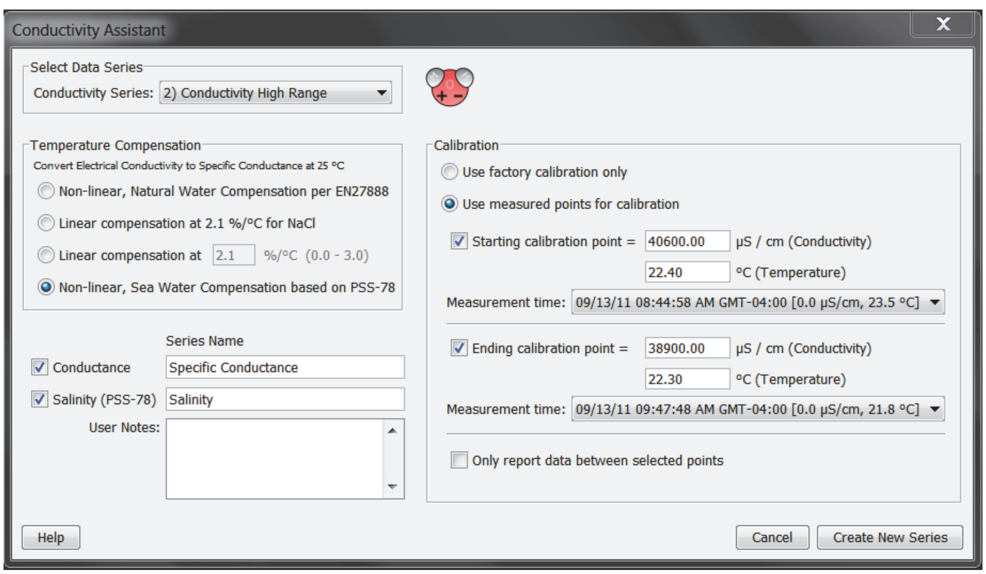
The Conductivity Assistant converts raw conductivity data from a U24 logger to Specific Conductance and/or Salinity. You can also use it to enter field calibration measurements recorded at the beginning and end of a deployment for calibration and to compensate for drift and sensor fouling effects.

1. Read out a U24 series logger or open a datafile from a U24 logger.
2. From the Plot Setup window, select the Conductivity Assistant and click the Process button.
3. In the Conductivity Assistant window, select the conductivity series that corresponds to the range of your data. **Note:** If you only selected one range at launch time, only one series will be listed.

- For the U24-001 logger, select either Conductivity Low Range when the data is always less than 1,000 µS/cm or select Conductivity Full Range (default) when the data goes above 1,000 µS/cm as shown below.



- For the U24-002-C logger, select either Conductivity Low Range when the data is always less than 10,000 µS/cm or select Conductivity High Range (default) when the data goes above 10,000 µS/cm as shown below.



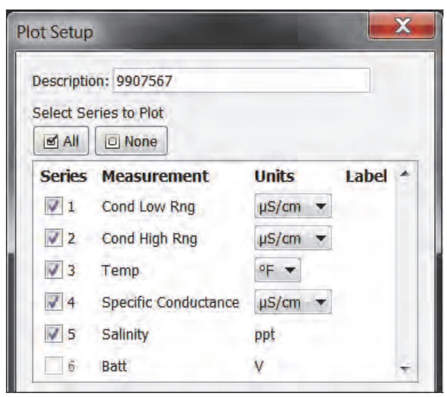
4. Select your desired Temperature Compensation method.
   - Use "Non-linear, Natural Water Compensation per EN27888" for freshwater lakes and streams.
   - Use "Linear compensation default at 2.1 %/°C" or "Linear compensation at <your own value>" for NaCl solutions or other linear solutions.
   - Use "Non-linear, Sea Water Compensation based on PSS-78" for salt water or salt marshes.
5. Select a Calibration Method. By default, data is calibrated using the factory calibration. To enter your own calibration values, select "Use measured points for calibration" and then enter temperature and actual conductivity (not specific conductance) values from your calibration readings taken with a field meter. These field measurements will be used to provide calibrated conductivity and salinity data

series by adjusting the data as a percentage of the reading. See *Calibration* below for more information.

- Starting and Ending Value: This method calibrates your data and adjusts for sensor drift or fouling. This assumes there is a linear change in calibration adjustment required.
- Starting value only: All readings are adjusted up or down by a fixed percentage of the reading based on this calibration point.
- Ending Value Only: The factory calibration value is used as the starting point. This assumes there is a linear change in calibration adjustment required.

Note: You cannot use a zero-point calibration solution for starting and ending values. The first data point cannot be used as the ending value; consider using that as the starting value instead.

6. Select the Only Report Data Between the Selected Points checkbox if you want readings from before or after the calibration points to be removed from the resulting series.
7. In the Series Name field, keep the default name or type a new one.
8. Type any User Notes concerning the series you are creating (optional).
9. Click the Create New Series button.
10. The Plot Setup dialog lists a series called Specific Conductance (or the name you entered for Series Name). The default units are microSiemens/cm (µS/cm). You can change the units to milliSiemens/cm (mS/cm) if desired. The default units for salinity are ppt (parts per thousand) and this cannot be changed.



11. Click the Plot button to plot the data. The Details Pane will show the series selected in the Plot Setup:

After the plot is displayed, you may apply minimum, maximum, and average filters to the scaled series as you would for any sensor data series in HOBOware Pro.

12. Save this plot as a Project to preserve this processed data.

Calibration

It is important to take temperature and conductivity calibration readings with a portable conductivity meter at both the beginning (launchtime) and end of a deployment (readout) because these readings are necessary for data calibration and to compensate for any measurement drift during deployment. The temperature and conductivity calibration readings should be the actual conductivity values (not in specific conductance at 25°C), and should be recorded in a notebook with the time and location of the reading. See the logger manual for details on different methods of obtaining water samples to record these values.

1. Once the logger is deployed and logging, record in a notebook the temperature and actual conductivity meter readings along with the date and time which will be entered into the Conductivity Assistance to correct the field data.
2. Before you remove the logger and read out its data, take another temperature and conductivity reading with the meter and record the exact date and time.
3. Enter these values under the "Use measured points for calibration" option in the Conductivity Assistant.

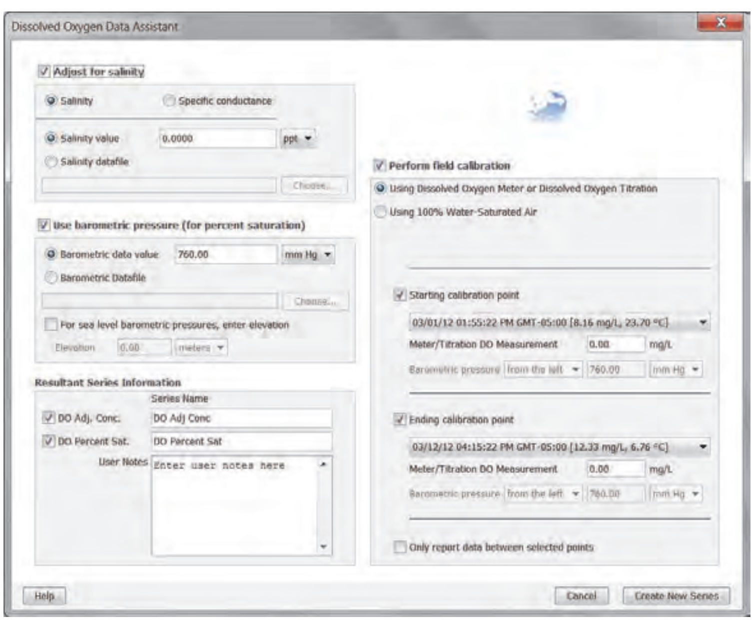
Notes:

- Whenever a logger is removed for downloading data, clean the sensor window using a cotton swab with a mild detergent and rinse.
- If the water in the field is not accessible to the conductivity meter sensor, such as in a deep well, a bailer can be used to fetch a water sample for testing. See the logger manual for more details.

Dissolved Oxygen Assistant

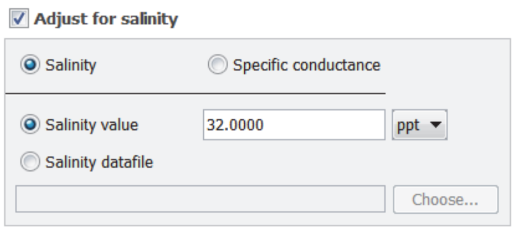
The Dissolved Oxygen Assistant corrects for measurement drift from fouling and provides salinity-adjusted DO concentration as well as percent saturation data.

1. Read out a U26 series logger or open a datafile from a U26 logger.
2. From the Plot Setup window, select the Dissolved Oxygen Assistant and click the Process button.
3. With the Dissolved Oxygen Data Assistant, you can adjust the data for salinity (step 4), enter barometric pressure information for percent saturation calculation (step 5), select the resultant series you wish to generate (step 6), and enter field calibration data (step 7).

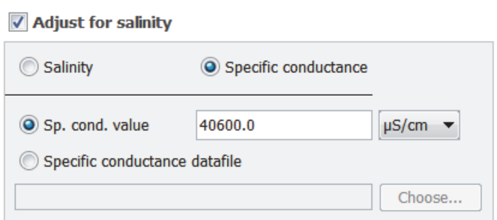


4. **Adjust for salinity.** If you deployed the logger in saltwater, you must adjust for salinity to get either a DO concentration or percent saturation. To do this, select the "Adjust for Salinity" checkbox (you will also need to select the checkboxes under Resultant Series Information for the series you would like). Select whether the series should be adjusted based on salinity or specific conductance.

   - **If you chose salinity:** Select "Salinity value" if you have a specific value from a conductivity meter reading or other source; type the value in ppt as shown below. This works well if the salinity is constant during the deployment. If the salinity changes during the deployment, select "Salinity datafile" to use a data file from a U24 conductivity logger or a text file. Click the Choose button and select the file. (See the Important note for more details about using files.)



   - **If you chose specific conductance:** Select "Sp. cond. value" if you have a specific conductance value from a meter reading or other source; type the value in either µS/cm or mS/cm as shown below. This works well if the specific conductance is constant during the deployment. If it is not constant, select "Specific conductance datafile" to use a data file from a U24 conductivity logger or a text file. Click the Choose button and select the file. (See the Important note for more details about using files.)



Important: When using a file for salinity or specific conductance data, you can select either a .hobo file from a HOBO U24 Conductivity Logger or a .txt file from a U24 logger after it has been calibrated with the Conductivity Assistant. Using a U24 .hobo file is the easiest while a calibrated U24 text file provides the highest accuracy. Follow these steps to create a text file from a U24 Conductivity Logger in the proper format:

A. Click Cancel to close the DO Assistant and Plot Setup windows if they are open.

B. From the File menu, select Preferences.

C. In the General Preferences, select Export Settings.

D. Click the "Use default BoxCar Pro export settings" button and click OK. This will ensure the text file you create is the proper format for the Dissolved Oxygen Assistant.

E. From the File menu, select Open Datafile and select the U24 .hobo file.

F. In the Plot Setup window, select the Conductivity Assistant and click Process.

G. In the Conductivity Assistant, create a calibrated specific conductance or salinity data series.

H. Back in the Plot Setup window, select the specific conductance or salinity series only. Click None under Select Internal Events to Plot so that no events are plotted.

I. Click the Plot button.

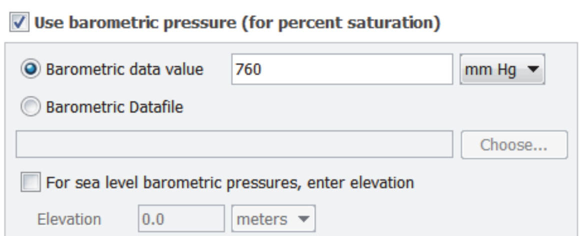
J. From the File menu, select Export Table Data. Choose "Export to single file" if prompted.

K. To use the calibrated conductivity file, open the DO file again. In the Plot Setup window, select the Dissolved Oxygen Assistant and click Process. Select the text file you just created in the previous step for the salinity or specific conductance datafile. This file will be used to generate the series adjusted for salinity.

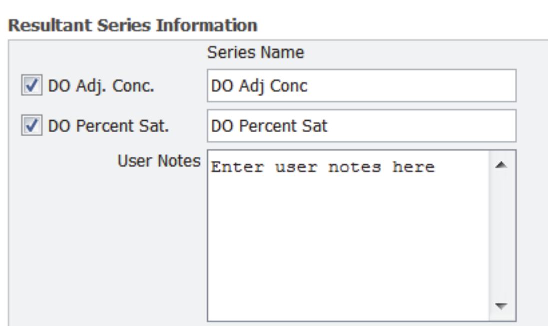
5. **Use barometric pressure (for percent saturation).** Check the "Use barometric pressure (for percent saturation)" box if you want to generate a DO percent saturation series (you will also need to select the DO Percent Sat. checkbox under Resultant Series Information). For the best accuracy, use a data file from a HOBO Water Level logger deployed in the air or a nearby weather station. Select "Barometric Datafile" and click the Choose button to select the .hobo or .txt file. **Important:** If you are using a .txt file from a non-HOBO device, it must follow specific requirements as described in Import Text File Requirements.

   If you do not have a barometric pressure file, then select "Barometric data value" and type in the average barometric pressure during your deployment in one of the five available units.

   If the barometric pressure readings are from barometric data that has been adjusted to sea level readings (such as those taken from a National Weather Service weather station), then you must also select the "For sea level barometric pressures, enter elevation" checkbox and type the elevation where the logger was deployed in either meters or feet. Absolute pressure values, such as those obtained from a HOBO Water Level logger, do not need to be adjusted for elevation.

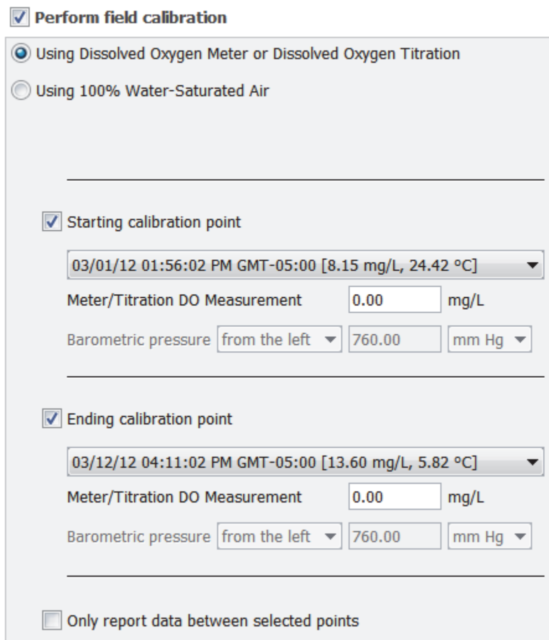


6. **Resultant Series Information.** Make sure the series you want to plot are selected in the Resultant Series Information pane. To generate a series for adjusted DO concentration, check the "DO Adj Conc." box. To generate a series for percent saturation, check the "DO Percent Sat." box. The default series names display automatically to the right of the selected series. Edit those series names as needed. You can also type up to 250 characters of optional user notes.



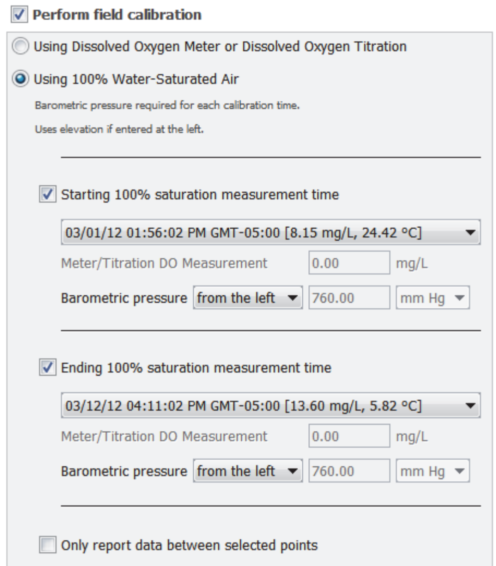
7. **Perform Field Calibration.** Use field calibration to compensate for measurement drift due to fouling or if the logger was not lab calibrated. (Lab calibration typically remains accurate for the full 6-month life of the sensor cap if there is no fouling.) Check the "Perform field calibration" checkbox and select the type of field calibration: either "Using Dissolved Oxygen Meter or Dissolved Oxygen Titration" or "Using 100% Water-Saturated Air."

- **For calibration using a dissolved oxygen meter or titration:** Select the "Starting calibration point" checkbox and select the date/time of the calibration reading. View the logged data values shown in the drop-down box to be sure that the logger readings have stabilized. It is more important that you use a good stabilized logger reading than exactly matching the times. Type in the Meter/Titration DO Measurement in mg/L taken at that date/time. If using an ending calibration reading, or, if desired, select the "Ending calibration point" checkbox and select the date/time of that calibration reading. Make sure the logger reading you use for calibration is one from when the logger was in the water, keeping in mind that the logger time may be slightly different from the time used for your field readings. You can usually see the data points that were recorded when the logger was out of the water. Type in the Meter/Titration DO Measurement in mg/L for this ending calibration point.



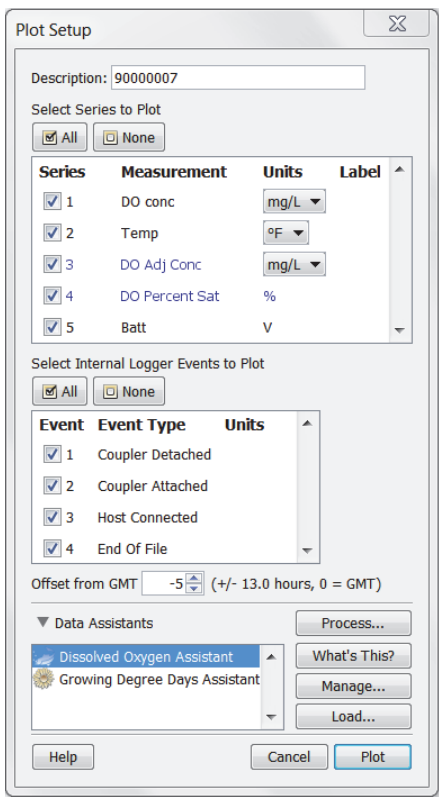
Note: If only an “Ending calibration point” is entered (“Starting calibration point” not checked), then the assistant will use the logger calibration for the starting calibration. This assumes you are starting with an accurately calibrated logger and saves you from having to do your own starting point calibration. However, if you select a “Starting calibration point” and no “Ending calibration point,” the series will be adjusted for the one calibration point. This may be accurate enough for applications where there is no significant fouling during the deployment time.

- **For calibration using 100% water-saturated air:** Select the "Starting calibration point" checkbox and the "Ending calibration point" checkbox and select the date/time for the first calibration reading. View the values shown in the drop-down list to be sure the readings are stable at this calibration point (using a calibration point from when the logger is in air or has not reached temperature equilibrium will result in incorrect calibration). Select the source of the barometric pressure readings. From the Barometric Pressure drop-down list, select "from the left" to use the barometric pressure data file already entered in the assistant or select "entered here" to enter a specific barometric pressure value in one of five available units. If you are using an ending calibration reading, select the “Ending calibration point” checkbox and select the date/time of that calibration reading following the same guidelines as you did for the starting calibration point. For the ending point, enter the barometric pressure information (select “from the left” or “entered here” as described above).



Check the "Only report data between selected points" if you want the new series to only include data between the selected calibration points. Leave this option unchecked to include all data.

8. Click the Create New Series button when finished entering information in the data assistant.
9. Depending on which series you selected to add, the Plot Setup dialog lists two news series: DO Adj Conc and DO Percent Sat (or the names you entered for Series Names). The default units for the DO Adj Conc series are mg/L. You can change the units to ppm if desired.



10. Click the Plot button to plot the data. After the plot is displayed, you may apply minimum, maximum, and average filters to the scaled series as you would for any sensor data series in HOBOware Pro.
11. Save this data and plot setup as a Project to preserve the new series you created for future use.

Field Values

These are the minimum and maximum values allowable in the fields in this assistant.

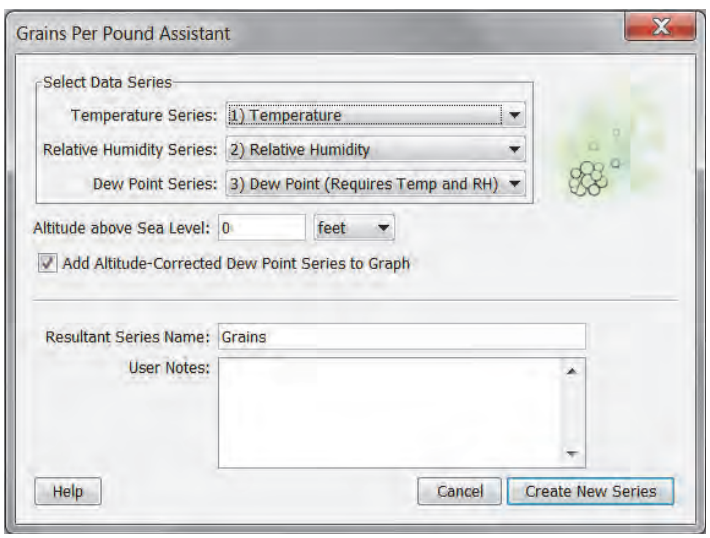
Measurement, Units	Minimum	Maximum
pressure, mm Hg	380.00	836.00
pressure, in Hg	14.9700	32.9100
pressure, millibars	507.0	1,114.0
pressure, kPa	51.000	112.000
pressure, Pa	51,000	112,000
pressure, psi	7.3480	16.1600
elevation, m	-304.80 2	2,438.40
elevation, ft	-1000.00	8,000.00
salinity, ppt	0.0000	42.0000
sp. cond., µs/cm	0.0	65,000.0
sp. cond., ms/cm	0.0000	65.0000
meter/titration DO conc, mg/L	0.00	30.00

Grains Per Pound Assistant

The Grains Per Pound Assistant calculates the absolute amount of water in the air, based on temperature, humidity, dew point, and altitude. You can also create an altitude-corrected dew point series.

To create a grains per pound and altitude-corrected dew point series:

1. Read out a logger or open a datafile that contains temperature, humidity, and dew point series.
2. From the Plot Setup window, select the Grains Per Pound Assistant and click the Process button.
3. In the Grains Per Pound Assistant window, choose the data series you want to convert from the Temperature, Relative Humidity, and Dew Point Series drop-down lists.



4. To correct for the Altitude above Sea Level (optional), enter the altitude and use the drop-down menu to indicate whether this number is in feet or meters.
5. Select the Add Altitude-Corrected Dew Point Series to Graph checkbox to plot an altitude-corrected dew point series.
6. In the Resultant Series Name field, keep the default name or type a new one.
7. Type any User Notes concerning the series you are creating (optional).
8. Click the Create New Series button. The new grains per pound series (and altitude-corrected dew point series, if applicable) is listed and selected in the Plot Setup window.

9. Click the Plot button.

The scaled series will appear in the plot and the settings for the scaled series are listed in the Details pane:

After the plot is displayed, you may apply minimum, maximum, and average filters to the grains per pound and altitude-corrected dew point series as you would for any sensor data series in HOBOware Pro.

Growing Degree Days Assistant

The Growing Degree Days Assistant calculates growing degree days based on temperature data spanning at least one full calendar day (midnight to midnight). Growing degree days are used for agricultural and turf management applications, such as estimating harvest time or pest growth.

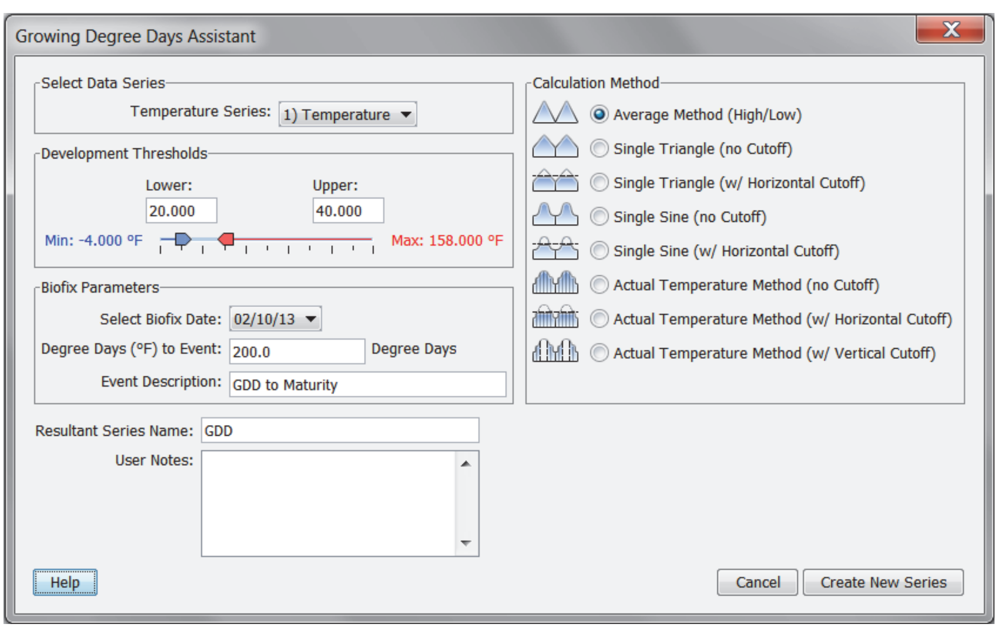
One growing degree day (GDD) is equivalent to a one degree increase above a minimum threshold temperature for a period of one day. For example, assuming no horizontal cutoff, if the minimum threshold temperature is 70°F and the temperature was a constant 85°F for the day, the GDD for that day is 15 GDD.

A single GDD value is calculated for each full calendar day of temperature data, and plotted at noon for that day. GDD values are cumulative; that is, the GDD for each day adds to the previous days’ GDD value.

Important: Time of day is a factor in the GDD computation. When you launch a logger, be sure that your computer’s clock is set to the proper time zone for the area where the logger will be deployed. If you try to correct it later by entering a different offset in the Plot Setup window, you may get confusing or misleading results.

To create a series for growing degree days:

1. Read out a logger or open a datafile that contains data from a temperature sensor.
2. From the Plot Setup window, select Growing Degree Days Assistant and click the Process button.
3. In the Growing Degree Days Assistant window, choose the data series you want to convert from the Temperature Series drop-down list.



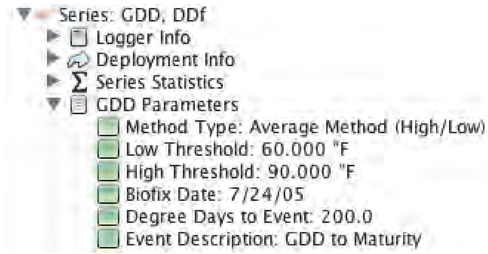
4. Select the Calculation Method you want to use.

    - **Average Method:** Calculates the average of the high and low temperatures for the day (adjusted to the lower and upper thresholds, if necessary), then subtracts the low threshold to compute the GDD.
    - **Single Triangle (no Cutoff):** Uses the low and high daily temperatures to compute a set of two linear equations to generate a triangle. The area between the curve and the low threshold is then used to compute the GDD.
    - **Single Triangle (with Horizontal Cutoff):** Uses the low and high daily temperatures to compute a set of two linear equations to generate a triangle. Then it adjusts any temperatures above the upper threshold to the upper threshold. The remaining area between the curve and the low threshold is then used to compute the GDD.
    - **Single Sine (no Cutoff):** Uses the low and high daily temperatures to compute a sine wave that assumes the low temperature occurred at midnight and the high temperature occurred at noon. The area between the curve and the low threshold is then used to compute the GDD.
    - **Single Sine (with Horizontal Cutoff):** Uses the low and high daily temperatures to compute a sine wave that assumes the low temperature occurred at midnight and the high temperature occurred at noon. Then it adjusts any temperatures above the upper threshold to the upper threshold. The remaining area between the curve and the low threshold is then used to compute the GDD.
    - **Actual Temperature Method (no Cutoff):** Uses the logging interval of the temperature data to perform a numerical integration. The area between the curve and the low threshold is used to compute the GDD.
    - **Actual Temperature Method (with Horizontal Cutoff):** Adjusts any temperatures above the upper threshold to the upper threshold. Then it uses the logging interval of the temperature data to perform a numerical integration. The area between the curve and the low threshold is then used to compute the GDD.
    - **Actual Temperature Method (with Vertical Cutoff):** Uses the logging interval of the temperature data to perform a numerical integration. Any interval in which the temperature exceeds the upper threshold is excluded from the calculation. The remaining area between the actual curve and the low threshold is then used to compute the GDD.

5. Select lower and upper Development Threshold values. These are the minimum and maximum thresholds that will be used in the GDD calculation. Use the sliders to set these thresholds, or enter the values manually. If the calculation method you chose does not use an upper threshold, the upper threshold option will be disabled. Temperatures are in degrees Fahrenheit if your default unit preference is US, and in degrees Celsius if your default unit preference is SI.
6. In the Biofix Parameters panel, choose a date that marks the beginning of the development phase for the Biofix date. The dates in this list are the full days contained in the datafile.
7. In the Degree Days to Event, enter the number of degree days needed to reach an event of interest (harvest time, pest emergence, etc.). This will create an alarm line on the graph to indicate when the event took place. Degree days are in Fahrenheit (DDf) if your default unit preference is US, and in Celsius (DDc) if your default unit preference is SI.
8. In the Event Description field, type any text to identify the event (optional).
9. In the Resultant Series Name field, keep the default name or type a new one.
10. Type any User Notes concerning the series you are creating (optional).
11. Click the Create New Series button.

12. The new series is listed and selected in the Plot Setup window. Click the Plot button.

The scaled series will appear in the plot and the settings for the scaled series are listed in the Details pane:



kWh Assistant

The kWh Assistant converts logged pulse data to kWh, average kW, and energy cost with WattNode, Veris, or other pulse-output energy transducers, and from Raw Pulse sensors attached to a HOBO 4-Channel Pulse Input Data Logger (UX120-017x) and the UX90-001.

This assistant can also be applied to logged data from an S-UCA-xxxx or S-UCC-xxxx Electronic Switch Pulse Input Adapter. It is not compatible with the S-UCB-xxxx or S-UCD-xxxx Contact Closure Pulse Input Adapter.

After you use the assistant and display the plot, you may apply filters to the new series.

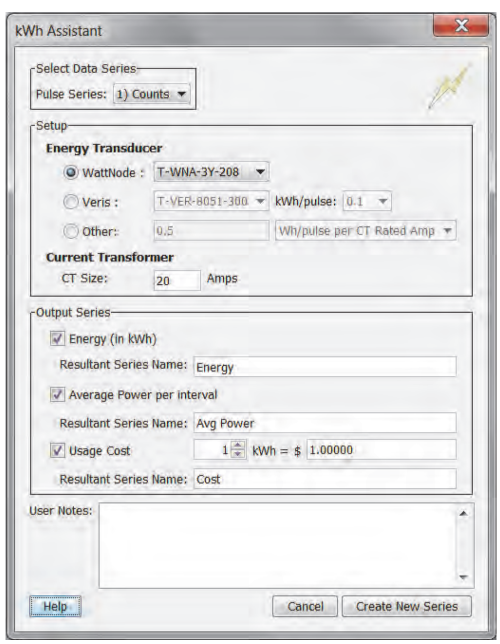
This data assistant is one of several launch utilities that can also be used at launch time for certain loggers.

Using the kWh Assistant

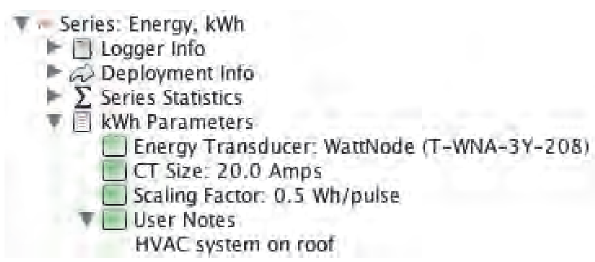
1. **At launch time:** Using a logger or sensor that supports scaling at launch time, click the Launch icon on the toolbar. Click the Scaling button. Double click the assistant name or select the assistant and click the Create button.

   At plot setup: Read out a logger or open a file that supports kWh scaling. Select the kWh Assistant and click the Process button.

2. In the kWh Assistant window, choose the data series you want to convert from the Pulse Series drop-down list.



3. In the Setup panel, select the Energy Transducer that was used, and choose the model number from the drop-down list. (Since the Veris transducers have a switch to define kWh/pulse, you must specify that here as well.) If your transducer is not listed, select Other and enter the conversion factor. Choose the type of conversion (Wh/pulse per CT Rated Amp, Wh/pulse, or kWh/pulse) from the drop-down list. Refer to the manual that came with your energy transducer for help with identifying the conversion factor
4. Enter the current transformer size (in Amps) in the CT Size field. (Veris transducer CT sizes are predefined.)
5. In the Output Series panel, select one or more series you wish to create. For each series, you may keep the default Resultant Series Name or type a new one.
    - To create a series that shows energy in kWh, check the Energy box.
    - To create a series that shows average power, check the Average Power per interval box.
    - To create a cost series, check the Usage Cost box and enter the cost per kWh.
6. Type any User Notes concerning the series you are creating (optional).
7. Click Create New Series.
8. If you are running this assistant at launch time, the kWh button displays the number of newly created series. If using this assistant while plotting, the new series is listed and selected in the Plot Setup window. Click the Plot button to display the series.
9. The scaled series will appear in the plot immediately or when you read out the logger if configuring this at launch time. The settings for the scaled series are listed in the Details pane of the plot:



After the plot is displayed, you may apply filters to the new series as you would for any other series in HOBOware Pro. In addition to the minimum, maximum, and average filters that are available for most series, the energy and cost series allow you to create new series showing totals over a period of time.

Exporting Data

While HOBOware offers many tools for analyzing data, there may be instances where you need to export data for use in other software. Refer to the following for exporting data and other related topics:

- Exporting Table Data
- Exporting Data in Classic (BoxCar Pro) Format
- Exporting Details
- Copying Points Data into Another Application
- Formatting the Date/Time Column in Excel
- The Bulk Export Tool

Exporting Table Data

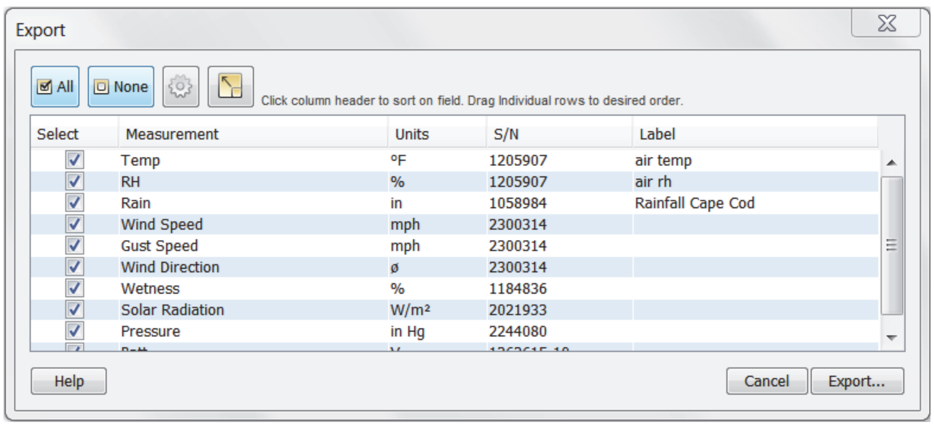
You can export the data shown in the points table to a Microsoft Excel file or to a text file (.csv or .txt) for importing into other applications. You can also export the data points gathered in a ZW wireless network via the Plot/Export Wireless Data window.

To export data:

1. From HOBOware files: Open a data or project file. Make sure the points table includes the series you want to export. This might include series pasted from other datafiles or series derived through filters or Data Assistants. Make any changes as necessary.

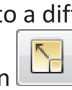
   From the Plot/Export Wireless Data window: Make the changes necessary to select the desired series and then click the Export button. Skip to step 3.

2. From the File menu, select Export Table Data or click the Export icon  on the toolbar.



3. To change the export settings, click the Preferences button . Make any changes to the settings and then click OK in the Preferences window to return to the Export window. **Note:** Changes to the "Use export ordering rules" preference are not automatically displayed in the Export window; they will take effect the next time you open the Export window.

4. Select the series you wish to include in the exported file. Use the All and None buttons or the checkboxes in the Select column to make your changes. **Note:** Only the series that are listed in the points table in a plotted HOBOware file or selected from the Plot/Export Wireless Data window are available to export from this window. To make additional series appear in this window, click Cancel and go back to step 1.

5. The data will be exported in the order displayed in the Export window. To change this sort order, click a column header in the Export window. You can sort the Measurement, Units, sensor S/N, and Label columns in both ascending and descending order. Or, click a row to drag that series to a different position in the list. To return to the original sort order, click the Restore Order button . Note that if you have the export preferences set to "Use export ordering rules," then the series will be listed in the order defined in that preference when you click the Restore Order button. If the datafile contains series with measurement types that are not defined in the export ordering rules preference, then those series will be listed after the defined series.

6. Click the Export button and then select where you want to save the file.

7. Click Save. You can now open the exported file in Excel or another software application. Note that if you have the export preference "Include plot details in exported file" enabled, then any information in the Details pane of the plot will be included in the exported file along with the sensor data.

Exporting Data in Classic (BoxCar Pro) Format

BoxCar Pro is legacy software from Onset Computer. HOBOware includes a preference setting that allows you to export and import data in a format compatible with Onset's Box Car Pro software. To change the export preferences to use settings compatible with BoxCar Pro:

1. From the File menu in Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the General category and then click Export Settings.
3. Click the "Use classic export settings" button and then click OK.

See Export Settings for details on all export preference settings.

Exporting Details

You can export the information in the Details pane to a text file, which can be opened in any text editor or imported into numerous applications, such as Microsoft Word or Excel.

To export details:

1. Make sure the Details pane includes the series you want to export. This might include series pasted from other datafiles or series derived through filters or Data Assistants.
2. From the File menu, select Export Details.
3. Accept the default file name, or type a new name.
4. Click Save.

If you would prefer to have the information in the Details pane and sensor data in the same file, select Preferences from the File menu in Windows or the HOBOware menu in Macintosh and click the General category. Click Export Settings and then enable the "Include plot details in exported file" checkbox and click OK. The next time you use the Export Table Data feature, the plot details will be included in the exported file along with the sensor data.

Formatting the Date/Time Column in Excel

In Excel, dates and times for each data point may initially appear as ####### and times may not have seconds listed. To display the full date and time with seconds in Excel:

1. Adjust the time column width so you can see the whole date and time.
2. Select the time column from row 3 down.
3. From the Format menu, click Cells.
4. Select the Custom category and then select "m/d/yyyy h:mm" as the type.
5. Add ":ss" (or ":ss.000" if you used a fast logging interval) to the end of the string in the Type field:

   m/d/yyyy h:mm:ss (normal logging interval)
   m/d/yyyy h:mm:ss.000 (fast logging interval)

6. Click OK. The seconds should be listed automatically.

To export the date and time in separate columns, go to Preferences> General > Export Settings and enable the "Date and time format: Separate into two columns" option.

The Bulk Export Tool

The Bulk Export Tool is a plug-in tool for HOBOware Pro that exports HOBOware files to text or Microsoft Excel format for use in other programs. This tool is particularly helpful when you need to export multiple files at once.

With the Bulk Export Tool, you can export the following file types:

- .hobo
- .dtf
- .hsec
- .dsec

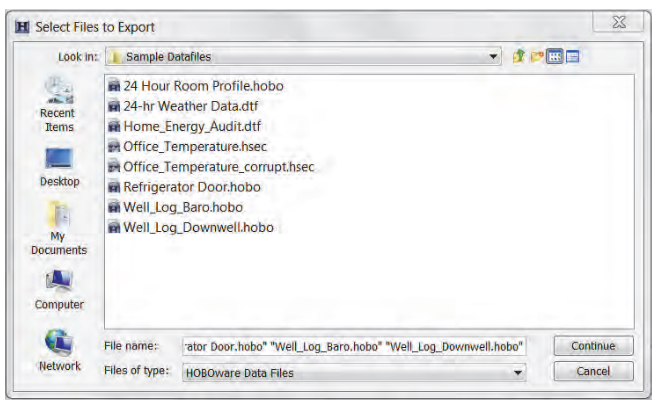
Any naming conflicts are automatically resolved to prevent overwriting any pre-existing files. A log summarizing the export results is saved in the same directory as the newly exported files.

The Bulk Export Tool uses the general export settings for HOBOware Pro. To configure the Export Settings, go to the File menu in Windows or the HOBOware menu in Macintosh and select Preferences. In the General category, select Export Settings.

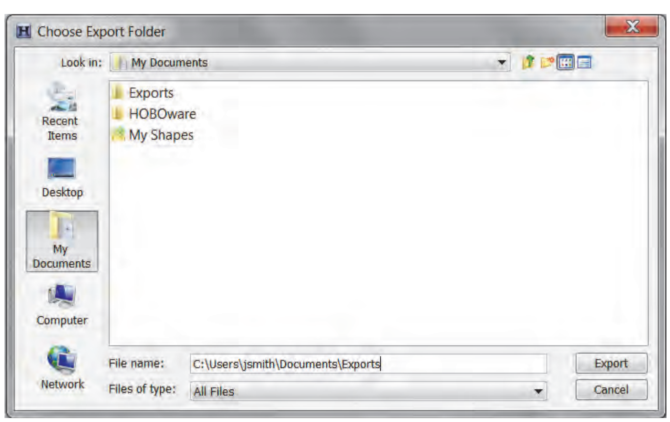
Using the Bulk Export Tool

To export files with the Bulk Export Tool:

1. From the Tools menu, select Bulk File Export and then Select Files to Export ...
2. In the Select Files to Export dialog, select the files you wish to export and click Continue.

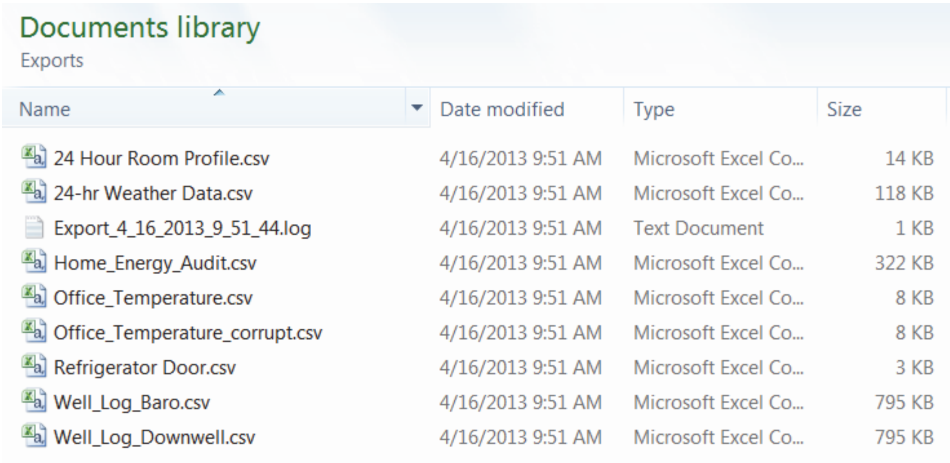


3. In the Choose Exports Folder dialog, navigate to the directory where you want the files to be exported and click Export.



4. A progress bar indicates the status of the export (if this happens very quickly, you may not see the bar). A message appears when the export is complete. Click OK.

The exported files are saved to the specified directory.



The native file extension is removed and appended with the file type selected in the export preferences (.txt, .csv, or .xls). For example, if the Export File Type preference is set to Excel, then exportfile.hobo is renamed exportfile.xls. If a file name already exists, new files will be appended with "_0", "_1" etc. For example:

exportfile.xls

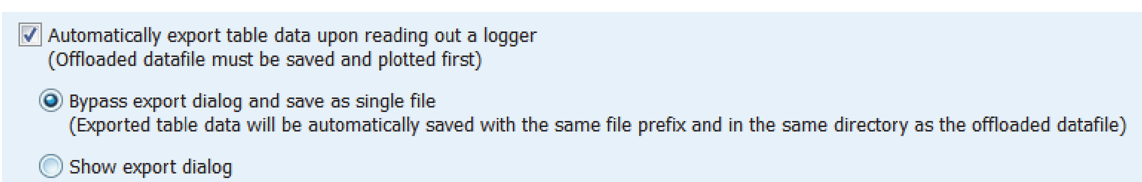
exportfile_0.xls

exportfile_1.xls

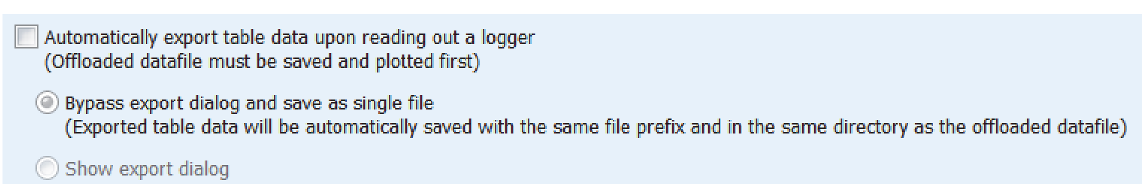
A log file showing the result of each exported file is also saved to the same directory. The log file lists either the successful export with the resulting file names or an error message if there was a problem. The log file has the date and time of the export in its file name like this:

Export_<day>_<month>_<year>_<hour>_<minute>_<second>.log

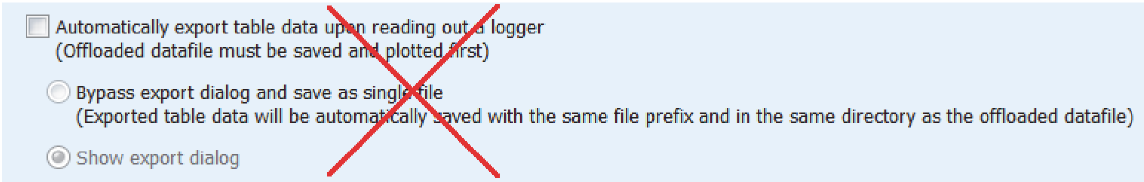
Important: The Bulk Export Tool will not export files properly if the "Show export dialog" setting is selected in the export preferences. To disable this setting, select Preferences from the File menu in Windows or the HOBOware menu in Macintosh. In the General category, select Export Settings. Make sure "Show export dialog" is not selected. Even if the "Automatically export table data upon readout of logger" option is disabled, the "Show export dialog" must not be selected for the Bulk Export Tool to export files properly. Your preferences must look like this:



or this:



but not like this:



for files to export correctly.

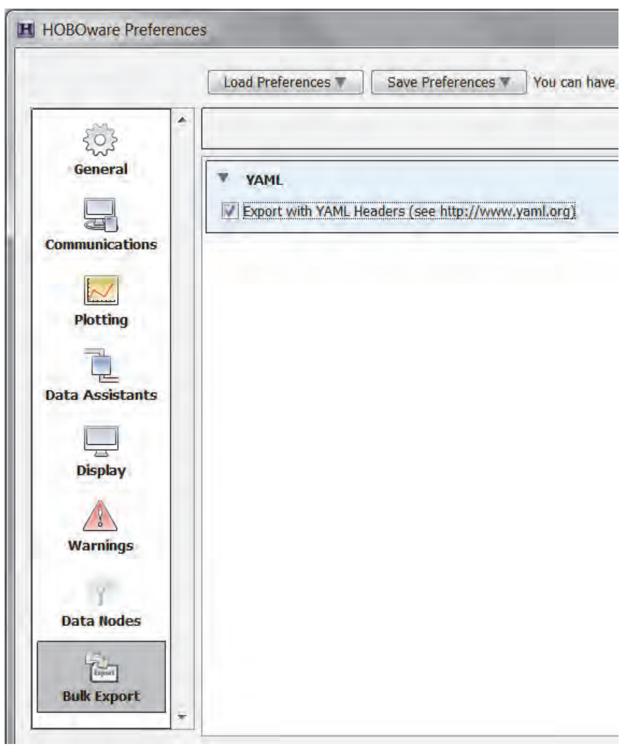
YAML

You can choose to have YAML ("YAML Ain't a Markup Language") headers added to the exported files (they are not inserted by default). If enabled, YAML headers are inserted at the front end of the file. You can remove the YAML header using any text editor.

YAML™ (rhymes with "camel") is a human-friendly, cross language; Unicode based data serialization language designed around the common native data structures of agile programming languages. For more information see yaml.org.

To enable YAML headers:

1. Go to the File menu in Windows or the HOBOware menu in Macintosh and select Preferences.
2. Scroll down to the Bulk Export category and select YAML.
3. Check the Export with YAML Headers box.



Importing Text Files

You can plot non-HOBOware data by importing data from certain text files including:

- Text files that were created by Onset's legacy Alarm & Readout Tool version 2.0 or higher. **Note:** This tool is no longer supported as of HOBOware 3.5.

- Text files that were exported from Onset's BoxCar Pro 4.3 software using the default BoxCar export settings. This allows you to view data from legacy Onset loggers that cannot be read out using HOBOware Pro.
- HOBOware CSV format exports from the Custom Data and Data Delivery features in HOBOlink. **Note:** Sensor labels entered in HOBOlink will be imported into HOBOware. However, if commas were used in the sensor labels or scaling parameters in HOBOlink, labels may not be imported correctly in HOBOware.
- With some adjustments, you can open text files that were exported from other software or that you create. See Importing Text File Requirements for more details.

Note: This feature is only available in HOBOware Pro.

To import data from a properly formatted text file:

1. From the File menu, select Import Text Data.
2. Select a text file or HOBOware CSV file and click Open.
3. If the file was created by the Alarm & Readout Tool or HOBOlink, go to step 8. Otherwise, HOBOware Pro attempts to parse the text file and displays the Text Import Information window. To conserve system resources, it displays only the first several records in the file.
4. Check the Delimiter Preview area to be sure the date, time, and data columns are separated correctly. If they are not, use the Data Separator, Date/Time Separator, and Decimal Separator pull-down menus to choose other delimiters until the data looks correct. You can resize the columns by clicking and dragging the dividers between the column headers.

   For text files that were not exported in BoxCar's default format, click the Edit Date/Time Format button and ensure that the import function is interpreting incoming date, time, and year formats and separators correctly. Use the current date and time displayed in the Sample panel as a guide.
5. When the Delimiter Preview is correct, click OK.
6. Depending on the file's contents, the Plot Setup window may be displayed at this time. If so, go to step 8.

   Otherwise, the Text File Information window is displayed. This window allows you to add optional information and change the units and time zone, if needed.

   - Type a description, which will become the plot title and be included in the Details pane.
   - Select a model from the list. If you select Other/3rd Party, you can enter a description (up to 20 characters) of the logger or other data source in the next field.
   - Type the logger's serial number, if applicable.
   - Verify the units are correct for the data in the file.
   - Select a time zone offset if necessary.
7. Click OK.
8. The Plot Setup window opens. Select the series you wish to view in the plot and click Plot. The plot is displayed. You may want to save your work in a project (.hproj) file for quick viewing later.

Import Text Files Requirements

When you import a text file, the file must meet certain requirements. You can view or edit text files in a text editor or word processor. To delete, rearrange, or reformat columns of data, you may need to use a spreadsheet program. Remember to save the corrected file in text (.txt) format. This feature is only available in HOBOware Pro. Internal events recorded by loggers, such as Host Connected, Started, and Stopped, cannot be imported.

Serial Number

The file can contain an optional header for serial number information located at the beginning of the file, before the column headings. The header must have the phrase "Serial Number:" followed by a space, then the serial number, then two dashes:

Serial Number: 733329 --

Note: Text files originating from HOBOlink and the Alarms & Readouts Tool may also contain YAML headers at the top of the file.

Contents

Below the header (if any), there should be the data, starting with column headings. There must be no other text in the file other than the optional header, column headings, and data. The first column must be date, the next must be time, and the rest must be data.

Delimiters

Valid delimiters for separating date and time and other data are commas, tabs, and semicolons. The delimiter used to separate the date from the time may be different from the delimiter used to separate the data. Do not use a space as a delimiter; there cannot by any spaces in the data.

Date

The date column must have the heading, "Date" and date values should be formatted as mm/dd/yy. If they are in a different format, remember to indicate the correct format in the Edit Date/Time Format window when you import the file.

Date
12/31/04
12/31/04
01/01/05
01/01/05

Time

The time column must have the heading, "Time" and time values should be formatted in 24-hour format as hh:mm:ss.sss (decimals are optional). If they are in a different format, remember to indicate the correct format in the Edit Date/Time Format window when you import the file. UTC offset is assumed to be the same as your computer's current time zone.

Time
23:59:59
23:59:59.5
00:00:00
00:00:00.5

- No thousands separator can be used.
- Rows of data must be separated with a paragraph return.
- There must be a last blank row.

Measurements

Data column headings must have the format "Measurement (Units)". Additional information (such as channel number or serial number) can follow, but is optional. Only spaces can be used between the end of the measurement name and the opening parenthesis. An example is "RH (%)".

RH (%)
38.7
38.9
39.0
39.0

If the column header and units of an imported series exactly matches the text in the table below, HOBOware will recognize the measurement and be able to perform unit conversions, apply data assistants, etc. to that series.

Measurements listed below that either have only one unit type, or can be any unit type, cannot have their units converted, but may still be used with applicable data assistants.

Measurement Type	Column Header	Units
Acceleration	x accel, y accel, z accel	g, m/s2, ft/s2
Active Energy	watt-hours, kilowatt-hours	Wh, kWh
Active Power	watts	W
Apparent Power	volt-amps	VA
Carbon Dioxide	co2	ppm
Conductivity	low range, full range, high range	µS/cm, mS/cm
Counts	counts	*[any units]*
Dew Point	dew point or DewPt	F, C
Gust Speed	gust speed	m/s, km/hr, mph, knots
Leaf Wetness	leaf wetness	*[any units]*
Light Intensity	intensity	lux, lum/ft2
PAR	par	*[any units]*
Power Factor	power factor	*[any units]*
Pressure	pres	kPa, Pa, mbar, mm Hg, psi, in Hg
Rain	rain	mm, in
Reactive Power	volt-amps-reactive	VAR
Relative Humidity	rh	%
RMS Current	amps	A
RMS Voltage	volts	V
Salinity	salinity	ppt
Soil Moisture	soil moisture	*[any units]*
Specific Conductance	conductance	µS/cm, mS/cm
Sum Vector	sum vector	g, m/s2, ft/s2
Temperature	temp	F, C
Tilt	x tilt, y tilt, z tilt	deg, rad
Wind Speed	wind speed	m/s, km/hr, mph, knots
Wind Direction	wind dir	*[any units]*

Measurements that are not listed in the table (or do not exactly match the text below) can be imported, but without any units conversions or use of Data Assistants. These include:

- Air Velocity
- Battery

- Compressed Airflow
- Conductance
- Current
- Gauge Pressure
- Power
- Solar Radiation
- Temperature for Thermocouples
- Water Flow
- Volatile Organic Compound
- Voltage
- Asynchronous Events/Readings
- State
- Runtime

Data

The datafile must have a data value for each logged time stamp for all series. There may be instances where data is missing from a series for a corresponding entry in the time column (such as certain when filtered data is using different time values than the logged data). The import will not work with missing data.

Importing Files from HOBOlink

This feature allows you to import the current data file for a remote HOBO U30 Station from HOBOlink directly into HOBOware for analysis. **Note:** This feature is only available in HOBOware Pro.

To import a file from HOBOlink into HOBOware:

1. From the File menu, select Import Data File from HOBOlink.

2. Type the serial number for the HOBO U30 Station.
3. Type the Username and Password for the HOBOlink account.
4. Select the "Save this information" checkbox if you want to HOBOware to retain the username and password for future use.
5. Click Go to import the file into HOBOware.

Chapter 5
Hardware Reference

Refer to the following topics for more information on using HOBOware with specific devices:

- Using the RX3000 Manager
- Working with the HOBO U30 Station
- Configuring FlexSmart Modules/Analog Sensor Ports
- Working with a Shuttle
- Configuring Loggers with the E50B2 Power and Energy Meter
- Checking Dates for the HOBO U26 Dissolved Oxygen logger Sensor Cap
- Using the Lab Calibration Tool with the HOBO U26 Dissolved Oxygen Logger
- Updating UX Series Logger Firmware
- Fixing "Read Header Failed" Error

Using the RX3000 Manager

The RX3000 Manager is available within HOBOware for monitoring the latest conditions in a HOBO RX3000 Remote Monitoring Station or for configuring Wi-Fi and Ethernet settings. Follow the steps below for viewing the latest conditions or configuring network settings with the RX3000 Manager. For details on operating the RX3000 station, see the product manual at www.onsetcomp.com/manual/rx3000.

Viewing Latest Conditions

1. Connect the station to the computer with the USB cable.
2. From the Device menu, select Manage RX3000. Note for Windows: You may see a warning that Windows Firewall has blocked some features. Select Domain networks and click Allow Access.
3. In the RX3000 Manager, the Latest Conditions panel shows the currently configured sensors and modules for the device. Click in the Latest Conditions panel to take a measurement for each sensor and display the value. You can also view general information about the RX3000 station in the Device Information panel.
4. Close the RX3000 Manager when done and disconnect the USB cable.

Note: The Latest Conditions and Device Information available in the RX3000 Manager are for reference only. Use HOBOlink to view complete station details, access logged data, and configure the device.

Configuring Ethernet Settings in an RX3001 Station

The RX3001 station uses DHCP by default. If your network uses DHCP, you do not need to follow these steps. Consult your Network Administrator if you are unsure whether your network uses DHCP or static IP addresses.

1. Connect the station to the computer with the USB cable.
2. From the Device menu, select Manage RX3000. Note for Windows: You may see a warning that Windows Firewall has blocked some features. Select Domain networks and click Allow Access.

3. In the RX3000 Manager, click the Actions button and select Network Access.
4. Deselect the Use DHCP checkbox.
5. Enter the IP Address, Subnet Mask, Gateway, and DNS Server. Consult your Network Administrator for the appropriate addresses to complete these fields.
6. Click Save in the RX3000 Manager. Click Done and then close the RX3000 Manager.
7. Disconnect the USB cable and press the Connect button on the station. See the product manual at www.onsetcomp.com/manual/rx3000 for further details.

Configuring Wi-Fi Settings in an RX3003 Station

1. Connect the station to the computer with the USB cable.
2. From the Device menu, select Manage RX3000. Note for Windows: You may see a warning that Windows Firewall has blocked some features. Select Domain networks and click Allow Access.
3. In the RX3000 Manager, click the Actions button and select Network Access.
4. Enter the Security information for your Wi-Fi network. Type the Network Name, select the Security Type, and type the Security Key. Select the Hide characters checkbox to hide any characters typed into the Security Key field (optional). Consult your Network Administrator or wireless router documentation for help with determining your network security type.
5. If your network uses static IP addresses: Deselect the Use DHCP checkbox. Enter the IP Address, Subnet Mask, Gateway, and DNS Server. Consult your Network Administrator if you are unsure whether your network uses static IP addresses or for the appropriate addresses to enter in this fields.
6. Click Save in the RX3000 Manager. Click Done and then close the RX3000 Manager.
7. Disconnect the USB cable and press the Connect button on the station. See the product manual at www.onsetcomp.com/manual/rx3000 for further details.

Working with the HOBO U30 Station

There are four models of the HOBO U30 Station: USB, cellular, ethernet, and wi-fi. The USB model works with HOBOware only. The cellular, ethernet, and wi-fi models are designed primarily for use with internet-based HOBOlink software, but can also work with HOBOware for specific tasks. This section describes when to use each of the four U30 Station models with HOBOware.

HOBO USB U30 Station (U30-NRC)

Use HOBOware for all tasks with the USB model, including launching, reading out, and checking status. You can also configure alarms, control the relay, configure excitation power, and set the scaling parameters.

HOBO Cellular (U30-GSM), Ethernet (U30-ETH), and Wi-Fi (U30-WIF) U30 Stations

Use HOBOlink to launch, read out, check status, configure alarms, and set up sensor scaling for cellular, ethernet, and wi-fi models. Although it is possible to perform these tasks with HOBOware, any parameters set in HOBOware will be overridden by the settings in HOBOlink. If you do attempt to launch, read out, or check the status using HOBOware, you may see a message indicating there is already a live HOBOlink session underway. You can choose to override the HOBOlink connection and use HOBOware instead. Alternatively, you may see a message indicating the HOBO U30 Station is busy and a HOBOware session cannot begin. Try again in a few minutes.

These models connect to HOBOlink on a schedule that you determine. Data is automatically read out from the U30 Station and uploaded to HOBOlink. There may be circumstances in which you want to override this schedule and contact HOBOlink immediately. For example, if you moved the HOBO U30 Station to a different location and you want to make sure it can still connect to HOBOlink, but you don't want to wait until the next connection. To force an immediate connection to HOBOlink, connect the U30 Station to a USB port. Click the Contact HOBOlink button in the Status window.

HOBOlink displays data read out from the HOBO U30 Station in line graphs and shows the readings from the last connection. The data is also saved in datafiles that can be downloaded and opened in HOBOware for additional analysis.

While most tasks should be done using HOBOlink, the following tasks can only be completed in HOBOware:

- Configuring the analog sensor port. This can only be done in HOBOware and is accessed through the Launch window. See Configuring FlexSmart Modules and Analog Sensor Ports for details.
- Changing the default relay setting or testing the relay. The default relay setting for the HOBO U30 Station is normally open and can only be changed in HOBOware. You can also use HOBOware to test the relay. See Controlling the Relay on the HOBO U30 Station for details.
- Testing the accuracy of individual smart sensors. Unplug all the sensors when the logger is not logging. Plug one sensor back in and check the current reading for the sensor in the Launch Logger window. Repeat this for the remaining sensors. **Note:** Sensors are listed in ascending order by serial number, regardless of their physical position in the logger.
- Checking cellular signal strength. Open the Status window in HOBOware to check the cellular signal for the HOBO U30 Station in its current location. This will help you determine if you need to reposition the station for optimal signal strength.

Controlling the Relay on the HOBO U30 Station

The U30 Station relay contact is a latching relay that can be configured as either Normally Open or Normally Closed. The factory-default setting is Normally Open.

To change the relay from the Device menu:

1. Connect the HOBO U30 Station to the computer with the USB cable.
2. From the Device menu, select Manage U30.
3. Select Control U30 Relay.
4. Select "Set default (deactivated) state."
5. Select either Open or Closed.

To conduct an immediate test of the relay from the Device menu:

1. Connect the HOBO U30 Station to the computer with the USB cable.
2. From the Device menu, select Manage U30.
3. Select Control U30 Relay.
4. Select "Activate (close) relay." You should hear a click in the HOBO U30 Station.
5. Select "Deactivate (open) relay." You should hear the click again.

To change the relay and test it using the Sensor Alarms window:

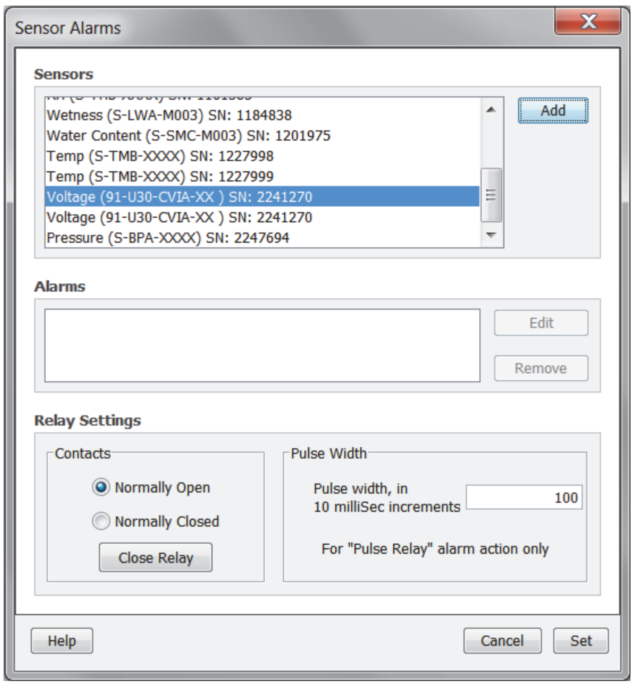
1. From the Device menu, select Manage U30.
2. Select Configure U30 Alarms and select Configure Alarms to open the Sensor Alarms window.
3. In the Relay Contacts section, select Normally Open or Normally Closed.
4. If you are setting an Alarm Action of Pulse Relay, you can set the Relay Pulse Width in milliseconds.

5. To test the relay, click the Close Relay or Open Relay button in the Sensor Alarms window. You should hear a click in the HOBO U30 Station. Click the button again to return to the default state. Use a digital multimeter to check for continuity to confirm that the relay is opened and closed as expected.
6. Click Set to send the alarm configuration to the U30 Station.

Setting Alarms on a HOBO U30 Station

You can set alarm to trip for individual sensors on a HOBO USB 30 Station (U30-NRC).

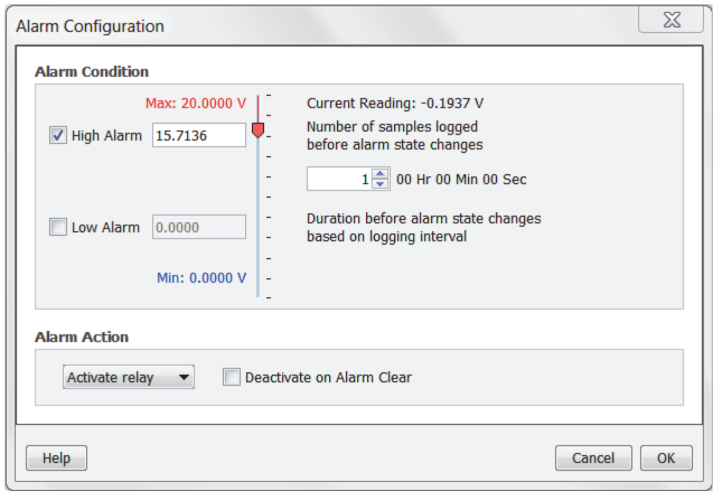
1. From the Device menu, select Manage U30 > Configure U30 Alarms > Configure Alarms.
2. Select a sensor and click Add.



3. In the Alarm Configuration window, select the High Alarm checkbox if you want an alarm to trip when the sensor reading goes above a value you specify. Type a High Alarm value or drag the top slider to set a value. and/or the Low Alarm checkboxes. Type a value for the alarm in the box(es) or use the sliders.

   Select the Low Alarm checkbox if you want an alarm to trip when the sensor reading goes below a value you specify. Type a Low Alarm value or drag the bottom slider to set a value.

   Note: If you type a High or Low Alarm value, the software may adjust them slightly to the nearest values supported by the logger.



4. Set the number of samples that will be logged before the alarm trips. **Note:** To avoid unintended activation of the relay contact, set the number of samples to allow for anticipated breaches of the alarm threshold. If the measurement is still out of range when the number of samples is reached, the relay contact will be activated.

5. Select an action to occur when the alarm is triggered: Activate Relay (Open/Close), Deactivate, Pulse, Toggle, Open, Close.

6. Select the Deactivate on Alarm Clear checkbox if you want the alarm action to stop automatically once the alarm condition clears.

7. Click OK to save the changes. The alarm will now appear in the Sensor Alarms window. Select the alarm and click Edit if you need to make changes or click Delete to remove an alarm.

8. Click Set in the Sensor Alarms window when finished configuring alarms.

Configuring FlexSmart Modules/Analog Sensor Ports

You can configure HOBO Energy Logger FlexSmart modules and the HOBO U30 Station analog sensor port to accommodate a wide range of Onset and third-party sensors. You can set up these modules/ports while selecting launch settings or you can create and save different configurations to be loaded into the modules/ports whenever needed.

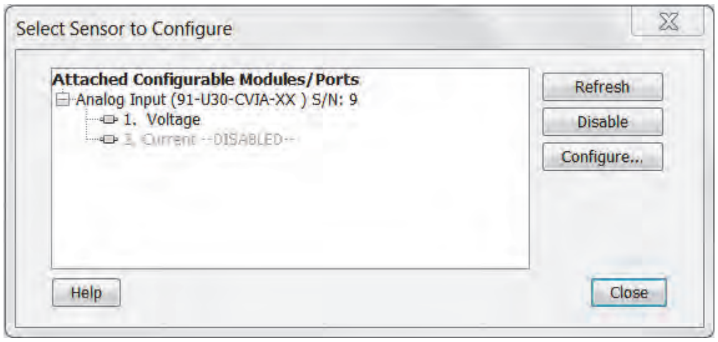
Notes:

- Modules, ports, and sensors are listed in ascending order by serial number regardless of their physical position in the logger.
- This procedure is for creating a new configuration and sending it to a port. To send an already saved configuration to a port, see Loading a Saved Configuration.

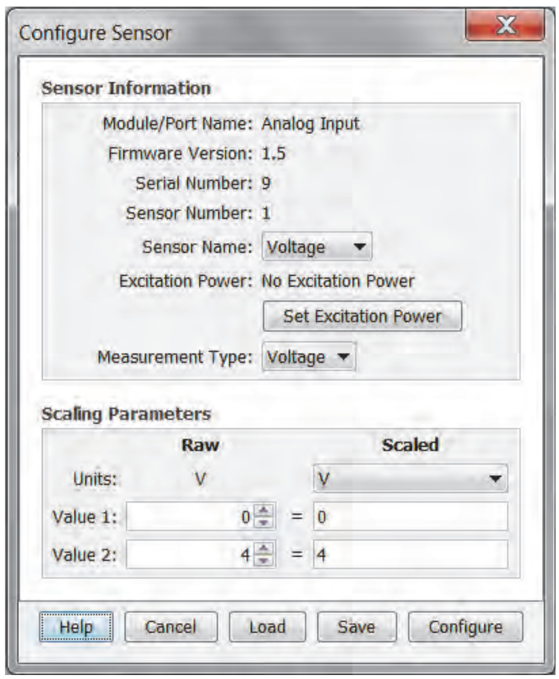
To configure an analog module or port, perform the following steps:

1. From the the Device menu, choose Configure Modules/Ports.

2. In the Select Sensor to Configure window, click the + sign to see the available modules/ports. If you are using the HOBO Energy Logger, you can attach additional modules while viewing this window. Click Refresh to update the module list. **Note:** The default channel names Voltage and Current can both be configured to measure voltage or current. For example, both channels can be used to monitor sensors with 4-20 mA output.



3. Select a sensor and then click the Configure button to open the Configure Sensor window. **Note:** You can also access this window from the Launch Logger window. Select the sensor and double-click the module/port name to expand it. Click the sensor name to select it and then click the Configure button.
4. In the Configure Sensor window, select the Sensor Name. Choose either a default name or select Custom and enter your own 16-character name, which you can also save to the list for future use. Note that a saved name is stored as a preference and removed when you restore preference defaults.



5. Set the excitation power, measurement type, and scaling as desired (options may vary depending on the sensor). For details on excitation power, see Configuring Excitation Power. If the module/port offers more than one type of input, select the correct the measurement type for the sensor. For details on scaling, see Setting Voltage Ranges and Scaling Parameters.
6. Although you do not have to save the configuration if you are going to send it to the module/port right away, you may find it convenient to save it for future use, especially if you have defined custom sensor settings. Click Save, type a name for the configuration file, and click Save again.

   By default, the file is saved to the following location with an extension of .hcfg.

   Windows: My Documents\HOBOware\Configs

   Mac: Users/<username>/Library/Application Support/HOBOware/Configs
7. Click Configure to send the currently displayed configuration to the module/port. The module/port will remain in this configuration until you send it a different configuration.

Configuring Excitation Power

You can configure sensor excitation power and warm up on the Analog Sensor Ports. Sensor excitation is a voltage output provided by the HOBO U30 Station to power a sensor that is connected to it. This power may be needed because the sensor is not self-powered or because the sensor's power capacity cannot support a long deployment.

When sensor excitation is required, the logger can provide 12 V DC sensor excitation voltage up to 200 mA total for transducers that require external power for proper operation. The excitation voltage has a programmable warm up time and is controlled by the Analog Sensor Port.

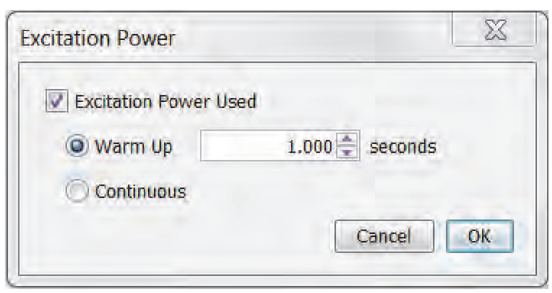
A warm up time can be up to 120 seconds. If the warm up required is longer than 120 seconds, or if you are not concerned with battery life, you may choose the Continuous option, which will power the sensor for the entire deployment.

Providing excitation power drastically decreases the logger's battery life (consult the logger manual for more information). To save battery power, you may specify the minimum time needed to power the sensor before taking a measurement. For example, if you specify a Warm Up of one second and set the logging interval in the logger to one minute, the logger will power the external sensor for one second, log data and then turn off the excitation power for the next 59 seconds.

Always enable the logger's internal battery channel when logging with excitation power. If the battery becomes too low to provide excitation power, excitation power is turned off, but logging continues as long as the battery can power the logger. This will cause the further readings on that channel to become inaccurate. If you are logging the internal battery channel when this happens, an Excitation Off event will be shown in your datafile to mark the point at which excitation power was disabled.

To configure excitation power:

1. From the Configure Sensor window, click the Set Excitation Power button. For information on accessing the Configure Sensor window, see Configuring FlexSmart Modules/Analog Sensor Ports.
2. Select the Excitation Power Used checkbox.



3. Select either Warm Up or Continuous mode. If you select Warm up, select the warm up time in seconds.

   In Warm up mode, the logger supplies excitation power for a brief period prior to each measurement. This mode allows you to select the minimum warm up time needed to allow for sensor stabilization, while conserving battery power. For example, if you specify a warm up of one second and set the Logging Interval to one minute, the HOBO U30 Station will power the external sensor for one second, log a measurement, and then turn off the excitation power for the next 59 seconds. The warm up time can be up to 120 seconds. If the warm up time selected is greater than the logging interval selected, the logger will interpret the excitation mode as continuous.

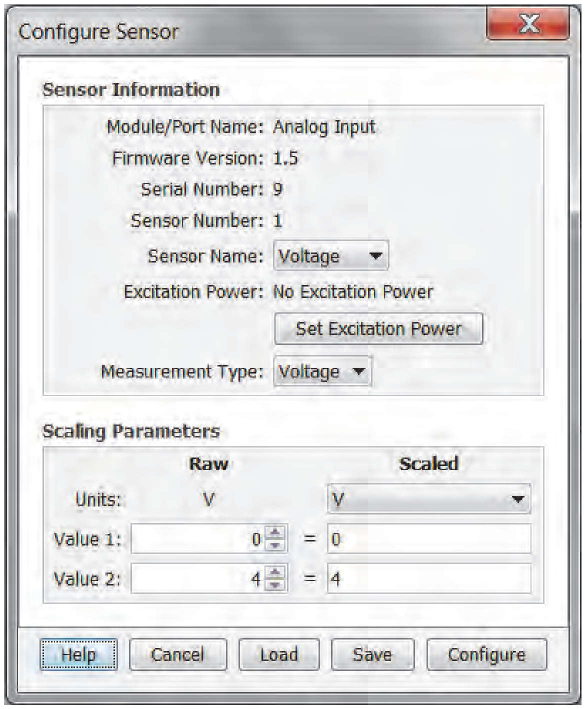
   In Continuous mode, the logger supplies constant excitation power to the sensor for the entire duration of the deployment. This mode will result in reduced battery life. Continuous mode is required if the sensor needs more than two minutes of warm up time.

4. Click OK.

5. Select Save to save these settings in a configuration for future use. Click Configure to send this configuration to the port immediately.

Setting Voltage Ranges and Scaling Parameters

You can set voltage ranges and scaling parameters for the HOBO Energy Logger FlexSmart modules and the HOBO U30 Station in the Scaling Parameters panel of the Configure Sensor window. For information on accessing this window, see Configuring FlexSmart Modules/Analog Sensor Ports.



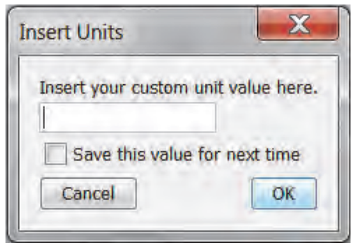
To set the scaling or voltage range:

1. Check the Raw Units. This is the type of output the sensor has; either V or mA, corresponding to the type of sensor selected. Raw Value 1 and Raw Value 2 should be input in these units. For example, if the external sensor has an output of 4 – 20 mA, the raw units would be in mA.
2. Set Raw Value 1, which is the low raw value given by the external sensor. In the previous example, this would be 4 mA.
3. Set Raw Value 2, which is the high raw value given by the external sensor. In the previous example, this would be 20 mA.

Important: The number entered for Raw Value 2 determines the voltage range the analog port will use. Use this table to determine what the range will be depending on the number entered in the Value 2 field.

If the raw voltage entered in the Value 2 field is:	The voltage range for the analog port will be:
Less than 2.5	2.5V
Greater than 2.5 and less than or equal to 5	5V
Greater than 5 and less than or equal to 10	10V
Greater than 10 and less than or equal to 20	20V

4. Select the Scaled Units. Choose one of the predefined units from the pull-down list or select Custom to define units for other types of sensors. If you select Custom, type up to eight characters of the units associated with the sensor. For example, if you are using a flow meter, you could specify CFS (Cubic Feet per Second) as the scaled unit. If you want to see data in particular SI or US units, you need to enter the appropriate scaling values in the next steps. Select the "Save this value for next time" checkbox to add this name to the Scale Units drop-down menu for future use. Note that a saved unit name is stored as a preference and removed when you restore preference defaults. Custom unit values do not allow for conversion between SI to US units. It is only a reference used to indicate how the module is configured and how the resulting data should be labeled. Click OK to save the changes and return to the Configure Sensor window.



5. Set Scaled Value 1, which is the value that will be displayed on the graph when the sensor reports a raw value equal to Raw Value 1. This value should be entered based on the Scaled Units selected in the previous step.
6. Set Scaled Value 2, which is the value that will be displayed on the graph when the sensor reports a raw value equal to Raw Value 2. This value should be entered based on the Scaled Units selected in Step 4.
7. Click the Save button to save this configuration for future use or click Configure to send these settings to the module/port immediately.

Loading a Saved Configuration

If you have created and saved a sensor configuration for a HOBO Energy Logger FlexSmart modules and the HOBO U30 Station analog sensor port, you can load it into any module/port of the same type. For example, a configuration for a FlexSmart TRMS module can be loaded into any other FlexSmart TRMS module, but not into a FlexSmart Analog module.

To load a saved configuration:

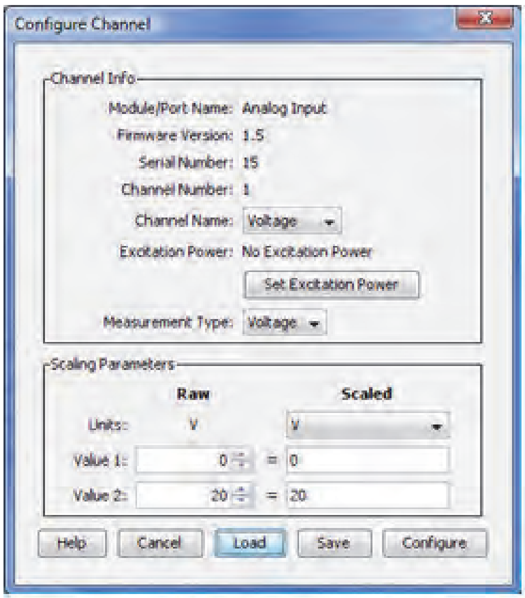
1. From the Device menu, select Configure Modules/Ports.
2. Click the Load button to see a list of all defined configurations in the currently selected folder that are compatible with the module/port.
3. Choose a configuration. To use one of the defined configurations, click the button next to Use Configuration File, then click the button next to the name of the configuration file you want to use. To get a file from a different location, click Choose Folder and browse to the desired directory. If you are experiencing problems with the module, you can reset the channel to its default configuration. Select Use Default Module Configuration.
4. Click Continue.
5. To send the currently displayed configuration to the module/port, click Configure. The module/port will remain in this configuration until you send it a different one.

Resetting a Module to the Default Configuration

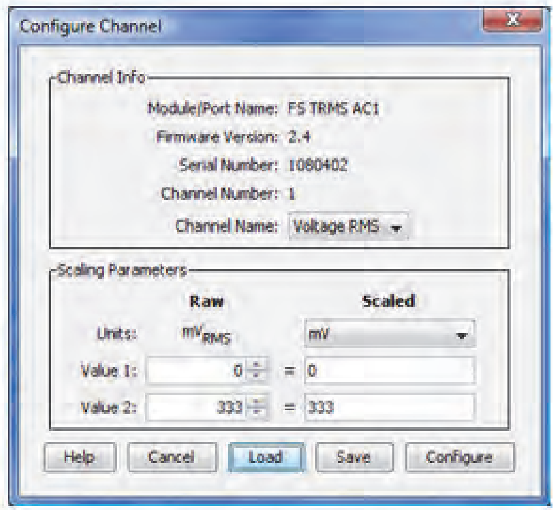
If you are experiencing problems with a module, you can reset it to the default configuration.

1. From the Device menu, select Configure Modules/Port.
2. Select a sensor and click Configure.
3. In the Configure Sensor window, click the Load button to view a list of all defined configurations in the currently selected folder that are compatible with the module/port.
4. Select Use Default Module Configuration and click Continue.
5. To send the currently displayed configuration to the module/port, click Configure. The module/port will remain in this configuration until you send it a different one.

The following examples show the default configuration for the analog modules. The configuration is the same for both channels.



CVIA Module



TRMS Module

Working with a Shuttle

HOBO shuttles provide a convenient way to read out and relaunch loggers in the field. The HOBO U-Shuttle features a text display and is compatible with all loggers that can be used with HOBOware Pro. The HOBO Waterproof Shuttle communicates with optic loggers. **Note:** To use a U-Series logger (other than the HOBO U30 Station) with a shuttle, the logger must first be launched with HOBOware version 2.2 or higher at least once. Consult the shuttle user guide for details.

After you read out a logger to the shuttle, you can then connect the shuttle to the computer and offload and save the files to view in HOBOware Pro. From the Device menu, select Manage Shuttle to open the Shuttle Management window to check the status and work with the shuttle. See Offloading and Saving Files from a Shuttle and Deleting shuttle files for more information on using the shuttle.

Note: While the Shuttle Management window is displayed, the U-Shuttle remains on battery power for up to an hour. After one hour, or any time the U-Shuttle's main battery level becomes low, the window closes and the shuttle powers down. To further conserve the shuttle's battery life, you should close the window, disconnect the shuttle, and turn the shuttle off as soon as you finish working with it.

U-Shuttle Firmware Updates

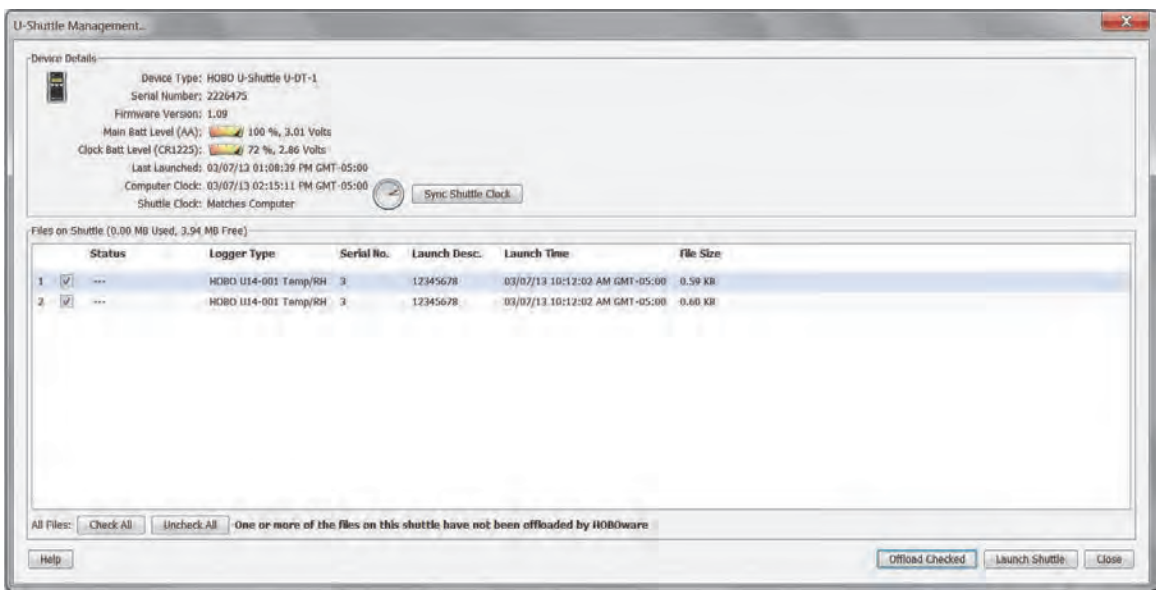
Occasionally, a firmware update may be available for the U-Shuttle. To check whether an update is available or if you are directed to update the firmware from Onset Technical Support:

1. Connect the U-Shuttle to the computer.
2. From the Help menu, select Update Device Firmware and then select U-DT-1/U-DT-2 from the submenu.
3. Follow the instructions on the screen to complete the upgrade process.

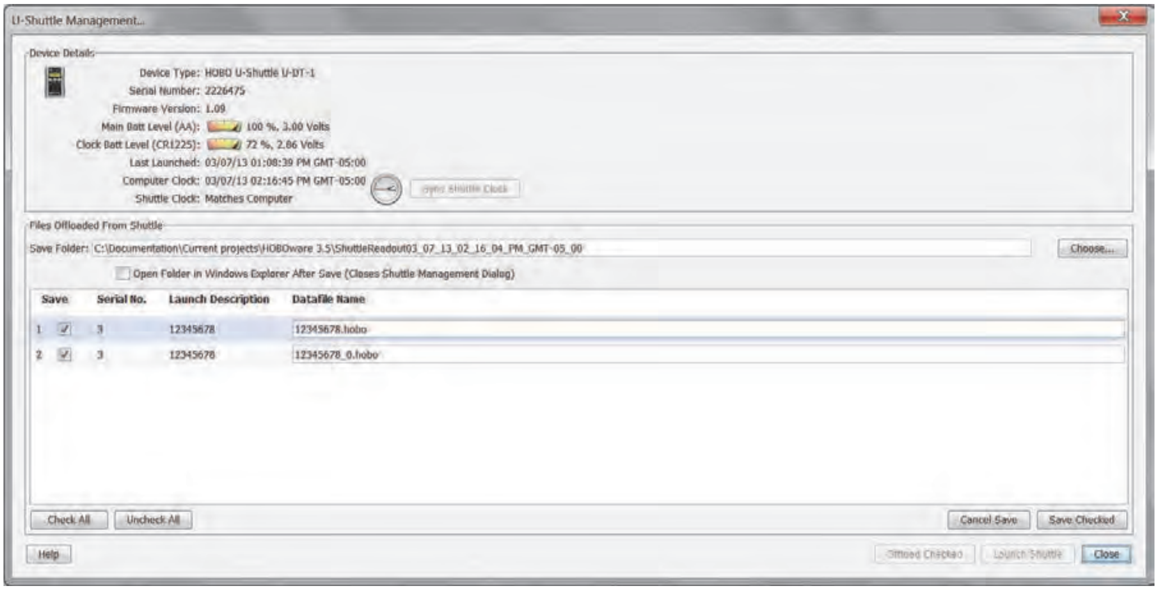
Offloading and Saving Shuttle Files

To offload datafiles from a shuttle to a compute:

1. Connect the shuttle to the computer. **Note:** HOBO Shuttles require HOBOware Pro.
2. From the Device menu, select Manage Shuttle. Or, to quickly offload all the new datafiles on the shuttle, select Readout from the Device menu.
3. In the Shuttle Management window, choose files to offload.
   - On the U-Shuttle, all files are selected by default if the shuttle has not been offloaded before. To deselect all files, click the Uncheck All button. To deselect individual files, click the checkbox next to each file.
   - On the Waterproof Shuttle, only the files that have not been offloaded AND saved previously are selected by default. To select or deselect individual files, click the chexbox next to each file. Use the Check All and Uncheck All buttons next to Previously Offloaded Files and New Files (Not Offloaded) to control the selection of these groups of files. To automatically delete files after you offload and save them, select the Delete Contents Upon Offload checkbox.



4. Click the Offload Checked button when you are ready to begin offloading the files from the shuttle. Once offloading begins, the Offload Checked button will change to Cancel Offload. When offloading is complete, the Files on Shuttle panel in the Shuttle Management window will change to a Files Offloaded From Shuttle panel.



5. The Save Folder indicates where the offloaded files will be saved. To change the location where these files are saved, click Choose and browse to another folder.
6. To open the folder automatically after they are saved, select the Open Folder in Windows Explorer after Save checkbox on Windows or the Open Folder in Finder after Save checkbox on Macintosh.
7. Select the files to save. By default, all the offloaded files are selected for saving. To deselect individual files, click the checkbox next to each file. To deselect all files, click the Uncheck All button. To save all files if you already deselected a few, click the Check All button.
8. Make any changes to the listed datafile names if desired for the files you are saving.
9. Click the Save Checked buttons to save all selected files in the folder specified in step 5.
10. Click the Launch Shuttle to reset the shuttle clock and delete all files from the shuttle. See Deleting Files from a Shuttle for more information.

The Shuttle Management Window

Use the Shuttle Management window to work with the HOBO U-Shuttle and Waterproof Shuttle.

Notes:

- HOBO Shuttles require HOBOware Pro.
- While the Shuttle Management window is displayed, the U-Shuttle remains on battery power for up to an hour. After one hour, or any time the U-Shuttle's main battery level becomes low, the window closes and the shuttle powers down. To further conserve the shuttle's battery life, you should close the window, disconnect the shuttle, and turn the shuttle off as soon as you finish working with it.
- The Waterproof Shuttle is powered by the USB port, and does not need to be turned off.

The Device Details panel displays the following information about the shuttle:

- **Device Type.** The shuttle model and description.
- **Serial Number.** Serial number of the shuttle.
- **Firmware Version.** Version number of the shuttle's firmware.
- **Main Batt Level (AA) (U-Shuttle only).** The condition of the shuttle's main batteries. Consult the U-Shuttle manual for specifics on battery capacity.

- **Clock Batt Level (CR1225) (U-Shuttle only).** The condition of the battery that provides backup power to the shuttle's clock. Consult the U-Shuttle manual for details.
- **Battery Level (Waterproof Shuttle only).** Condition of the shuttle's batteries when you opened the Waterproof Shuttle Management window. If the batteries are low, remember to change them before going into the field. Consult the Waterproof Shuttle manual for specifics on battery capacity.
- **Last Launched.** Date, time, and offset to Greenwich Mean Time (GMT, also known as UTC) when the shuttle was last launched.
- **Computer clock.** Time reported by the computer's clock.
- **Shuttle clock.** Status of the shuttle's clock in relation to the computer's clock. If the difference is more than five seconds, the shuttle clock label and icon will flash red. The shuttle's clock is synchronized to the computer when you launch the shuttle. Click the Sync Shuttle Clock button to synchronize the shuttle's clock to the computer clock without launching the shuttle. (Exit HOBOware Pro if you need to update the computer's clock first. **Important:** If the difference between the shuttle's clock and the computer's clock is more than 59 minutes, the Sync Shuttle Clock button is not available. You must launch the shuttle to correct the time difference

The Files on Shuttle panel lists the logger datafiles that are available to be offloaded from the shuttle. If the shuttle is empty, this panel displays "No Files Available on Shuttle." Use the Check All/Uncheck All buttons to select or deselect all files. The details for each file are:

- **Status.** The message that describes the state of the datafile on the shuttle. The status message is replaced by a progress bar while the file is actively being offloaded. For the U-Shuttle, the status message "Awaiting Offload" appears when HOBOware Pro is offloading files from the shuttle and "Finished" after each file is offloaded. For the Waterproof Shuttle, files have the status message "Offloaded" only if the file has been offloaded from the shuttle and saved as a datafile. If the files has not been offloaded, or it has been offloaded but not saved, its status is listed as "Not Offloaded."
- **Logger Type.** Model and description of the logger where the datafile originated.
- **Serial No.** Serial number of the logger where the datafile originated.
- **Launch Desc.** Description in place when the logger was launched. This description will be the default datafile name.
- **Launch Time.** Date, time, and offset to Greenwich Mean Time (GMT, also known as UTC) when the shuttle was last launched.
- **File Size.** Actual size of the datafile.

After clicking the Offload Checked button, the Files on Shuttle panel will change to a Files Offloaded from Shuttle panel. This panel lists the folder where the files will be saved (or click Choose to select a different directory). You can also select to a checkbox to automatically open the folder in Windows Explorer or Finder (Macintosh) after the files are saved. The serial number, Launch Description, and default file name is listed for each datafile. Click the Save Checked button to save all the selected files.

Use the Launch Shuttle button to delete all files (whether saved or not) from the shuttle and to reset the clock. Launching the shuttle also repairs a corrupted header.

Deleting Files from a Shuttle

You can delete files from a shuttle after they have been offloaded and saved. **Note:** HOBO Shuttles require HOBOware Pro.

To delete files from a shuttle:

1. From the Device menu, select Manage Shuttle.

2. Offload and save any files if necessary. You must at least offload all files before deleting (click Cancel Save if you do not want to save the files). If you are offloading a Waterproof Shuttle, select the Delete Contents Upon Offload checkbox to automatically delete all files after you offload and save them.
3. To delete ALL files regardless of whether they have been offloaded and saved, click the Launch Shuttle button. This will reset the shuttle's clock and its Last Launched time.

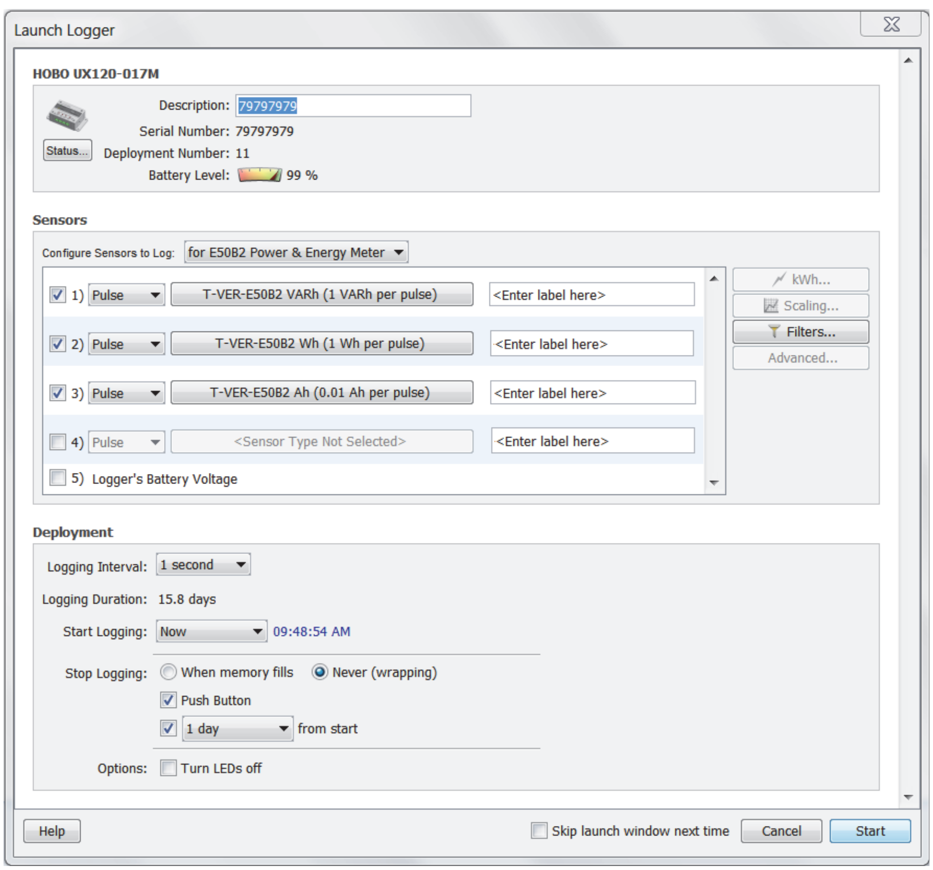
   To delete individual files from a Waterproof shuttle (you cannot delete individual files from a U-Shuttle), click the checkbox for each unwanted file. To select all files that have already been offloaded, click the Check All button next to Previously Offloaded Files. Click Delete Checked after you have selected all the files you want to delete.

Note: The maximum amount of free memory available on a U-Shuttle is 3.94 MB because the header information on a HOBO U-Shuttle occupies 64 KB.

Configuring Loggers with the E50B2 Power & Energy Meter

When the E50B2 Power & Energy Meter (T-VER-E50B2) is combined with a supported logger, there is a custom setting available to quickly configure the applicable channels or sensor types. To access this setting:

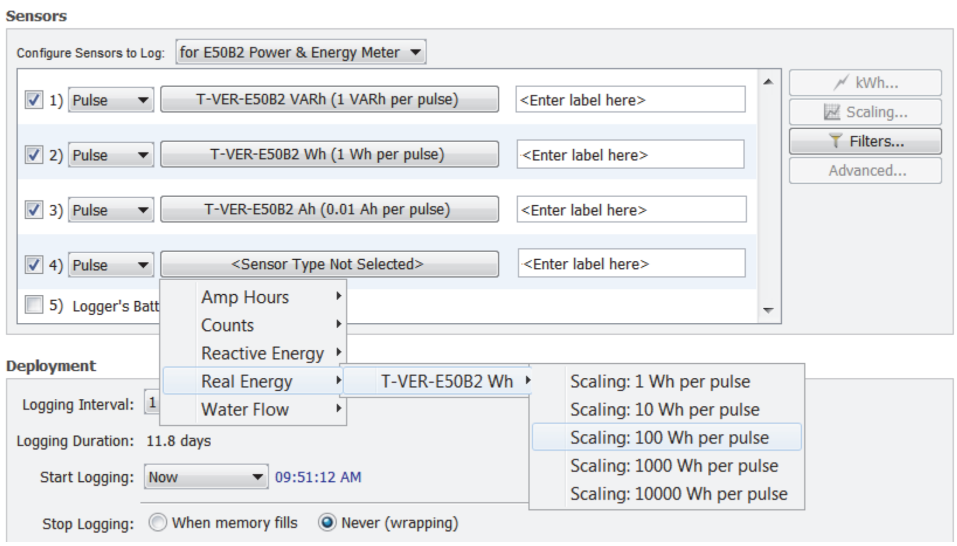
1. Connect a logger to the computer that supports the meter, such as the HOBO 4-Channel Pulse Input Data Logger (UX120-017x), and select Launch from the Device menu.
2. In the Launch Logger window, select "for E50B2 Power & Energy Meter" in the Configure Sensors drop-down list. The first three sensors, or data channels, listed will automatically be updated to display the appropriate settings for the E50B2 Power & Energy Meter as shown below.



When these settings are selected, the logger will record the default values from the Onset Power Meter. This means that when you read out the logger, the first three data channels will record the following by default:

- Reactive energy, at a rate of 1 pulse equal to 1 VARh
- Real energy, at a rate of 1 pulse equal to 1 Wh
- Amp hours, at a rate of 1 pulse equal to 0.01 Ah

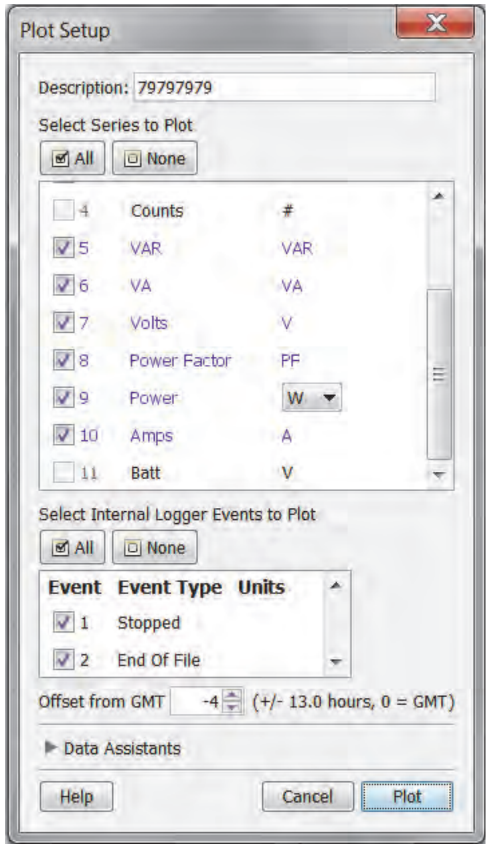
You can change the scaling for these three channels. Click one of the channel or sensor buttons and select the measurement type, sensor name, and then scaling factor. The example below shows changing scaling on channel 2 after clicking the "T-VER-E50B2 Wh (1000 Wh per pulse)" button. **Note:** The scaling factor must be the same for VARh and Wh channels. WARNING: If you change the default scaling parameters, you must also change the settings on the Onset Power Meter. Similarly, if you change the scaling on the device itself, you must also change the scaling in the software to match. Refer to the *Compact Power and Energy Meter (T-VER-E50B2) Full Install Guide* for details on how to change the settings on the device.



3. Select any other Launch settings as desired and then click Start to launch the logger with the Onset Power Meter settings (note that the Start button name changes depending on when you chose to begin logging).

Additional Series for Plot Setup

Datafiles from a logger with Onset Power Meter settings not only list logged sensor data, but they also contain additional derived series automatically calculated in relevant units. HOBOware uses the logged data from each of the three enabled sensors (reactive energy, real energy, and amp hours) to derive, or calculate, up to six additional data series that you can plot. These derived series are numbers 9 through 14 in the Plot Setup dialog box example below. Select the series you wish to view and then click Plot. These series are always available for plotting any time you open the datafile.



The following table lists the calculations for all derived series. It also specifies which of the three Onset Power Meter sensors/channels must be enabled at launch time for these series to be available upon readout.

Derived Series Name	Calculated By	Requires these Channel(s) to be Enabled at Launch
VAR	VARh / (logging interval in seconds / 3600)	Reactive Energy (VARh)
VA	VAh / (logging interval in seconds / 3600), where VAh = SQRT (Wh^2 + $VARh^2$)	Reactive Energy (VARh) and Real Energy (Wh)
Volts (V)	VAh / Ah, where VAh = SQRT (Wh^2 + $VARh^2$)	Reactive Energy (VARh) and Amp Hours (Ah)
Power Factor (PF)	Wh / VAh, where VAh = SQRT (Wh^2 + $VARh^2$)	Reactive Energy (VARh) and Real Energy (Wh)
Power (W)	Wh / (logging interval in seconds / 3600)	Real Energy (Wh)
Power (kW)	Wh / (logging interval in seconds / 3600) / 1000 OR W / 1000	Real Energy (Wh)
Amps (A)	Ah / (logging interval in seconds / 3600)	Amp Hours (Ah)

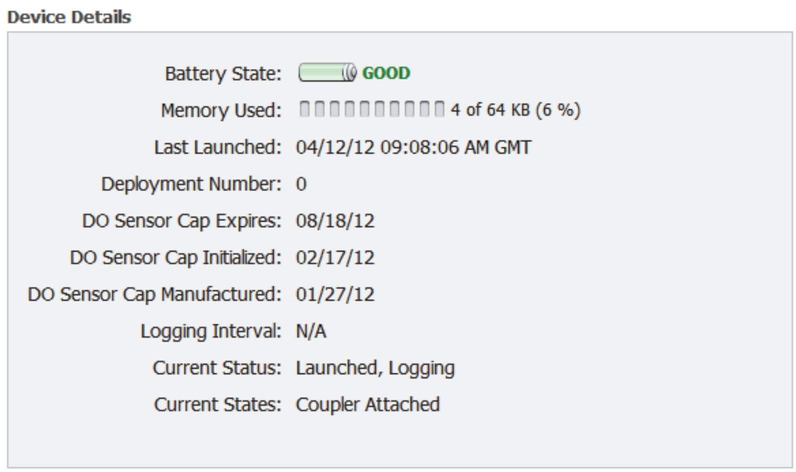
Checking Dates for the HOBO U26 Dissolved Oxygen Logger Sensor Cap

The HOBO U26 Dissolved Oxygen logger has a replaceable DO sensor cap intended for six months of use plus a one-month grace period. Once the cap is initialized, an internal clock within the logger will count down to the seven-month expiration date.

A new sensor cap can be initialized several ways:

- When the logger is launched, it will automatically be initialized when logging begins.
- You will be prompted to initialize it when checking the Status.
- You will be prompted to initialize it when using the Lab Calibration tool.
- If you replace an existing sensor cap while the logger is logging, it will automatically be initialized.

Once the 7-month countdown begins, you can see information about the sensor cap in the Status window as shown below.



In the Device Details pane, three key DO sensor cap dates are displayed:

- Expiration date, at which time you'll need to replace it with a new cap. **Important:** The logger will not collect any data after the cap has expired.
- Initialization date, which is the date the cap was initialized and the date the 7-month countdown began.
- Manufactured date; the cap has a shelf life and must be used within two years of this date.

For details on installing or replacing the DO sensor cap, see the logger manual.

Using the Lab Calibration Tool with the HOBO U26 Dissolved Oxygen Logger

Lab calibration is available for HOBO Dissolved Oxygen (U26-001) loggers. Use this tool when you need to calibrate the logger before deploying it or after replacing an expired sensor cap. The tool sets the gain and offset adjustment values for the logger by:

- Restoring logger calibration values to the factory defaults,
- Using your own gain and offset adjustment values, or
- Calculating the values with a three-step calibration procedure.

In the three-step procedure, the logger is first calibrated to 100% saturation by placing it in water-saturated air. Then, you can calibrate the logger to 0% saturation by placing it in sodium sulfite or another 0% oxygen environment (recommended if the logger will be deployed in water with DO levels of 4 mg/L or less).

Important: Lab calibration only affects future launches; any data saved in the logger will be based on the previous calibration values.

To complete these steps, you will need fresh water, the calibration boot and sponge supplied with the logger, and a source for current barometric pressure at your current location. You will also need sodium sulfite solution and a 3 inch beaker if you will be calibrating to 0% saturation.

The fresh water, logger, and sodium sulfite (if applicable) should be left out in the lab where the calibration is being done long enough so that they are at room temperature. If the logger had been deployed previously, make sure the sensor is clean and dry (see the logger manual for more details).

To use the Lab Calibration tool:

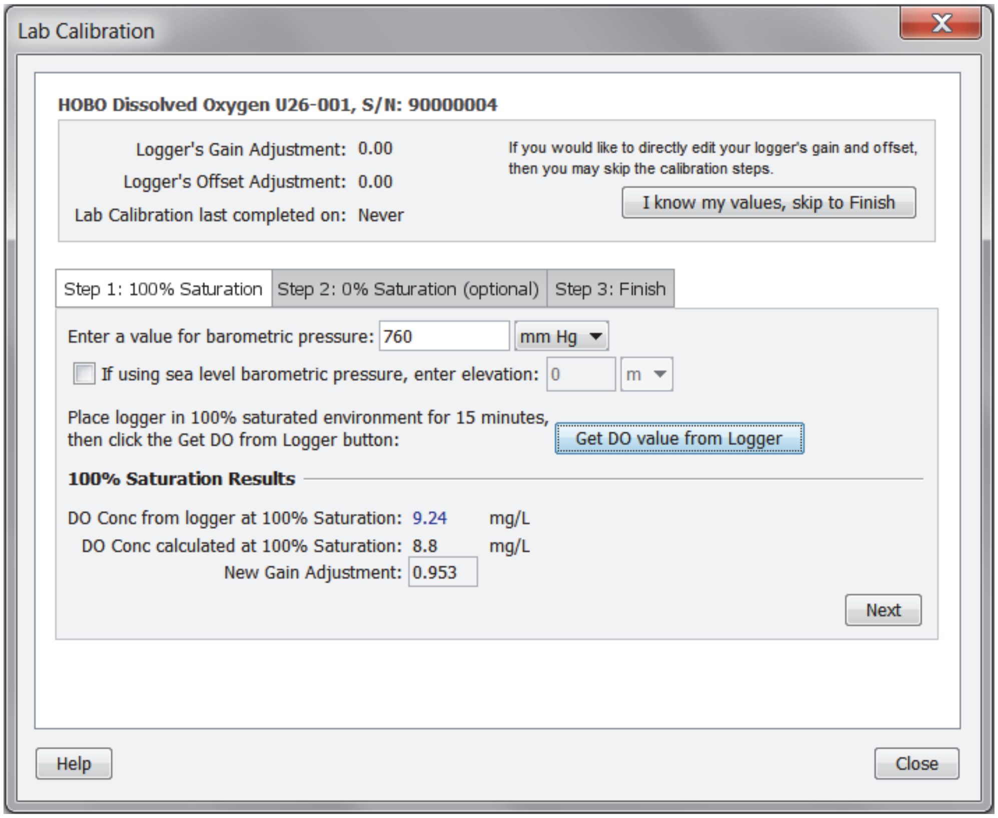
1. Connect a HOBO Dissolved Oxygen logger to the computer. Stop the logger if it is currently logging or awaiting a coupler or delayed start.
2. From the Device menu, click Lab Calibration. **Note:** If the sensor cap is installed and it has not yet been initialized, you will be prompted to do so. Follow the instructions on the screen. The sensor cap will expire in seven months once initialized.
3. The current gain and offset adjustments are displayed in the top pane of the window, along with the date and time the last lab calibration was completed (if applicable). Completing Steps 1 through 3 in this window will result in new gain and offset adjustment values based on the current logger conditions. Continue to the next section for details on how to complete these steps.

If you already know what the gain and offset values should be (for example, the values from a previous calibration that you want to use again) or want to return to the default factory values, click the “I know my values, skip to Finish” button. This will automatically move you to “Step 3: Finish.” Either click the “Reset to Factory Defaults” button or type in new gain adjustment and new offset adjustment values and click the “Send Calibration to the Logger” button. **Note:** If you decide you do not need to change the calibration, click Close to cancel the calibration and revert back to the last saved logger values.

Step 1: 100% Saturation

1. Enter the barometric pressure for your current location in one of five available units. If the barometric pressure reading has been adjusted for sea level (such as a reading taken from the National Weather Service weather station), select the "If using sea level barometric pressure, enter elevation" checkbox and enter your elevation in either meters or feet.
2. Make sure the logger either has the protective guard or the anti-fouling guard installed (whichever guard you plan to use in the deployment) so that the sensor is covered.
3. Wet the small sponge that shipped with the logger with fresh water. Squeeze out any excess water.
4. Place the sponge in the end of the calibration boot.
5. Insert the logger in the calibration boot so that there is approximately a 1 cm (0.5 inch) overlap between the end of the boot and the body of the logger. This will ensure there is enough space between the end of the logger and the sponge (the logger should not be pressed up tightly against the sponge).
6. Wait for approximately 15 minutes until the logger reaches temperature equilibrium. **Important:** The logger will "go to sleep" if there is no activity for 30 minutes. To avoid this, click the "Get DO value from the logger" button as described next in step 7 well before 30 minutes have passed. If the logger does go to sleep, a message will appear indicating that there was a communication failure. You may need to close and reopen the Lab Calibration window to reactivate the logger. Follow the instructions on your screen.
7. Click the "Get DO value from the logger" button to display the 100% saturation results. You can click this button as often as needed. The results are updated each time you click the button. To check for equilibrium, click the “Get DO value from the logger” button several times in a row to check the current “DO Conc from logger at 100% Saturation” value. If the value remains the same or varies very little with each button click, then temperature equilibrium has likely been reached.

8. When you are satisfied with the results displaying, click the Next button to proceed to "Step 2: 0% Saturation."



Step 2: 0% Saturation (optional)

If the logger will be deployed in water with DO levels greater than 4 mg/L, click the "Skip this Step" button. Otherwise, continue with the following procedure.

1. Make sure the logger either has the protective guard or the anti-fouling guard installed (whichever guard you plan to use in the deployment) so that the sensor is covered.

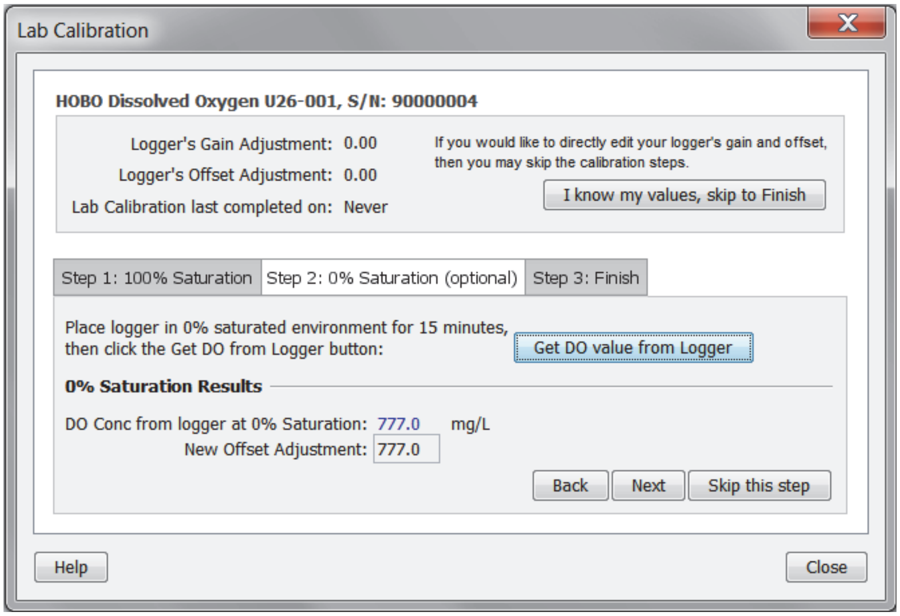
2. Pour the sodium sulfite into the beaker so that it is about two-thirds full.

3. Place the sensor end of the logger into the solution so that the entire protective cap or anti-fouling guard and at least 2.5 cm (1 inch) of the logger body are submerged in the beaker. Allow it to rest on the bottom of the beaker.

4. Wait a few minutes until the logger reaches temperature equilibrium. **Important:** The logger will "go to sleep" if there is no activity for 30 minutes. If this happens, you will need to close and reopen the Lab Calibration window to reactivate the logger and, as a result, repeat the calibration for 100% saturation. To avoid this, click the "Get DO value from the logger" button as described next in step 5 well before 30 minutes have passed.

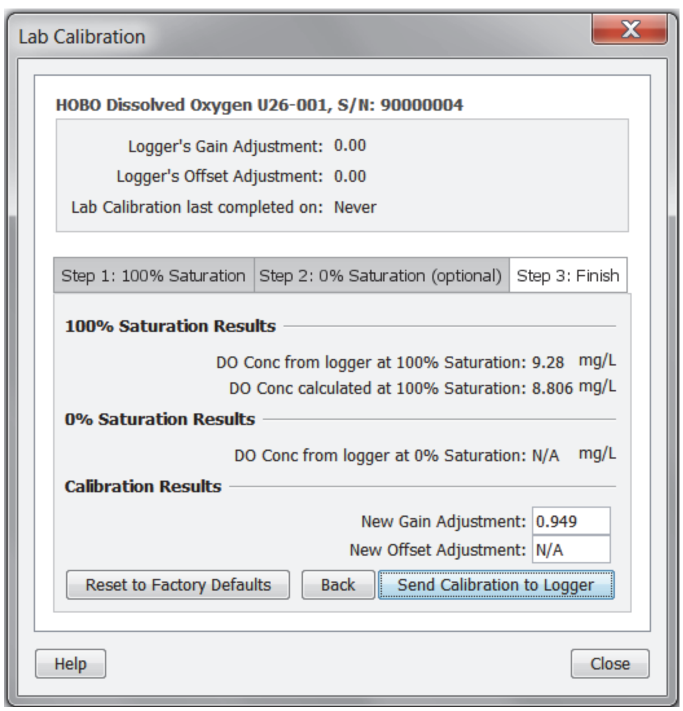
5. Click the "Get DO value from the logger" button to display the 0% saturation results. As with the 100% calibration, you can click this button as often as needed. The results are automatically updated each time you click the button. If the value remains the same or varies very little with each button click, then temperature equilibrium has likely been reached.

6. When you are satisfied with the results displaying in the Step 2: 0% Saturation tab, click the Next button to proceed to "Step 3: Finish."



Step 3: Finish

The results from the first two steps are displayed as well as the overall calibration results and the new gain and offset adjustment values. If you are satisfied with the results, click the "Send Calibration to Logger" button. The logger will then be calibrated based on the new values. Click the Back button to return to a previous step if you wish to repeat Step 1 or Step 2. These values will not take effect until the logger is launched. If you do not want to save these values, click Close to cancel the calibration and revert back to the last saved logger values. Or, click "Reset to Factory Defaults” to return to the original values. If you performed Step 2, then remove the logger from the solution and thoroughly rinse it with fresh water to remove any excess sodium sulfite. See the logger manual for additional details on cleaning the logger.



Updating UX/MX Series Logger Firmware

You can update the firmware in a UX or MX series logger as needed with HOBOware. You may see that an update is available when opening the Launch Logger or Status window, or Onset Technical Support will notify you when this is necessary. If you download a firmware file as instructed by Onset Technical Support, then place the downloaded file into the following directory:

For Windows 7 or Windows 8: C:\Users\Public\Documents\HOBOware Public Files\FWUpdates

For Windows XP: C:\Documents and Settings\All Users\Shared Documents\HOBOware Public Files\FWUpdates

For Macintosh: /Users/<user>/Documents/HOBOware/FWUpdates

To update UX series logger firmware:

1. Connect a UX or MX series logger to the computer.
2. **Important: Stop and read out the logger and save the file before updating the firmware.** The update process will delete all existing data in the logger so be sure to stop and read out the logger before continuing with the next step.
3. From the Help menu, select Update Logger Firmware and then select Update UX/MX Series Logger Firmware. **Note:** This is not necessary if a message indicates that a firmware update is available after opening the Launch Logger or Status window. Continue with the next step instead.
4. If there is a newer firmware version available than the version currently installed in the logger, a message appears indicating a firmware update is available. Click Yes to continue.

   If a newer firmware version is not detected, then a message appears indicating there are no updates available for this logger. There may be instances where you have downloaded a firmware .hex file from the Onset website and need to locate this file. If so, click Yes when this message appears to find the file. Otherwise, click No to close the message and exit the update process.
5. In the Update UX/MX Series Logger Firmware window, the suggested firmware file for use with the current logger is displayed. The logger model number will be listed within the file name for you to double-check that it is the correct version for the logger you are updating. If the file listed is the one you wish to use, then click Continue. If it is not the correct file or you wish to locate a different file based on instructions from Onset Technical Support, click Select Firmware and locate the appropriate file. **Note:** If you click Cancel, you may still be prompted for an additional firmware update in some instances. Click Cancel again to completely exit the procedure.
6. A message appears warning you not to disconnect the logger until the update process is complete. The update process should take a couple of minutes. If you have not already read out the logger and saved the data, then click No to cancel the update and return to step 2. Otherwise, if you are ready to update the firmware in the logger, click Yes to continue.
7. As the firmware update process takes place, "Boot" will display on the logger LCD screen. Do not disconnect the logger during this process. Once the update is complete, a message will appear indicating the update was successful. UX100 series loggers require an additional firmware update. A message will appear automatically if a second update is necessary.

   For HOBO Plug Load (UX120-018) loggers only: Once "HOBO" appears on the LCD screen, disconnect the USB cable and then reconnect it before continuing to the next step.

   Repeat steps 4–7 if another firmware update is available.

   Note: If "Boot" remains on the logger LCD screen after this is complete, the device may need to be reset. Contact Onset Technical Support for help.
8. After the firmware update process is complete, you will need to launch the logger before you can use it again. If you'd like to launch the logger immediately, click Yes. Otherwise click No to close the message and click Launch from the Device menu to launch the logger at a later time.

Fixing "Read Header Failed" Error

Occasionally, when trying to launch, check status, or read out a U-Series logger (other than a HOBO U30 Station), HOBO Waterproof Shuttle, or HOBO U Shuttle, you may receive the following error: "Read Header Failed." These messages occur when a device's header cannot be read, usually because of a communication error or corrupted header. Disconnect the device from the computer, then reconnect it and try to launch, check status, or read out again.

If you receive the message again, the header has probably become corrupted. The most common cause of header corruption is a communication problem during launch, such as the USB cable coming loose or an optical logger slipping out of its base station/coupler while the Launching Logger progress bar is displayed. In that case, there is a possibility that valid data has been logged, but cannot be read out.

You can restore the header by launching the logger or shuttle. This will reset the device's launch options to factory defaults. However, it will also cause any logged data or offloaded data from a shuttle to be lost. If you receive a "Read Header Failed" message and are unable to read out the logger or offload a shuttle, please contact the vendor that sold you the device. It may be possible to retrieve the logged data.

Chapter 6
HOBOnode Manager

HOBOnode Manager is the software tool within HOBOware Pro for setting up and managing a ZW wireless data network, which consists of a receiver, data nodes, and router nodes.

For information about setting up a network, refer to the ZW Series Wireless Network Quick Start Guide available on www.onsetcomp.com.

For help with deploying a network in your facility, refer to the HOBO Data Node Deployment Guide also available at www.onsetcomp.com.

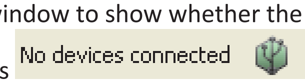
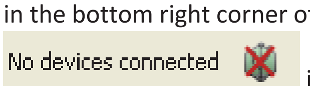
To open HOBOnode Manager for the first time, select the Device menu and choose Manage HOBO Data Node Network.

Notes about operating HOBOnode Manager:

- When HOBOnode Manager is open, two HOBOware icons appear in the Windows taskbar.
- You cannot access HOBOnode Manager if a HOBOware window, such as Logger Launch or Status, is open.
- You can close HOBOnode Manager and leave HOBOware running, but you cannot close HOBOware and leave HOBOnode Manager running. If you close both HOBOnode Manager and HOBOware, device communication can continue to run, which allows incoming data from the network to be uploaded to the computer. A HOBOware icon appears in your system tray when device communication is running. Note that the next time you open HOBOnode Manager, it could take several minutes for the real-time plots to reflect all the stored data.

  To stop device communication, right-click (or left-click on a Mac) the system tray HOBOware icon to access the Device Communication menu, which shows the receiver status and has options for stopping device communication and starting HOBOnode Manager. Device communication must be stopped when updating HOBOware software.

- An icon appears in the status bar at the bottom of the main HOBOware window to show whether the receiver is currently connected. If the receiver is connected, you'll see this  in the bottom right corner of the HOBOware window. If the receiver is disconnected, you'll see this  instead. The "No devices connected" message next to the receiver icon does not refer to devices within your data node network; it indicates that other devices, such as loggers and shuttles, are not currently connected. If you were to connect a logger or a shuttle, that message is updated independently of the receiver icon.

A Tour of HOBOnode Manager

This topic provides a description of the elements in HOBOnode Manager.

1. Tabs. Click the tabs to toggle between the Plots, Map, and Alarms pages.
2. Device Table. The Device Table displays information about the receiver and each node and configured sensor in your network. Use the Device Table to:

   - Select a device by checking the appropriate box in the Select column.
   - Double-click the <Enter label here> field to assign a name, or label, to the node or sensor. Type in the name and press Enter.
   - See a list of all network devices in the Type column, which lists the device by part number, followed by sensor part number as applicable.
   - View the serial number for the device in the S/N column.
   - Check the current status of the device, listed in the Status column. Data nodes and router nodes are listed as either Active (communicating with the receiver) or Missing (not communicating with the receiver). As with data notes and router nodes, sensor status can be Active or Missing, but it also be listed as Off if it is an external sensor that has not been configured. Receiver status is either listed as Connected or Not Connected.
   - See what the sensor is configured to measure in the Meas. type column. The measurement type is automatically filled in for internal sensors. The measurement type listed for external sensors is determined by the selections in the Configure Sensor dialog.
   - Check the latest reading for each sensor in the Reading column, and the time that reading was taken in the Time column.
   - View device readings in a real-time plot. Check the box in the Plot column to generate a real-time plot for that device.
   - See what group(s) the sensor has been assigned to in the Group column.

- Add the device to a map. Check the box in the Map column to add that device to the map. Drag the icon to the desired location on the map click the mouse button.
- Check whether an alarm has tripped for a specific device in Alarm column. A grey alarm icon means an alarm has not been set up for the device. A green alarm icon means an alarm has been set up, but has not tripped as of the latest reading. A red alarm indicates the alarm for that sensor has tripped.
- Check the signal strength between the device and receiver or the device and the nearest router in the Signal column. If the signal is low, there may be obstructions or other interference preventing the device from communicating to the receiver or router.
- Check the battery level for a specific device in the Battery column.

You can change the sort order in a column by clicking the column header. Right-click anywhere in the Device Table to restore the sort order. You can also show or hide individual columns by clicking the icon above the vertical scroll bar in the Device Table.

3. Configuration Bar. Use the Configuration Bar to select all or none of the devices, to quickly change the sensor type for external sensors, to assign sensors to groups, or to open the Configure window for additional sensor settings.
4. Help button. Click this button to access HOBOnode Manager help. Click the *Open topic with navigation* link to open the full Help table of contents.
5. Actions button. From the Actions button, you can print a copy of the device table, edit preferences, or create a new deployment.
6. Plot/Export Data button. Click this button to open the Plot/Export Wireless Data window, from which you can select sensor data to plot in HOBOware or export to a .csv or .txt file for use in another program.
7. Form Network button. Click this button to create a network and add data nodes and router nodes to it.

Viewing Real-Time Plots

In the plots window, you can view sensor data in real-time plots. You can plot a maximum of 20 sensors at once.

To view the real-time plot for sensors:

1. Select the Plot box in the Device Table for each sensor you want to view.
2. Select Sensor or Measurement view tab.

   In Sensor View, there is a separate plot for each sensor.

   In Measurement View, there is one plot for each Measurement Type (such as temperature), which may contain separate entries for multiple sensors.
3. Change the time frame of the plot using the Time Frame tabs.

- Use the Sort Plots By drop-down list to change the order of the plots.
- Use the Reorder Plots arrow to reverse the order of plots.
- Use the Plot Toolbar to zoom in or out, pause the plot, or print the plot.

Plotting Preferences

To change preferences that apply to real-time plots only, see Setting HOBOnode Manager Preferences.

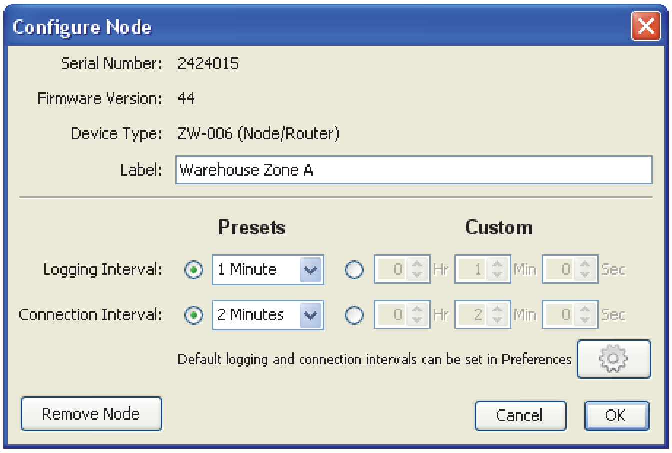
Use the general HOBOware Plotting Preferences to change the appearance of plots. To apply changes to real-time plots, re-start HOBOnode Manager or uncheck the sensor Plot box and then re-check. To open the Plotting Preferences, from the main HOBOware menu select File > Preferences and then click the Plotting tab.

Determining Data Node Type

There are three types of devices displayed within HOBOnode Manager: the data receiver (ZW-RCVR), end-point data nodes (ZW-0xx), and node/routers. A node/router can be either a data node (ZW-0xx) that was initially powered by an AC adapter instead of batteries or a router node (ZW-ROUTER) that routes data only and does not have recording capability. Use the icons in the device table to identify data node types. This is particularly helpful if you need to verify whether a data node (ZW-0xx) is acting as a data node only or if it also has routing abilities.

	Type	S/N	Status
Receiver	ZW-RCVR	2372376	CONNECTED
End-point Node	ZW-005	2431949	ACTIVE
	CABLE-TEMP/RH (Temp)	2431949-1	ACTIVE
	CABLE-TEMP/RH (RH)	2431949-2	ACTIVE
	<Select Analog Sensor>	2431949-3	OFF
	<Select Pulse Sensor>	2431949-4	OFF
Node/Router	ZW-006	2424015	ACTIVE
	TMCX-HX	2424015-1	ACTIVE
	TMCX-HX	2424015-2	ACTIVE

For another way to see whether the device is a data node only or a data node/router, double-click the device to open the Configure Node dialog. Check the Device Type for the device part number and description. In the example below, the device is operating as a both a data node and a router so the Device Type is listed as "ZW-006 (Node/Router)." If this device was powered by batteries only, then it would be operating as a data node and not a router, and listed as "ZW-006 (Node)."



Changing Logging and Connection Intervals

There are two types of intervals associated with data nodes:

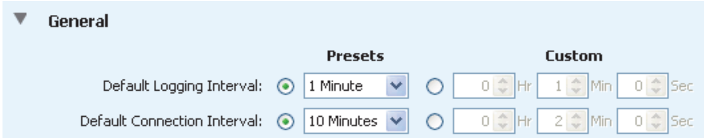
- the logging interval, which is how often the node records data and
- the connection interval, which is how often the node transmits data to the receiver.

When a data node joins a network, it uses the default logging and connection intervals that are set within the general preferences (upon installation of the software, the default logging interval is 1 minute and the default connection interval is 10 minutes). However, you can also define logging and connection intervals on a per-node basis, which gives you the flexibility of having data nodes logging and transmitting data at different rates.

Changing Default Values in Preferences

To change the default logging and connection intervals, click the Actions button in HOBOnode Manager and select Edit HOBO Data Node Preferences. Or, within HOBOware, select File > Preferences on Windows or HOBOware > Preferences on Macintosh and click Data Nodes. The default logging and connection intervals are under the General category of the data node preferences.

Select a preset value or set a custom interval. The minimum logging interval is 1 minute, and the minimum connection interval is 2 minutes.

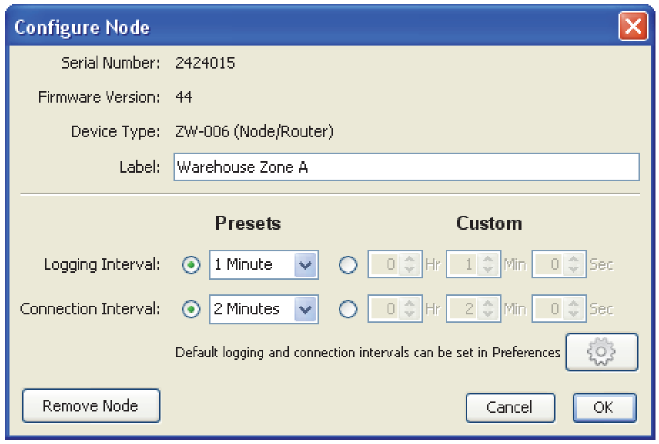


These default values will only be used for new data nodes that join the network. Changes to these default intervals will not affect data nodes that are already logging or that have been previously configured with their own individual logging or connection interval.

Changing Intervals for Individual Data Nodes

To change the logging and connection intervals on an individual data node:

1. Double-click the data node entry in the Device Table to open the Configure Device window.



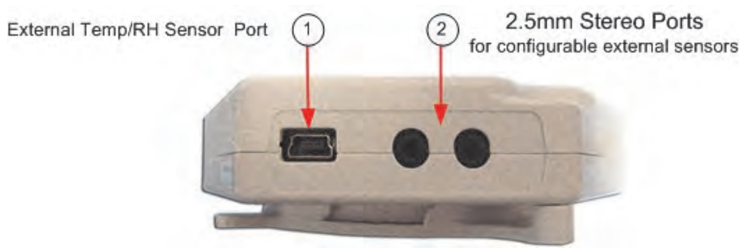
2. Change the logging interval and connection interval as required.
3. Click OK.

The changes will take effect the next time the data node connects to the receiver; they will only apply to that particular data node and its sensors. All other data nodes in the network will continue logging and connecting at their current intervals.

Setting up External Sensors

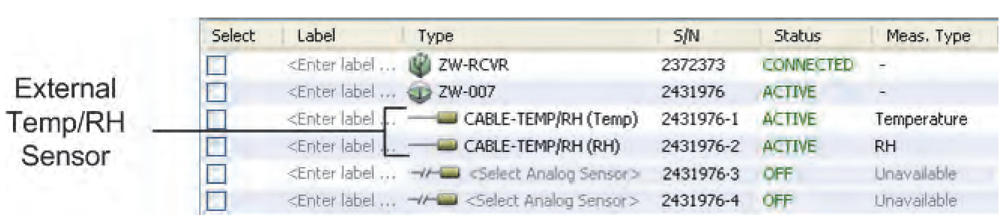
Important: Refer to the documentation that came with your sensor for specific connection and wiring information.

Data nodes support various external sensors that plug into one of two kinds of ports:



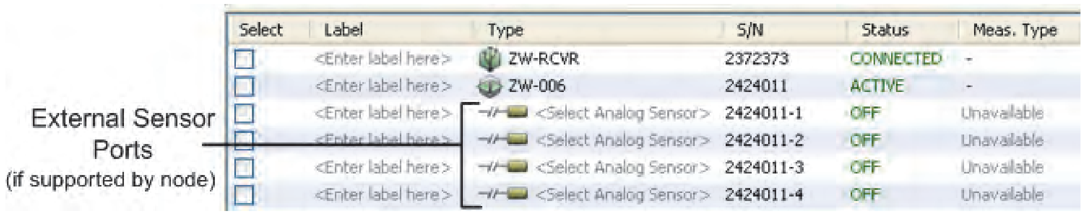
Most external sensors are not automatically configured. You must assign a sensor type for any external sensors connected to the data node (except for the External Temp/RH sensor). If you do not assign a sensor type, the device will not record any data for that sensor.

The ZW-005 and the ZW-007 support the External Temp/RH sensor (Part # CABLE-TEMP/RH), which plugs into the External Temp/RH Sensor Port (#1 in the photo above). This sensor is preconfigured and you do not have to select a sensor type. Separate rows appear under the node for the Temperature and RH channels with corresponding entries in the Type column.



Some data nodes support up to four configurable external sensors, which plug into one of the 2.5mm Stereo Ports shown (#2 in the photo above).

You must select a Sensor Type in HOBOnode Manager for these sensors. When the data node appears in the Device Table, configurable external sensors will not have an entry in the Type column.



To select a Sensor Type for an external sensor:

1. Double-click the row for the sensor in the Device Table.
2. Select the Sensor Type from the drop-down list.
3. Add a label for the sensor (optional).
4. Click OK.

Once you select a sensor type, the Status will change to ACTIVE and the appropriate measurement type will appear in the Measurement Type column.

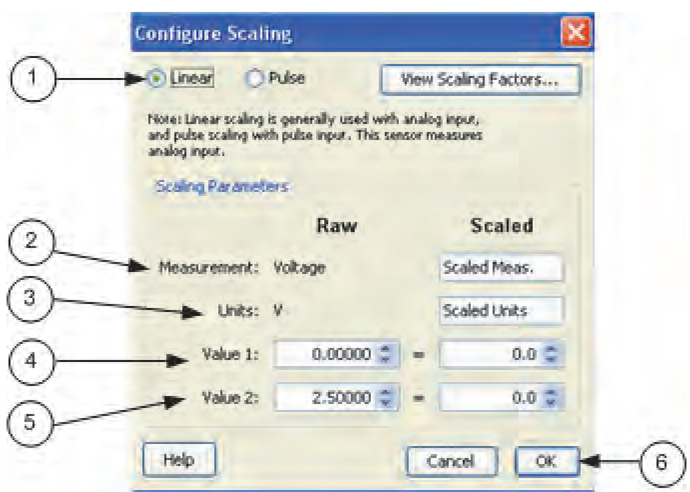
Some sensors must be scaling to give you meaningful data. Refer to Configuring Scaling on a Sensor for more details.

Configuring Scaling on a Sensor

Some sensors need to be scaled to provide meaningful data. Scaling is set through the Configure Scaling window. To open this window:

1. Double-click the sensor in the Device Table to open the Configure Sensor window.
2. Select the Sensor Type if not already selected.
3. Click the Configure button.

To set scaling for the sensor:



1. Check the scaling type is correct. The scaling type is automatically selected based on the type of sensor selected. Linear scaling is enabled for analog sensors; pulse scaling is enabled for pulse sensors. Note: Click the View Scaling Factors button to see scaling factors by sensor.
2. Enter the scaled measurement type. The Raw Measurement is the source measurement type, such as Current, Voltage, or Counts.

3. Enter the scaled units. The Raw Units is the type of output the sensor uses, either V or mA, corresponding to the type of sensor selected. Raw Value 1 and Raw Value 2 should be entered using these units.

4. Type in the Raw and Scaled numbers for Value 1. For Raw Value 1, enter the low raw value given by the external sensor. For Scaled Value 1, enter the value in the same units that were specified in the Scaled Units box. The Scaled Value 1 is the value that will appear on the plot when the sensor reports a raw value equal to Raw Value 1.

5. Type in the Raw and Scaled numbers for Value 2. For Raw Value 2, enter the high raw value given by the external sensor. For Scaled Value 2, enter the value in the same units that were specified in the Scaled Units box. The Scaled Value 2 is the value that will appear on the plot when the sensor repors a raw value equal to Raw Value 2.

6. Click OK when done.

Once scaling is configured on a sensor, the scaled icon will appear in the Meas. Type column in the Device Table.

Scaling Factors

Click the link below to see the scaling factors for your sensor model.

- Wattnode: T-WNB-3Y-208/ T-WNB-3D-240 / T-WNB-3D-480
- Veris: T-VER-8051-300/ T-VER-8053-800
- Veris: T-VER-H970-200
- Veris: T-VER-971BP-200
- Veris: T-VER-PXU-L/ T-VER-PXU-X
- Ion: T-ION-TVOC

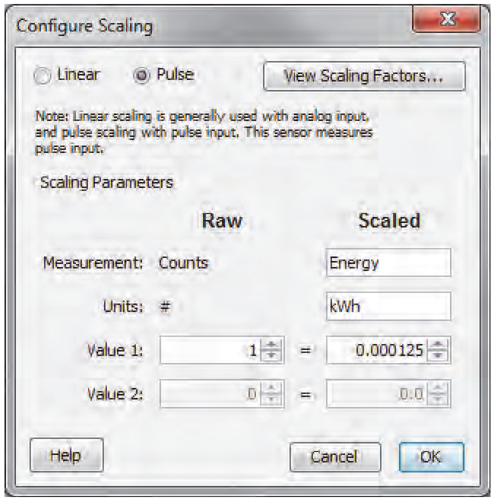
Wattnode Scaling Factors: T-WNB-3Y-208/T-WNB-3D-240/ T-WNB-3D-480

Use the table below to find the Kilowatt-hours per pulse for your CT Size and WattNode model and enter it in the Scaled Value 1 box.

Cable Required/Sensor Type: CABLE-2.5-STEREO

Example

This example shows the values you would enter in the Configure Scaling window for a Wattnode 3Y-208 with a 5 amp CT. Pulse should be selected automatically. In the Scaled column, type "Energy" for Measurement and "kWh" for Units. For this example, the Raw Value 1 is "1" and the Scaled Value 1 is "0.000125."



Kilowatt-hours per pulse

	Kilowatt-hours per pulse	
CT Size (amps)	Model #: 3Y-208/3D-240	Model #: 3D-480
5	0.000125	0.0002885
15	0.000375	0.0008656
20	0.0005	0.0011541
30	0.00075	0.0017313
50	0.00125	0.0028854
60	0.0015	0.0034625
70	0.00175	0.0040396
100	0.0025	0.0057708
150	0.00375	0.0086563
200	0.005	0.011542
250	0.00625	0.014427
300	0.0075	0.017313
400	0.01	0.023083
600	0.015	0.034625
800	0.02	0.046167
1000	0.025	0.057708
1200	0.03	0.06925
1500	0.0375	0.086563
2000	0.05	0.11542
3000	0.075	0.17313

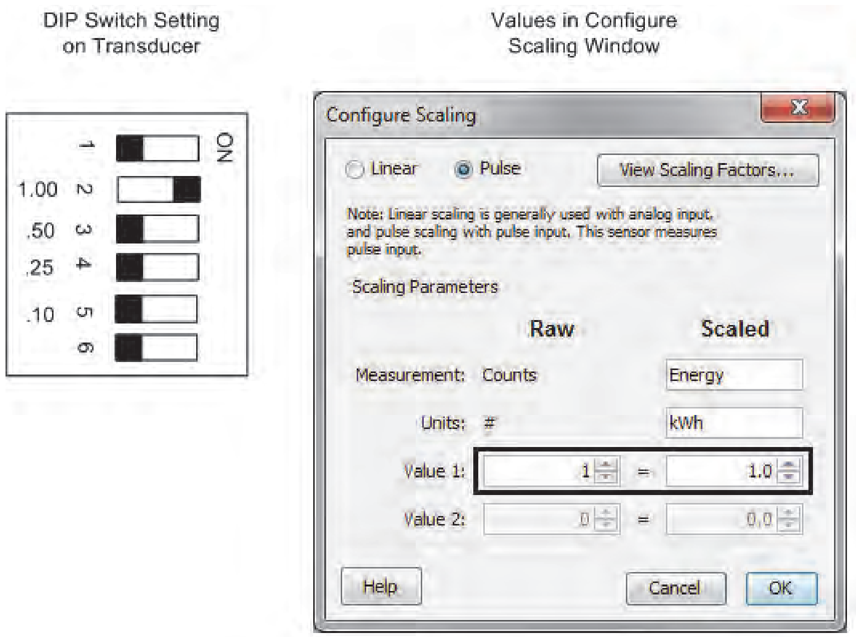
Veris Scaling Factors: T-VER-8051-300/T-VER-8053-800

The consumed energy in kilowatt-hours (kWh) per pulse for these sensors is determined by the DIP switch setting on the transducer. The default is "1.00" kWh / pulse, at which the scaling factor is 1 = 1. If you change the default DIP switch settings, adjust your scaling factors accordingly, as shown below.

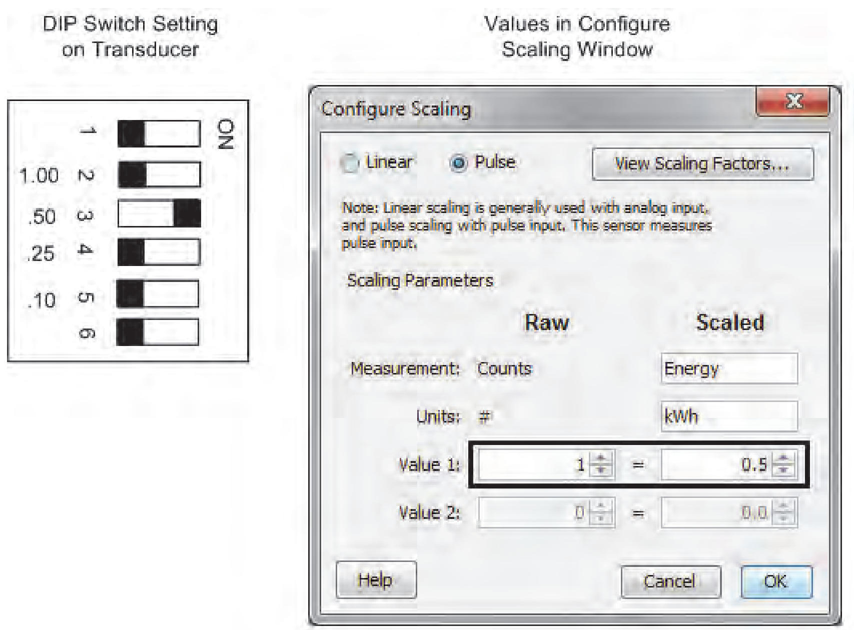
The data recorded by the data node will be the number of counts (pulses) per sampling interval.

Cable Required/Sensor Type: CABLE-2.5-STEREO

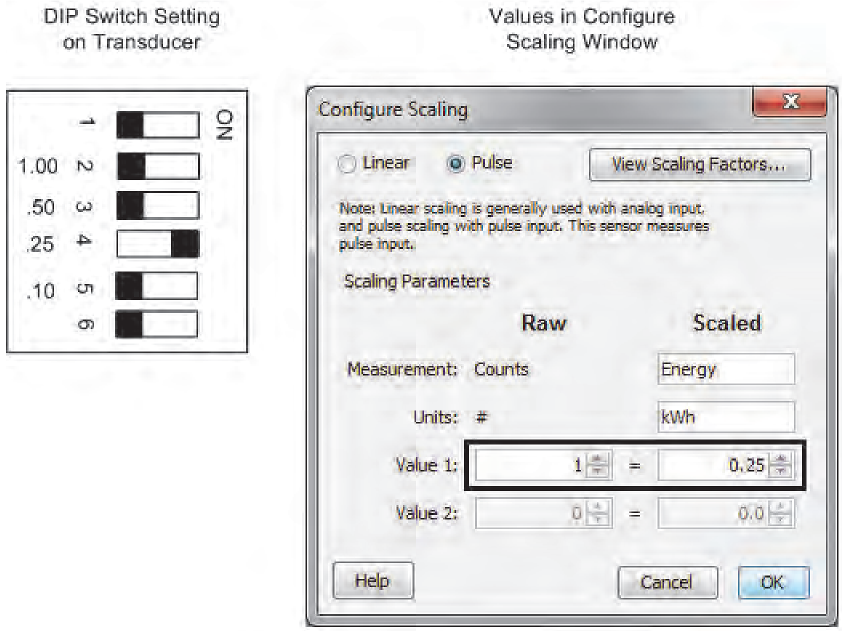
1.0 kWh Per Pulse (Default)



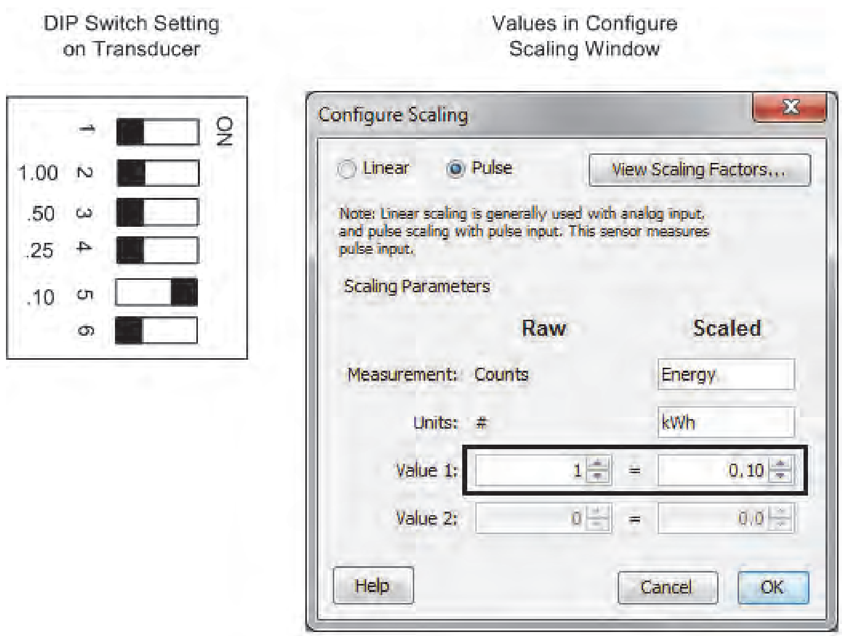
0.5 kWh Per Pulse



0.25 kWh Per Pulse



0.10 kWh per Pulse



Veris Scaling Factors: T-VER-H970-200

The T-VER-H970-200 has a selectable range for Linear Scaling: mA or Volts -> Amps. An AC-DC power adapter with a minimum of 6W @ 35mA is required for excitation power.

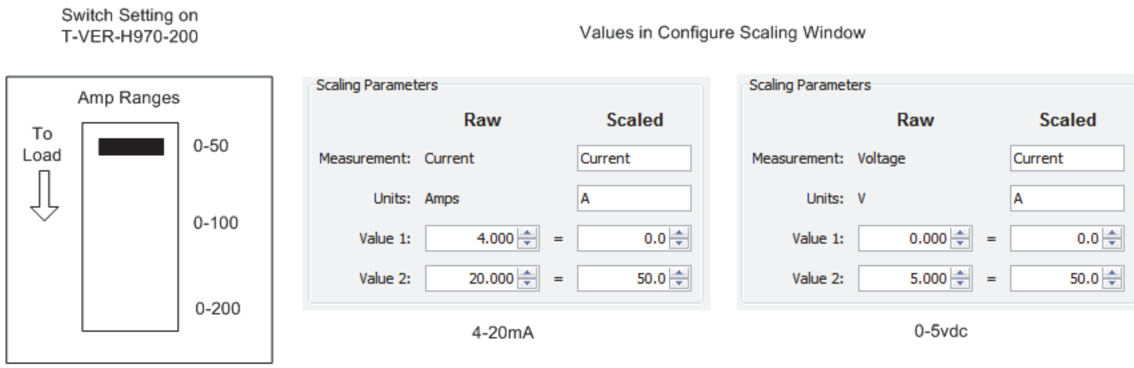
Cable Required/Sensor Type

Use the appropriate cable to connect the sensor to the data node and select the corresponding cable in the Sensor Type drop-down when configuring the External Sensor in HOBOnode Manager.

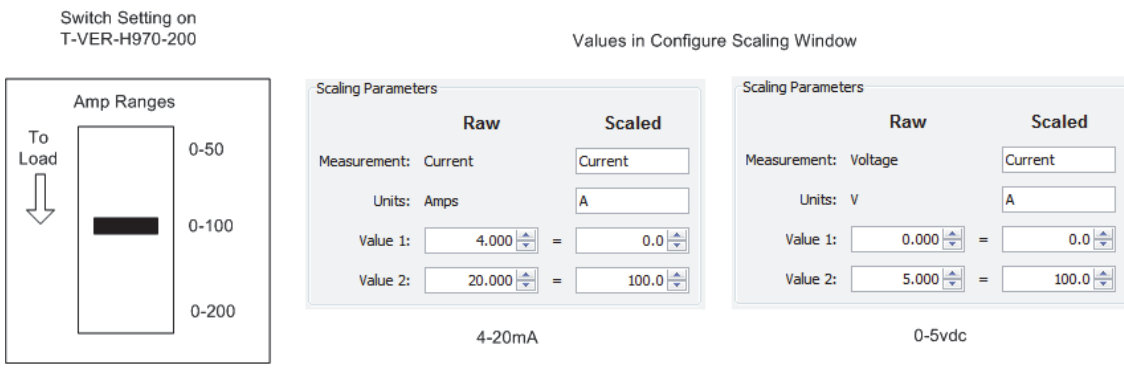
- For 4-20mA output, use CABLE-4-20mA.

- For 0-5vdc output, use CABLE-ADAP5.

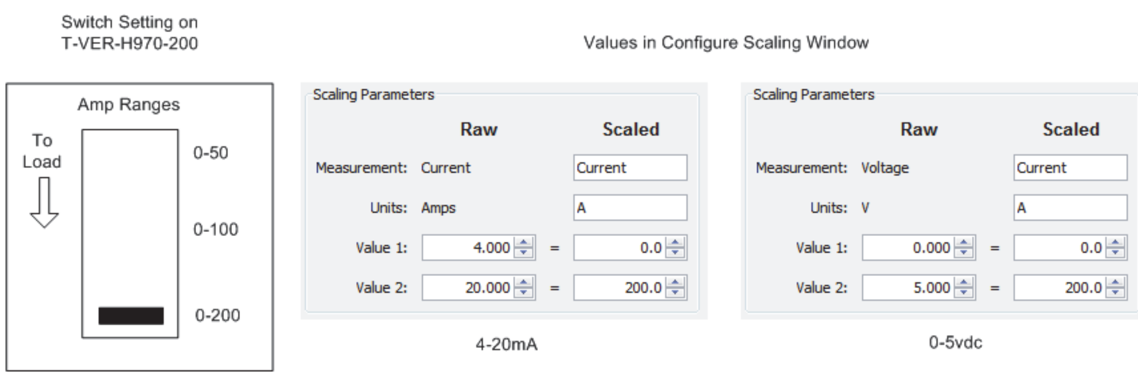
0-50 Amps



0-100 Amps



0-200 Amps



Veris Scaling Factors: T-VER-971BP-200

The T-VER-971BP-200 has a selectable range for Linear Scaling of mA to Amps for current flow in both directions.

Cable Type/Sensor Type

Use a CABLE-4-20mA to connect the sensor to the data node and select CABLE-4-20mA in the Sensor Type drop-down when configuring the External Sensor in HOBOnode Manager.

Notes:

- Requires 12-24VDC @ 35 to 110 mA excitation power depending on DC current load.
- An AC-DC power adapter with a minimum of 6W @ 65mA is required.
- For currents over 120 Amps, supply voltage to CT must be at least 15V to maintain accuracy.
- Minimum Warm-up Time is 8-10 seconds.

Span Setting

The H971 comes preset at the maximum (0-200A) span. To adjust the H971 to a different span, locate the potentiometer on the top of the device. This potentiometer is a multi-turn device, taking about 23 turns to adjust the span from ±20A to ±200A. Use the potentiometer to adjust the maximum amperage range used by the sensor.

The smallest amperage range (0 to ±20 A) is set by turning the potentiometer fully counterclockwise; the greatest amperage range (0 to ±200 A) is set by turning the potentiometer fully clockwise.

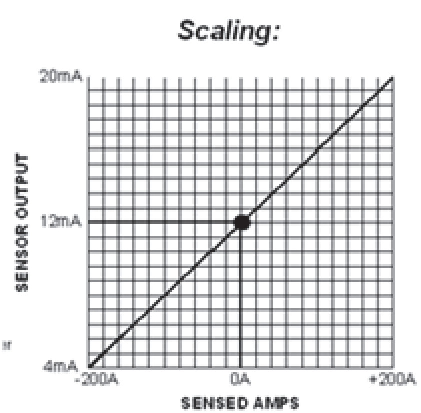
To determine the best amperage range for an application, first set the load to the maximum amperage that will be used. Use the LED as a guide to adjust the potentiometer to its optimum setting. Verify the measured output current matches the load current using a current clamp meter.

LED Activity	Potentiometer Adjustment
Steady green blink	Turn CCW until LED blinks rapidly, then slowly turn CW just until blink returns to steady rate.
Rapid green blink	Turn CW until LED blinks at a steady rate.

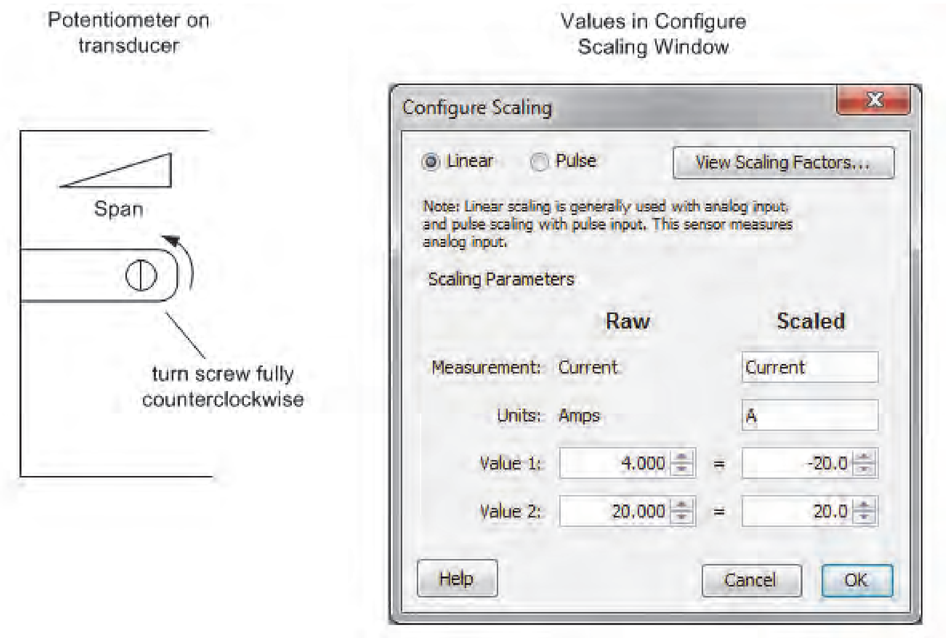
For an alternate method, see the Veris Installation Manual:

http://www.veris.com/docs/Installs/h971_971SP_i0d2.pdf

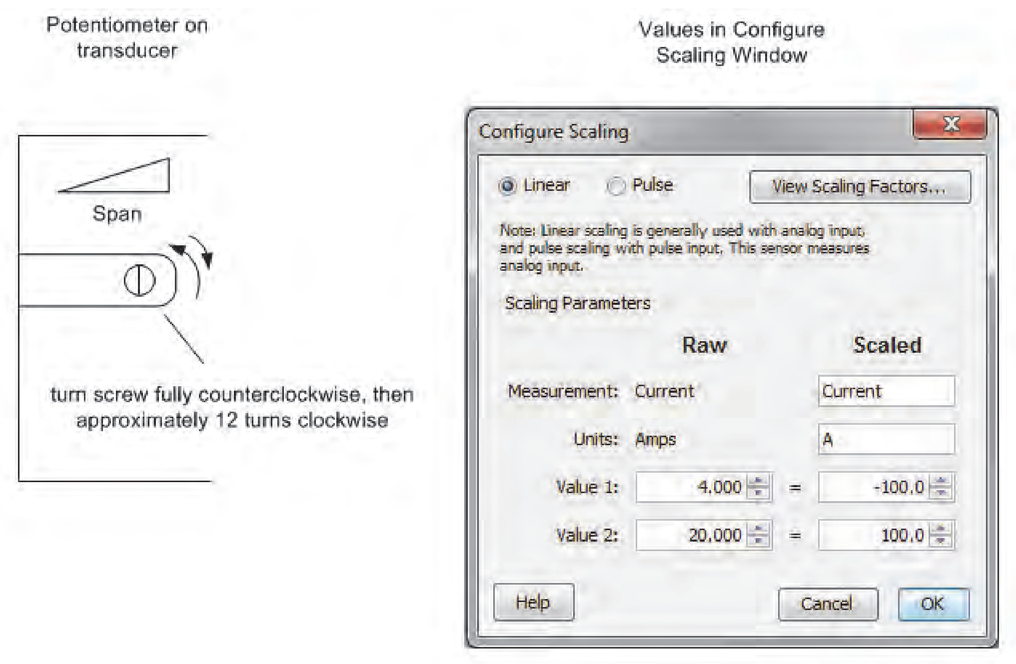
Scaling Graph



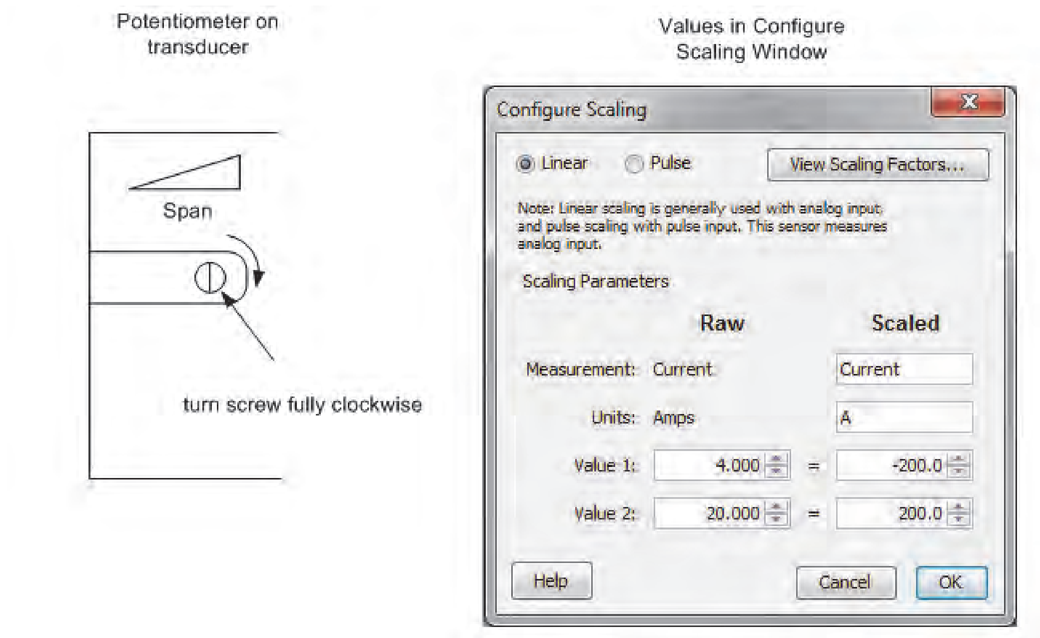
0-20mA



0-100mA



0-200mA



Veris Scaling Factors: T-VER-PXU-L/T-VER-PXU-X

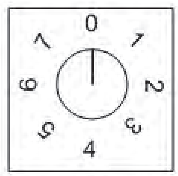
These Veris differential pressure transducers use Linear Scaling, mA or Volts -> "WC".

The analog output for these Veris sensors is determined by which screw terminals are connected either to a CABLE-4-20mA or to CABLE-ADAP5 or to CABLE-ADAP10. See the documentation that came with the hardware for details.

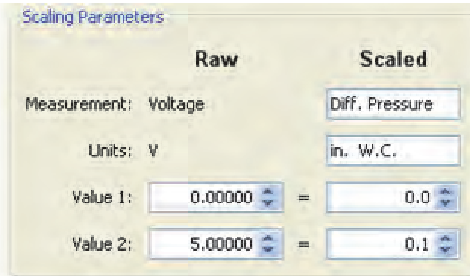
Both models have switch-selectable ranges and scales. The examples below show the scaling parameters you enter in the Configure Scaling window for the supported output ranges and raw values.

0 - 0.1 in. W.C.

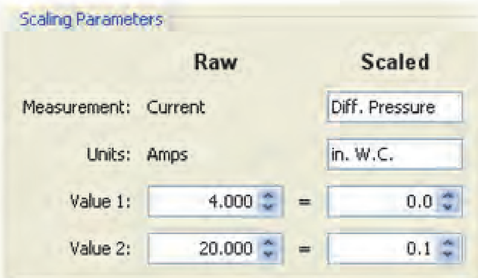
Range Setting on Sensor



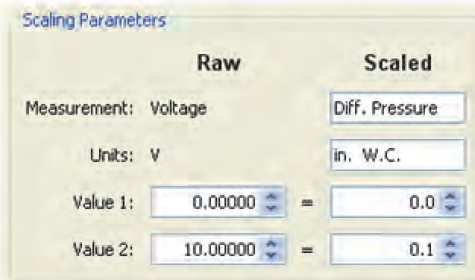
0 = 0 - 0.1 in. W.C.



Voltage: 0 - 5 V



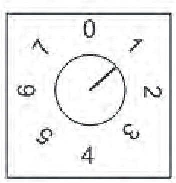
Current: 4 - 20mA



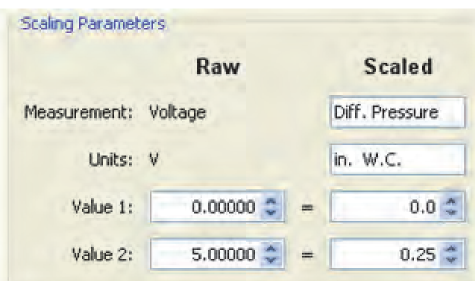
Voltage: 0 - 10 V

0 - 0.25 in. WC

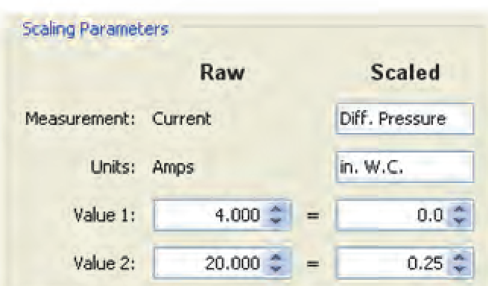
Range Setting on Sensor



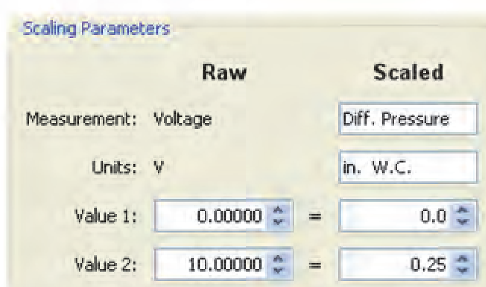
1 = 0 - 0.25 in. W.C.



Voltage: 0 - 5 V



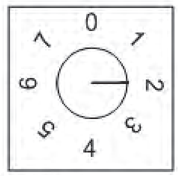
Current: 4 - 20mA



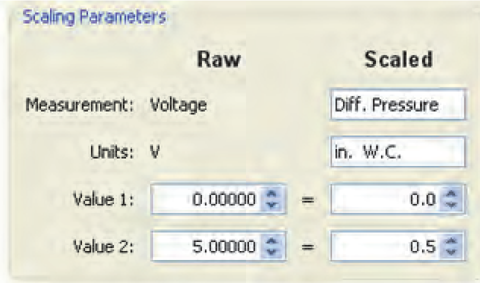
Voltage: 0 - 10 V

0 - 0.5 in. WC

Range Setting on Sensor



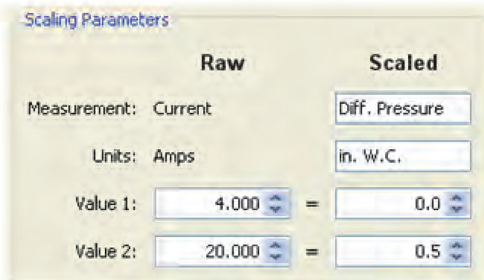
2 = 0 - 0.5 in. W.C.



Scaling Parameters

	Raw		Scaled
Measurement:	Voltage		Diff. Pressure
Units:	V		in. W.C.
Value 1:	0.00000	=	0.0
Value 2:	5.00000	=	0.5

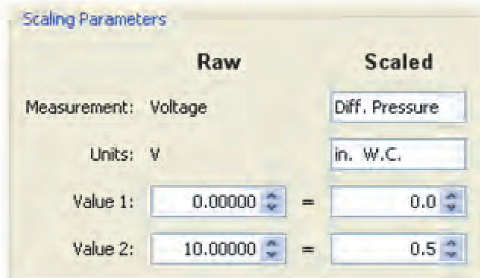
Voltage: 0 - 5 V



Scaling Parameters

	Raw		Scaled
Measurement:	Current		Diff. Pressure
Units:	Amps		in. W.C.
Value 1:	4.000	=	0.0
Value 2:	20.000	=	0.5

Current: 4 - 20mA



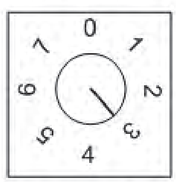
Scaling Parameters

	Raw		Scaled
Measurement:	Voltage		Diff. Pressure
Units:	V		in. W.C.
Value 1:	0.00000	=	0.0
Value 2:	10.00000	=	0.5

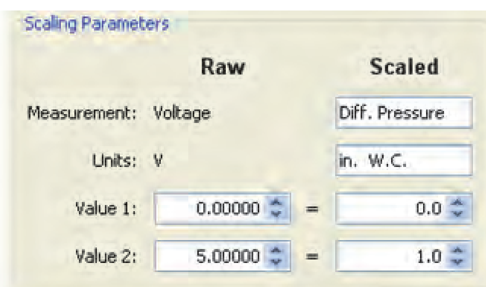
Voltage: 0 - 10 V

0 - 1.0 in. WC

Range Setting on sensor



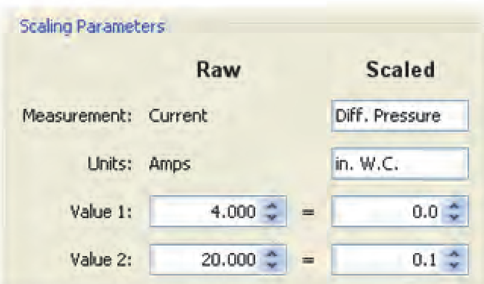
3 = 0 - 1.0 in W.C.



Scaling Parameters

	Raw		Scaled
Measurement:	Voltage		Diff. Pressure
Units:	V		in. W.C.
Value 1:	0.00000	=	0.0
Value 2:	5.00000	=	1.0

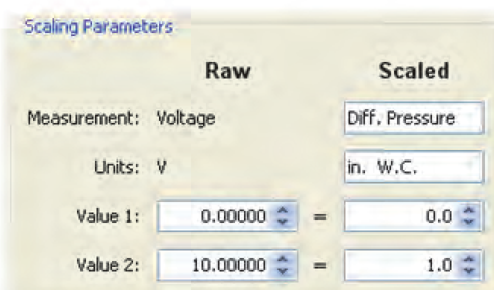
Voltage: 0 - 5 V



Scaling Parameters

	Raw		Scaled
Measurement:	Current		Diff. Pressure
Units:	Amps		in. W.C.
Value 1:	4.000	=	0.0
Value 2:	20.000	=	0.1

Current: 4 - 20mA

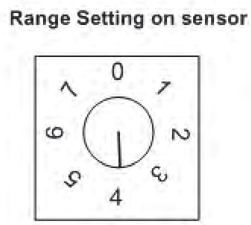


Scaling Parameters

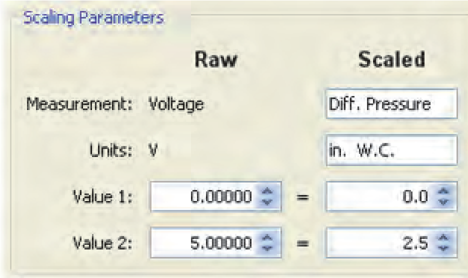
	Raw		Scaled
Measurement:	Voltage		Diff. Pressure
Units:	V		in. W.C.
Value 1:	0.00000	=	0.0
Value 2:	10.00000	=	1.0

Voltage: 0 - 10 V

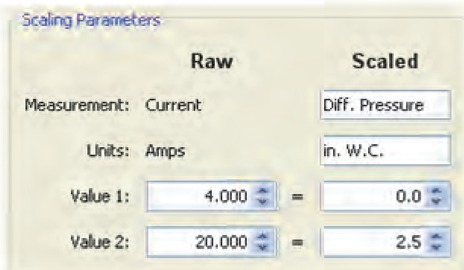
0 - 2.5 in. WC



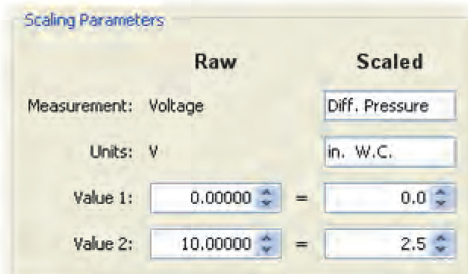
4 = 0 - 2.5 in. W.C.



Voltage: 0 - 5 V

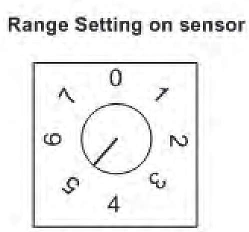


Current: 4 - 20mA

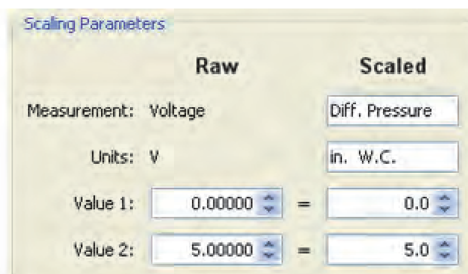


Voltage: 0 - 10 V

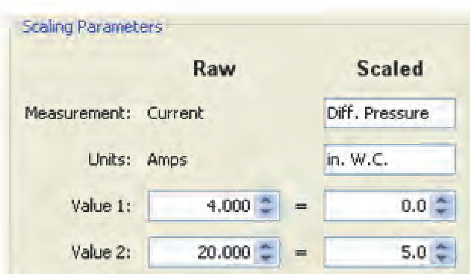
0 - 5.0 in. WC



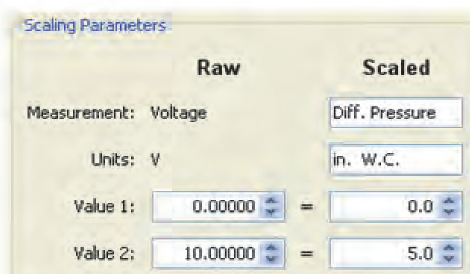
5 = 0 - 5.0 in. W.C.



Voltage: 0 - 5 V



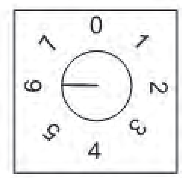
Current: 4 - 20mA



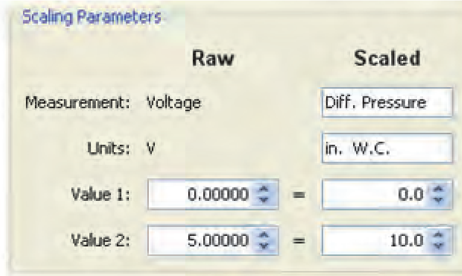
Voltage: 0 - 10 V

0 - 10.0 in. WC

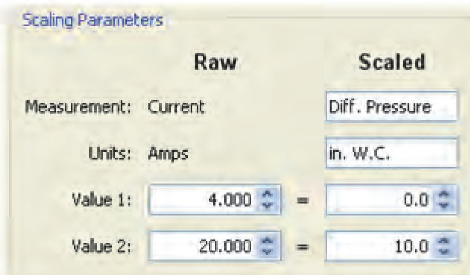
Range Setting on sensor



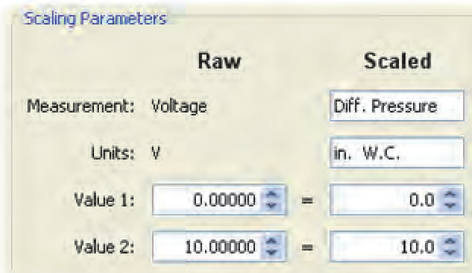
6 = 0 - 10.0 in. W.C.



Voltage: 0 - 5 V



Current: 4 - 20mA



Voltage: 0 - 10 V

Ion Scaling Factors: ION-TVOC

The ION-TVOC uses Linear Scaling, mA -> ppm.

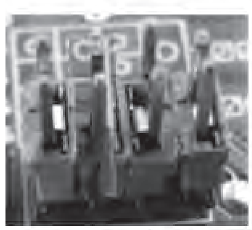
Cable Required/Sensor Type: CABLE-4-20mA

NOTES

- Requires Loop power of 22 mA. Lamp and electronics require 65 mA.
- An AC-DC power adapter with a minimum of 6W @ 35mA is required for excitation power.

0-10 ppm

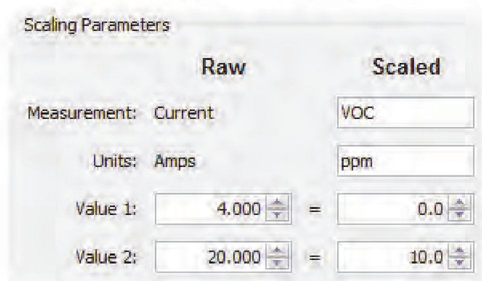
Hardware Setting



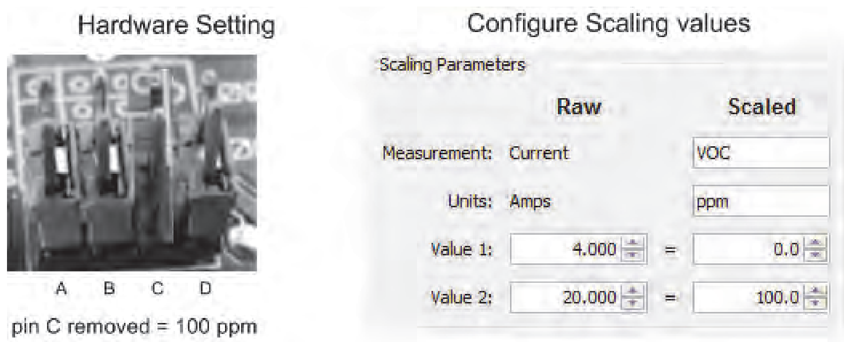
A B C D

pin B removed = 10 ppm

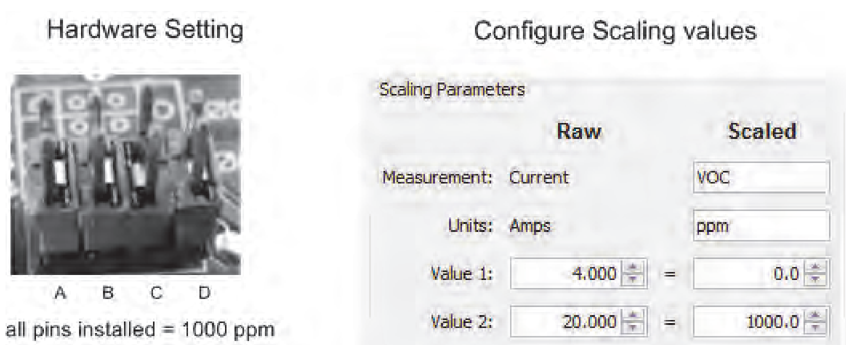
Configure Scaling values



0-100 ppm



0-1000 ppm



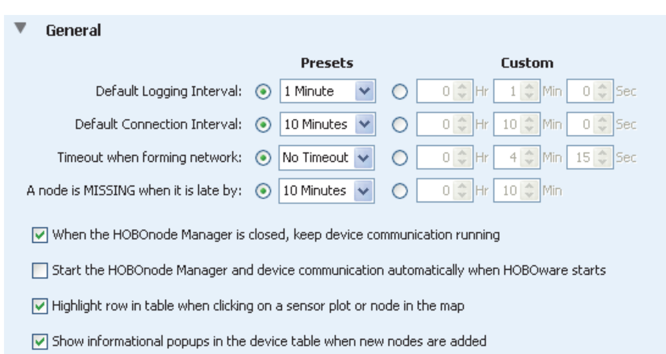
Setting HOBOnode Manager Preferences

You can change preferences for several features within HOBOnode Manager. You can access HOBOnode Manager preferences one of two ways:

- In HOBOware, select File > Preferences on Windows or HOBOware > Preferences on Macintosh and click Data Nodes.
- At the bottom of the HOBOnode Manager window, click the Actions button and select Edit HOBO Data Node Preferences.

General Preferences

The following general preferences are available:



- **Default Logging Interval.** This is how often data nodes will log data. The default is 1 minute.

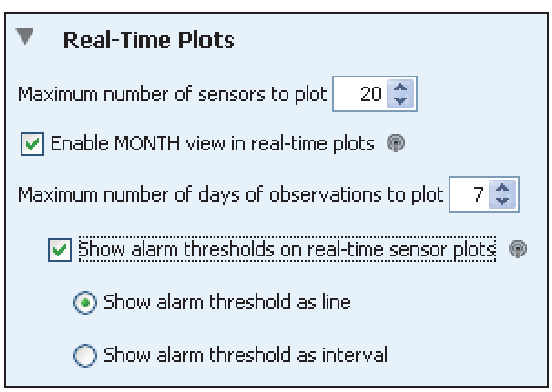
- **Default Connection Interval.** This is how often data nodes will send data to the receiver. The default is 10 minutes.
- **Timeout when forming network.** This is the amount of time that you can add a data node to the network after you click the Form Network button. By default, Form Network mode will remain active until you click the X on the Form Network progress indicator.
- **A node is MISSING when it is late by.** This is how long a node must go without sending data to HOBOnode Manager for it to be marked as missing. When a data node is missing, its status in the Device Table will be MISSING, and a MISSING NODE alarm will be tripped (if configured). The default is 10 minutes.
- **When the HOBOnode Manager is closed, keep device communication running.** This controls whether device communication automatically remains running when you exit HOBOnode Manager. The default is to keep it running.
- **Start the HOBOnode Manager and device communication automatically when HOBOware starts.** This controls whether HOBOnode Manager and the device communication automatically starts immediately upon opening HOBOware. The default is to not automatically open HOBOnode Manager and the device communication when HOBOware is opened.
- **Highlight row in table when clicking on a sensor or data node in the map.** This controls whether the corresponding row in the device table is automatically highlighted when you select a device in the HOBOnode Manager map. This is enabled by default.
- **Show informational popups in the device table when new nodes are added.** This controls whether a message is displayed every time a new device is added to the device table. This is enabled by default.

Alarms Preferences

See Setting Alarms Preferences.

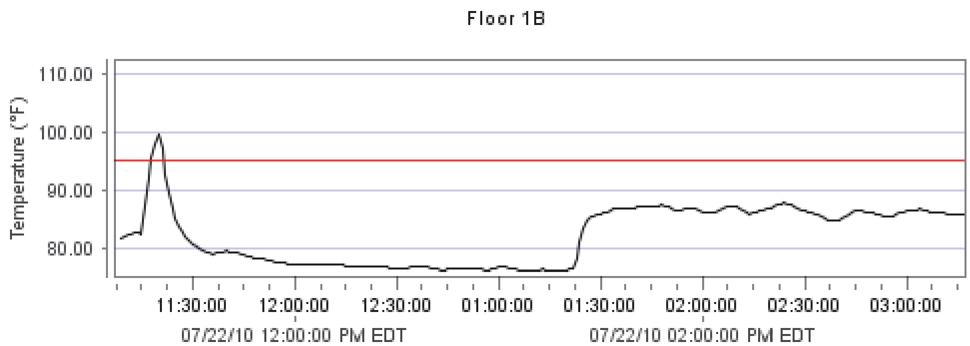
Real-Time Plots Preferences

You can customize the plots that appear in HOBOnode Manager by increasing the number of sensors you can plot at one time, adding the ability to view monthly data, displaying alarm thresholds, and more. These preferences are specific to real-time plots only. See Plotting Preferences for details on how to change general plot appearance, such as changing font type and size, adding gridlines, or modifying axis details.

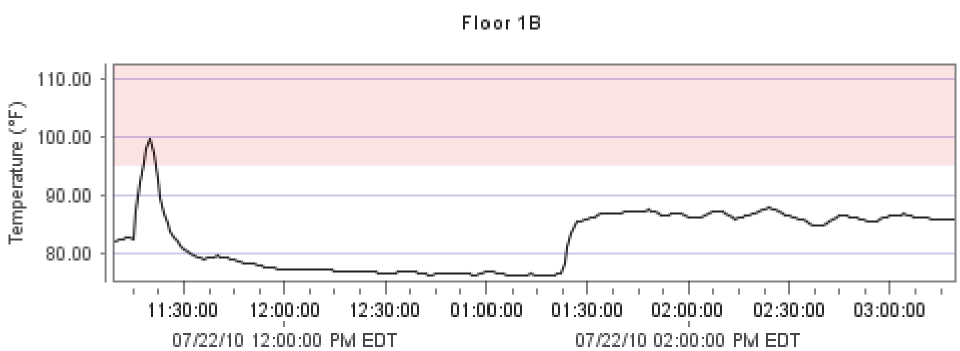


- Maximum number of sensors to plot. Select how many data node sensors you want to be able to plot at one time within HOBOnode Manager. You can select from 1 sensor to 100, with a default of 20.
- Enable MONTH view in real-time plots. Select this checkbox to add a Month button to the Plots tab in HOBOnode Manager. You can then plot data by hour (4 hours), day, week, or month. The Month view is disabled by default.

- Maximum number of days of observations to plot. Select how many days worth of data you want to view in the plot, up to 31. The default is 7 days.
- Show alarm thresholds on real-time sensor plots. Select this checkbox to add a visual indicator, or reference point, when a sensor alarm has tripped.
  - Select Show alarm threshold as line to display the alarm threshold on the real time plots as a horizontal line. An example of this type of reference point is the red line in the following plot where an alarm was configured to trip at above 95 degrees Fahrenheit.



  - Select Show alarm threshold as interval to display the alarm threshold as a shaded area: red when the alarm is above the specified threshold and blue when it is below. Using the same example, there is a red shaded area from above 95 degrees on the following plot instead of a single red line.



Data Storage

This lists the current location of the HOBOnode Manager database. For more information, see Data Storage Location.

Sharing

This provides options for sharing HOBOnode Manager data via HOBOnode Viewer or automatic data delivery. See Enabling HOBOnode Viewer and Setting up Data Delivery.

Working with HOBOnode Manager Data

There are several ways you can analyze data gathered in HOBOnode Manager. In addition to the viewing the real-time plots and information in the Device Table, you can:

- Plot or export data for use in HOBOware or external programs
- Set up groups to organize data
- Set up a HOBOnode Viewer web page for viewing on a local area network
- Automatically send data to others via email or FTP, or save it to a computer on a local area network

Plotting or Exporting Wireless Data

With HOBOnode Manager, you can view data and plots from your HOBO data node wireless network in real time, but you also have the ability to plot or export previously logged data. Using the Plot/Export Wireless Data capability, you can plot data directly in HOBOware or you can export it to a text or .csv file to open in another program for further analysis. You can pinpoint the exact data you wish to plot or export, allowing you to view data from:

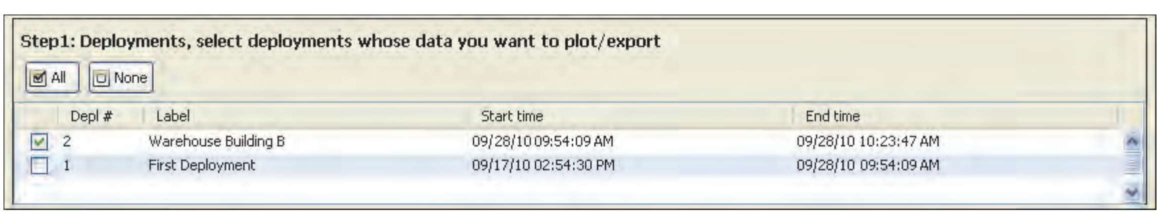
- Current and/or previous network deployments,
- Specific data nodes,
- A subset of certain sensors from selected data nodes,
- Groups of data nodes as configured in HOBOnode Manager, and
- A specific date range or timeframe.

In addition, you can save frequently used settings for quick plotting and exporting in the future and for use with data delivery, which allows you to share data automatically via email, FTP, or saved to a drive on a regular schedule.

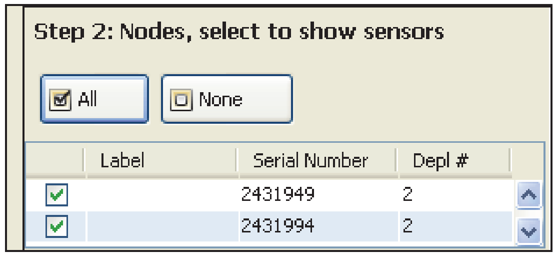
To open the Plot/Export Wireless Data tool, click the Plot/Export Data button in HOBOnode Manager (or from the File menu in HOBOware, select Plot/Export Wireless Data).

To use the Plot/Export Wireless Data tool:

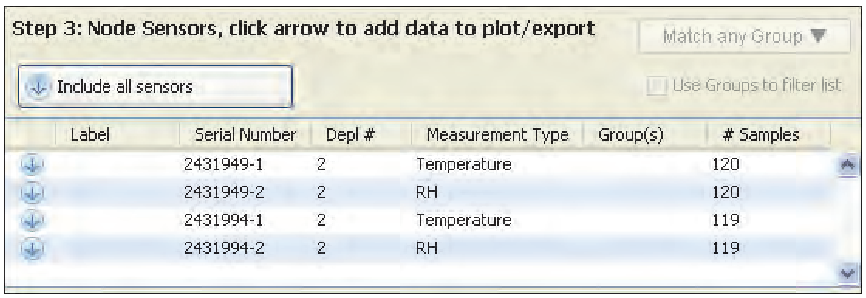
1. Select the deployment that contains the data you wish to plot or export.



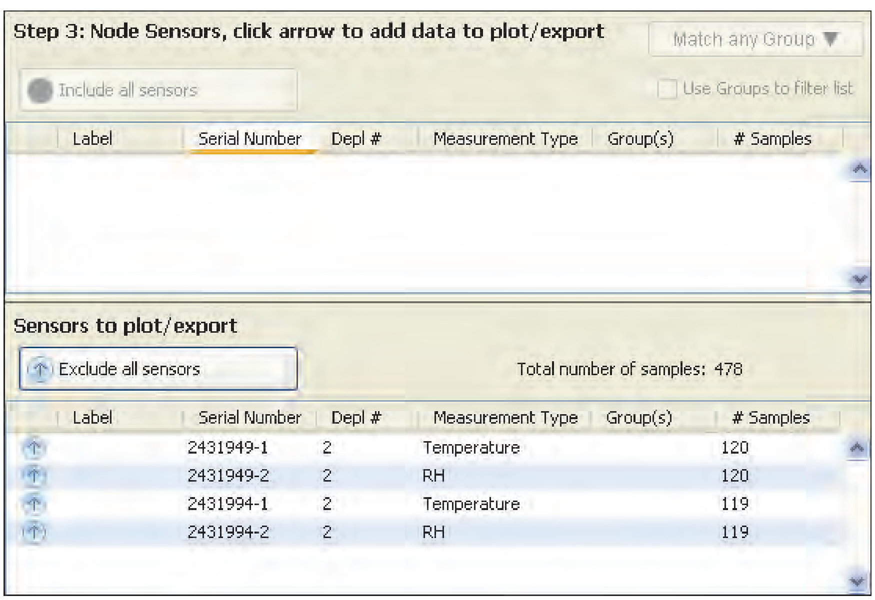
2. Select the data nodes with the sensors whose data you wish to plot or export.



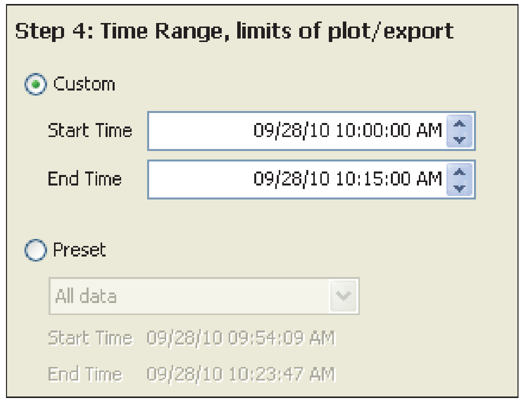
3. Each sensor for the data node that you selected in Step 2 will appear in a list as shown below. Click the down arrow icon for each sensor you wish to plot or export, or click the Include All Sensors button if you want to plot or export data from all sensors in the list. **Note:** If you have set up groups in HOBOnode Manager, you can also sort and select sensors within those groups. See Using Groups in the Plot/Export window.



The sensors that you selected will move from the top half of the Step 3 pane to the bottom half as shown below. In this example, all sensors were included and are now shown in the "Sensors to plot/export" list. If you wish to make changes, you can either click the up arrow icon remove a specific sensor from the list, or click the Exclude all sensors button to move all the sensors back to the top (you'll then need to select the sensors you wish to plot or export again).



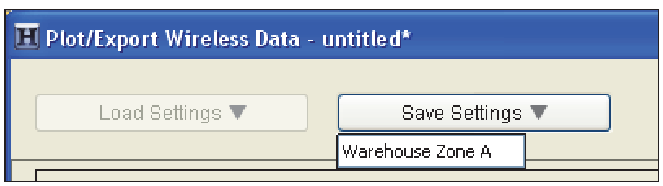
4. Choose the time range for the data you wish to plot or export. Select Custom and specify your own start and end time, or select Preset and choose one of several pre-defined ranges from the drop-down list.



5. Once you have all the settings selected, click the Export or Plot button. Clicking the Export button will open the Export window. Clicking the Plot button opens the Plot Setup window, where you can select the series that will appear in the graph in HOBOware.

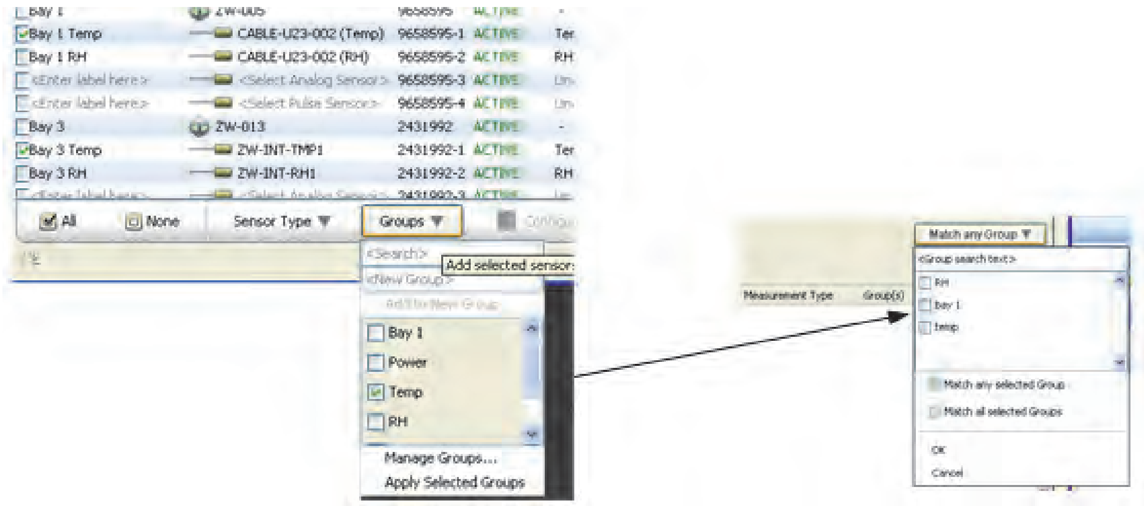
Notes:

- If you want the current settings to always appear in the Plot/Export Wireless Data window, then select the "Use these settings as window default" checkbox.
- You can save different combinations of settings to a configuration file in the Plot/Export Wireless Data window for future use, or for use by the data delivery feature. Click the Save Settings button, type a name, and press Enter. Then click the Load Settings button and choose the configuration file you wish to use for the current plot or export.



Using Groups to Sort Sensors

You can assign sensors to groups in the Device Table and then use them to sort rows in the table, or to refine a list of sensors in the Plot/Export Wireless Data window.

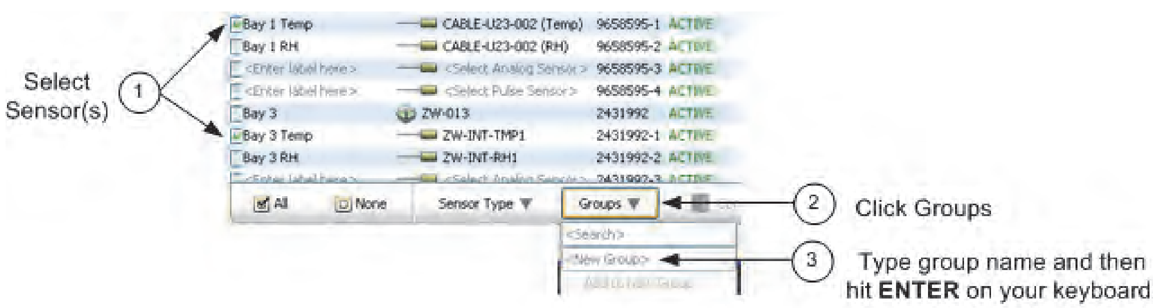


Apply Groups in the Device Table

Use Groups sort sensors in the Plot/Export Data Window

Creating Groups and Adding Sensors

1. In the Device Table, select the sensor(s) you want to add to a group.
2. Click Groups.
3. In the <New Group> box, enter a name for the group and press Enter.

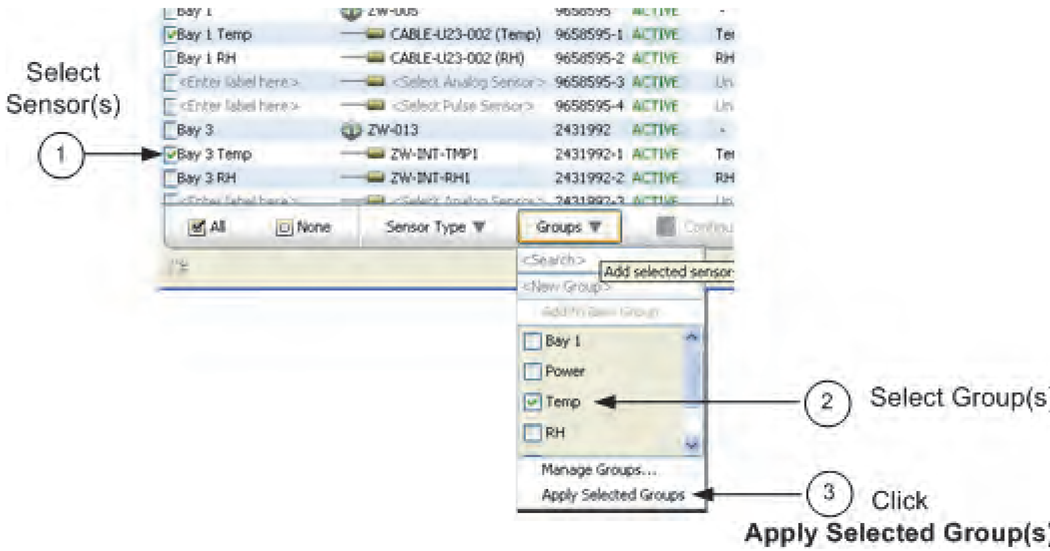


The Group Name appears in the table for each sensor selected.

Adding Sensors to a Group

To add a sensor to an existing group:

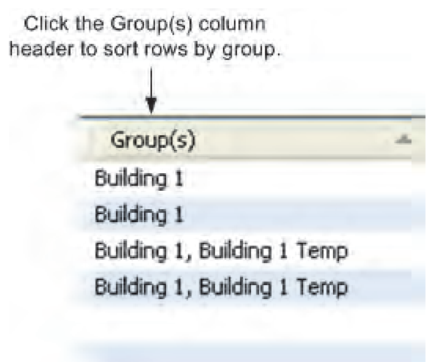
1. Select the sensor(s).
2. Click **Groups**.
3. Check desired groups(s).
4. Click Apply Selected Groups.



See Using Groups in the Plot/Export Data Window.

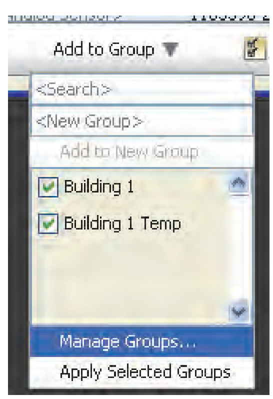
Sorting by Group

Click the Group(s) column header to sort rows by groups.

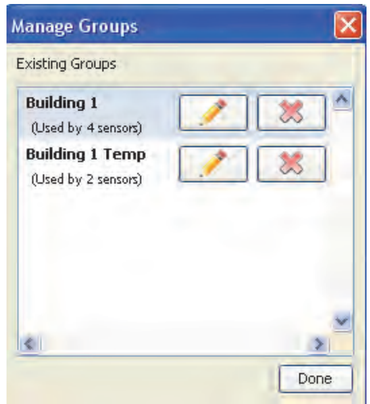


Deleting or Renaming a Group

Select Manage Groups from the Groups drop-down.



The Manage Groups window appears.

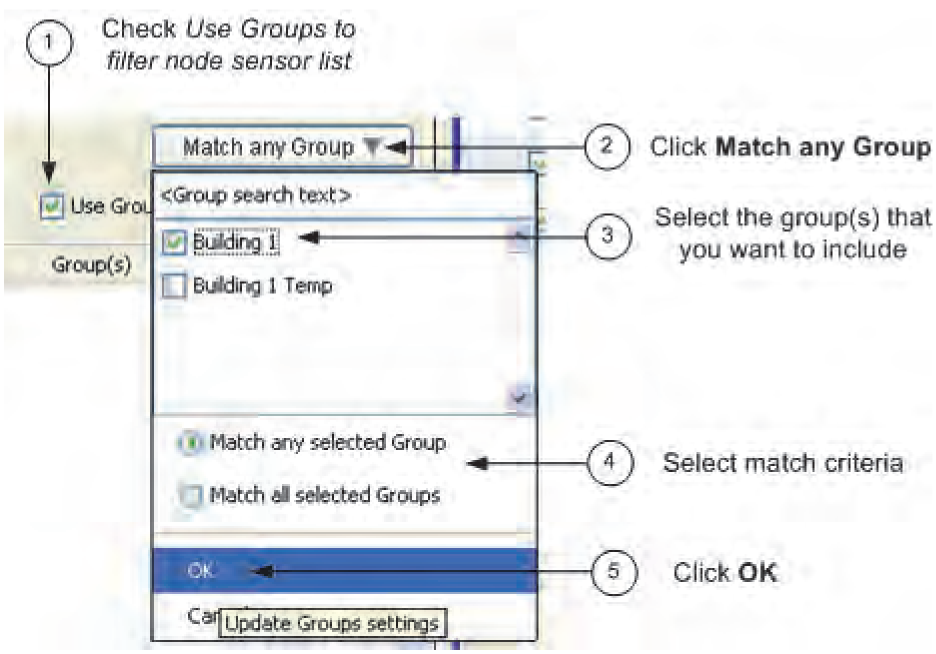


- To change the name of the group click the Edit icon and enter the new name.
- To delete a group, click the X.

Using Groups in the Plot/Export Wireless Data Window

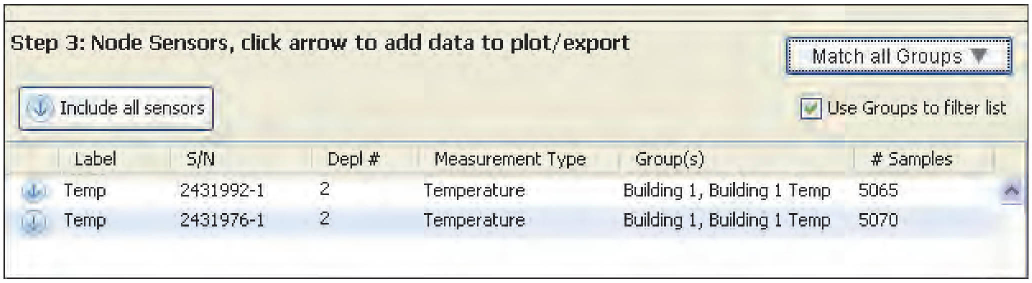
Once you have set up groups in the Device Table, you can use them to refine the list of available sensors in the Plot/Export Wireless Data window.

To set up groups, see Using Groups to Sort Sensors.

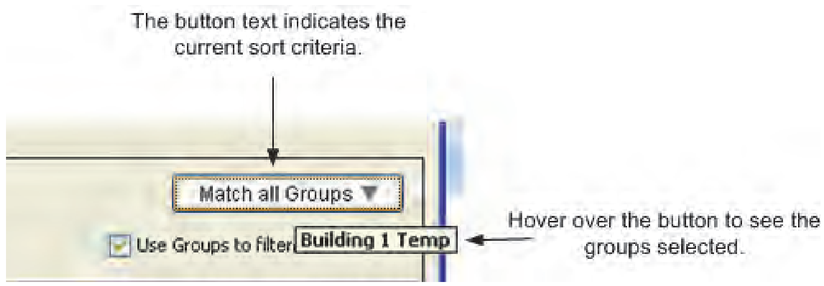


1. Check the "Use Groups to filter list" box.
2. Click the Match any Group button.
3. Select Groups. Select the groups you want to include in the list.
4. Select the Match Criteria. Select "Match any selected Group" and any sensors that are a member of any of the groups selected will appear. Select "Match all selected Groups" and only sensors that are a member of all of the groups selected will appear.
5. Select **OK**.

Only the sensors that match the group criteria will appear in the Node Sensors list.



Viewing Current Sort Criteria



Enabling HOBOnode Viewer

You can view plots and data from your HOBO data node network on your local area network with HOBOnode Viewer. While HOBOnode Manager requires a direct connection on a dedicated PC to monitor your network, HOBOnode Viewer gives you the flexibility to see data node plots and network status anywhere. This allows you to:

- Look at real-time data from your local area network with any browser
- Check on the data node network remotely to make sure it is running properly and that no devices are missing or alarms have tripped
- Share data with others by sending them a link to HOBOnode Viewer

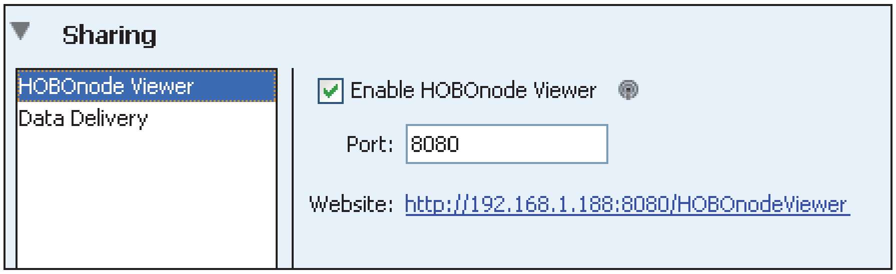
HOBOnode Viewer is a locally hosted website easily configured within HOBOware preferences. Once HOBOnode Viewer is enabled, HOBOware will create a link for your own web page that displays the real-time plots and data for your data node network. The HOBOnode Viewer web page will always be available as long as HOBOnode Manager remains open on the computer with your HOBOnode database.

To access HOBOnode Viewer, you must first enable that feature within HOBOware preferences on the computer running a data node network. This will create a link to a HOBOnode Viewer web page that you can use and share with others. If you have not already set up a data node network using HOBOnode Manager, you must do that first and then you will be able to activate HOBOnode Viewer from the same computer.

Windows note: If Windows Firewall is enabled on your computer, you may need to adjust the security settings to allow access to HOBOware before enabling HOBOnode Viewer. To check this, open Control Panel, go to Security, and select Allow a program through Windows Firewall (or click Windows Firewall and click the Exceptions tab on some versions of Windows). Make sure HOBOware is selected in the allowed access/exceptions list. Note that you must be administrator to make these changes.

To enable HOBOnode Viewer:

1. Open the preferences for data nodes. From HOBOnode Manager, click the Actions button and select Edit HOBO Data Node Preferences. Or, to access preferences within HOBOware, select File > Preferences on Windows or HOBOware > Preferences on Macintosh and click Data Nodes.
2. Click Sharing within the Data Nodes preferences, and then click HOBOnode Viewer.
3. Select the Enable HOBOnode Viewer checkbox.



4. By default, the port number assigned for HOBOnode Viewer is 8080. You may use this one or change it to any other available port. In most cases, the default 8080 port number will be available. However, if this number is already in use by another web service application on the same computer, then you can change it to any other available port. There are 0 to 65,535 ports. Port numbers 0 to 1023 are restricted ports reserved for use by system services, such as FTP, Telnet, and HTTP. You may use any other available port number from 1024 to 65,535 for HOBOnode Viewer.
5. Click OK in preferences and then restart HOBOnode Manager (close HOBOnode Manager and then from the Device menu in HOBOware, select Manage HOBO Data Node Network to reopen it). HOBOnode Viewer will not be fully enabled until you restart HOBOnode Manager.
6. After HOBOnode Manager has restarted, return to the HOBOnode Viewer preferences. Click the link, or URL, to go to your HOBOnode Viewer web page.

The URL has the following structure:

htttp://<IP address>:<port number>/HOBOnodeViewer

where <IP address> is the IP address for the computer where your data node network is running and <port number> is the port assigned for the HOBOnode Viewer in preferences.

To share the URL with others, click the link and then copy the URL from your browser and paste it an email message to send to others who would like to view your data node network.

Note: HOBOnode Viewer is only available while HOBOnode Manager is running. If you close HOBOnode Manager and then attempt to access HOBOnode Viewer, the web page will not open. Also note that the HOBOnode Viewer will not be available outside your local area network unless you expose that computer outside of the network. Contact your IT department if you would like to expose the HOBOnode Viewer.

To disable HOBOnode Viewer:

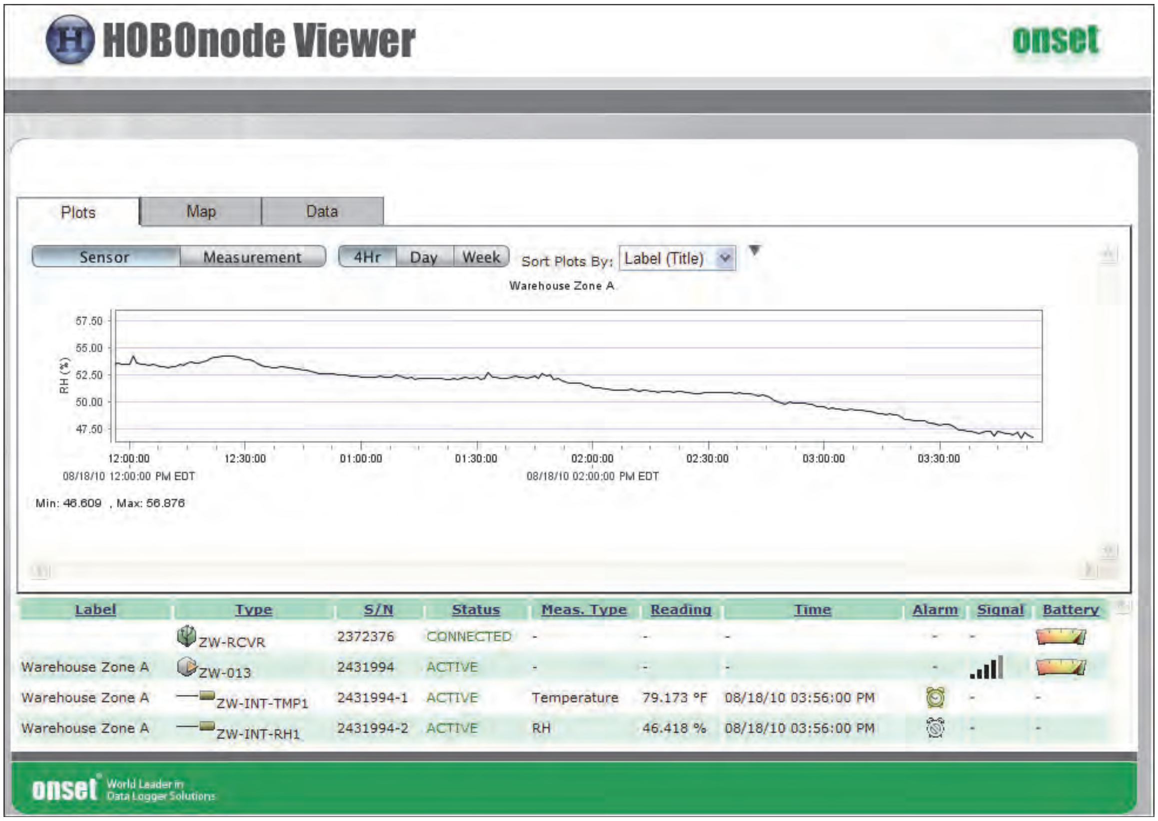
1. Open the preferences for data nodes. From HOBOnode Manager, click the Actions button and select Edit HOBO Data Node Preferences. Or, to access preferences within HOBOware, select File > Preferences on Windows or HOBOware > Preferences on Macintosh and click Data Nodes.
2. Click Sharing within the Data Nodes preferences, and then click HOBOnode Viewer.
3. Deselect the Enable HOBOnode Viewer checkbox.
4. Click OK in preferences and restart HOBOnode Manager.

Using HOBOnode Viewer

Many of the elements in HOBOnode Viewer are the same as HOBOnode Manager. Specifically, you can do the following with HOBOnode Viewer just as you would with HOBOnode Manager:

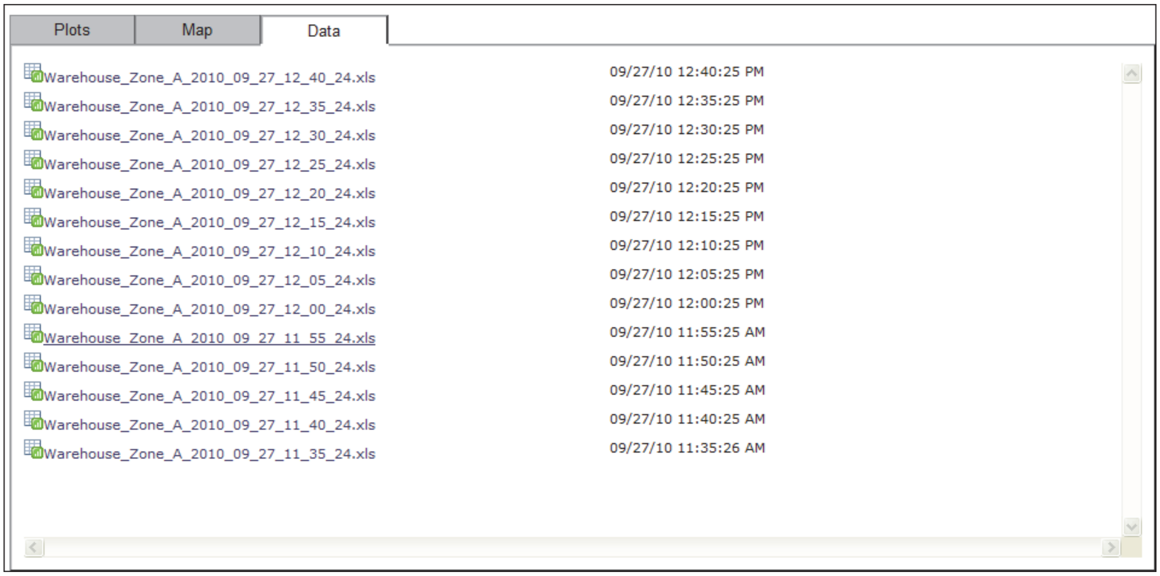
- Organize plots by sensor or by measurement type
- View plot data hourly, by day, by week, or by month (the month view must be enabled in the preferences for real-time plots)
- Sort the plots several ways, including by serial number, current reading, and alarm state

- View a map of your network devices
- Check the device table for details on each device in your network
- Change the device table view by sorting the columns



There are, however, some key differences between HOBOnode Manager and HOBOnode Viewer.

- HOBOnode Viewer, as its name implies, is a viewer only. Any changes you wish to make to your network, including updates to alarms or modifications to the map, need to be done directly in HOBOnode Manager.
- With HOBOnode Manager, you can see all available sensor channels on all devices, including those without a sensor type selected. HOBOnode Viewer displays enabled sensor channels only. If a device in HOBOnode Manager has a channel listed as "OFF," then that channel will not appear in HOBOnode viewer.
- There may be some minor differences in plot appearance if you are comparing the plots in HOBOnode Viewer to HOBOnode Manager. In general, plots are nearly identical, but there could be slight differences in scaling.
- If you set up data delivery and chose to have files saved to your computer or a network drive, then a Data tab will be visible in HOBOnode Viewer with a list of all files delivered through that service as shown below. Click a file name to open or save the file.



Note: If you change the file directory location in the data delivery settings, then you must restart HOBOnode Manager before you can access the files from the Data tab in HOBOnode Viewer.

Any changes you make to your network with HOBOnode Manager will be reflected in the HOBOnode Viewer upon the next refresh, or update. HOBOnode Viewer refreshes every 30 seconds. You can also use your browser's refresh feature if you want to see a change immediately.

Important: HOBOnode Viewer is only available while HOBOnode Manager is running. If you close HOBOnode Manager and then attempt to access HOBOnode Viewer, the web page will not open. Always keep HOBOnode Manager running to ensure anyone accessing HOBOnode Viewer can see the real-time plots and data.

Setting up Data Delivery

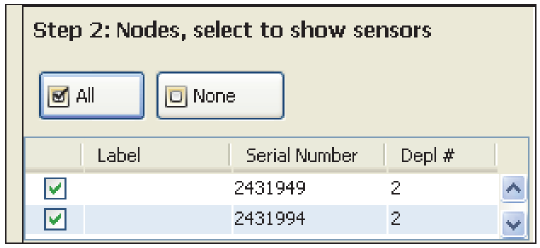
With data delivery, you can automatically save recorded sensor data from nodes in your network to a single .txt, .csv, or .xls file on a regular schedule. This allows you to:

- Store data from your current data node network deployment for future reference and analysis,
- Access data remotely when you are away from the network, and
- Share data with others in a file that is distributed automatically via FTP or email, or saved to a computer or network drive.

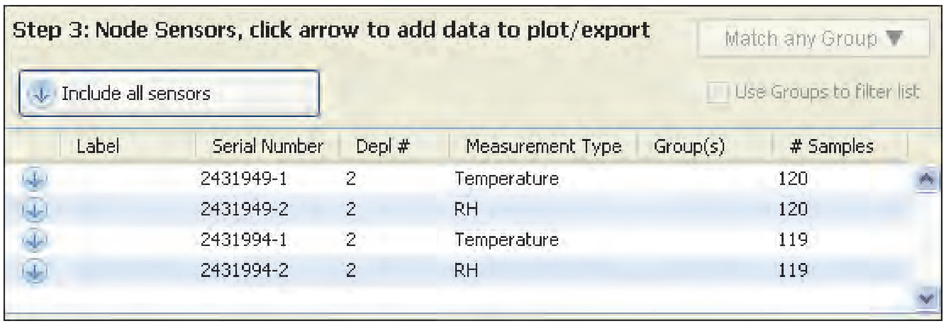
Before you can set up data delivery, you must first select which nodes and sensors you wish to include in the file by saving the configuration settings. To do this:

1. From HOBOnode Manager, click the Plot/Export Data button.
2. Select the deployment name from the list.

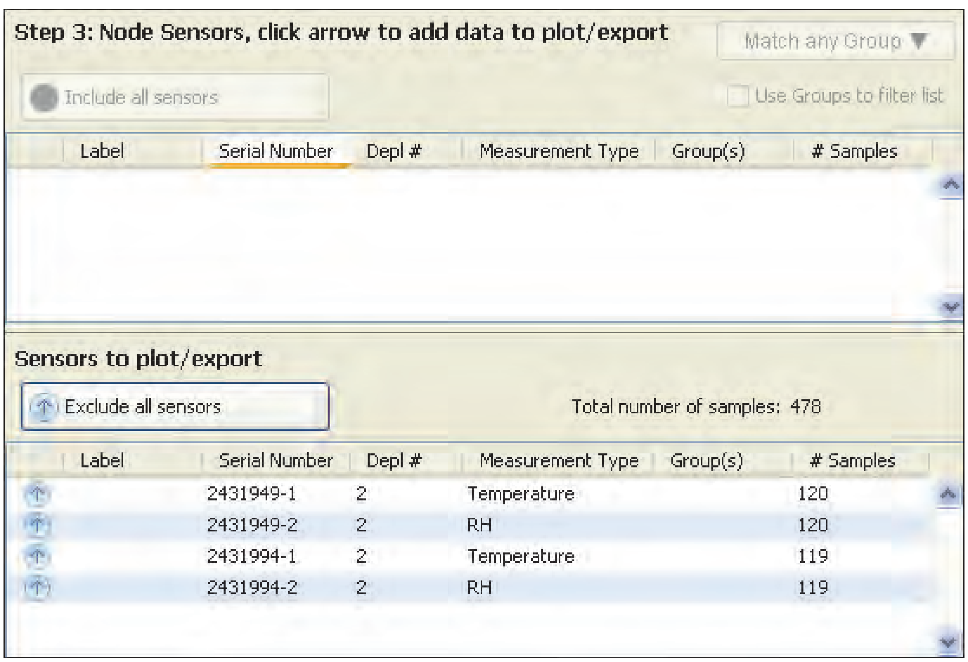
3. Select the individual nodes you would like to include in the file or click the All button to select all nodes.



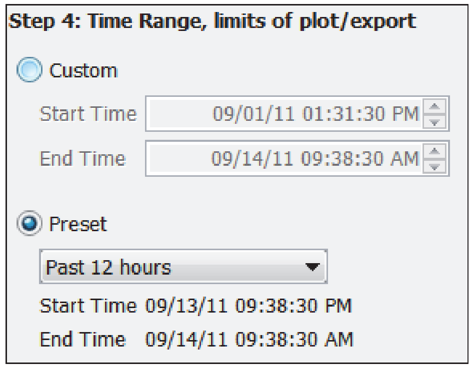
4. Select the sensors you would like to include in the file or click the Include all sensors button.



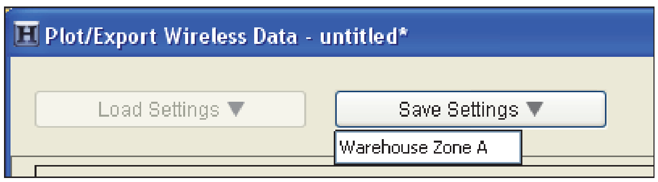
5. Make sure all the sensors you wish to share in your datafile appear in the Sensors to plot/export list.



6. Select Preset and choose a preset time range to determine how much data will be exported each time data delivery runs. In this example, we chose "Past 12 hours," which means only data from the past 12 hours will be exported via data delivery. The most recent 12 hours worth of data is shown for reference. **Note**: Do not choose a custom time range. This is for immediate exports only. If you choose a custom time range for data delivery, then data from that custom time-range only will be exported every time data delivery runs.



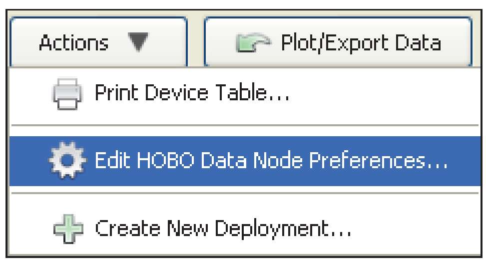
7. Click the Save Settings button and type a name, which will also be used for the data delivery file name, and press Enter. Your configuration settings will be saved.



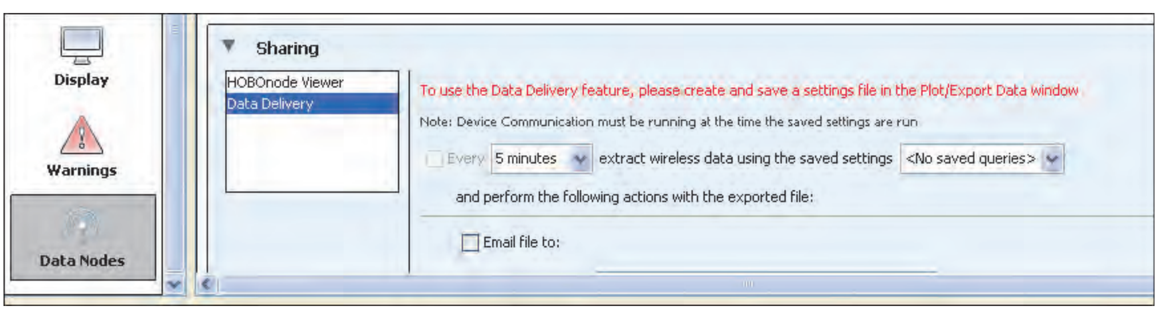
After you have selected the sensors you wish to include in the shared data file, you can then set up data delivery within Preferences.

To do this:

1. Open HOBOnode Manager.
2. Click the Actions button and select Edit HOBO Data Node Preferences.

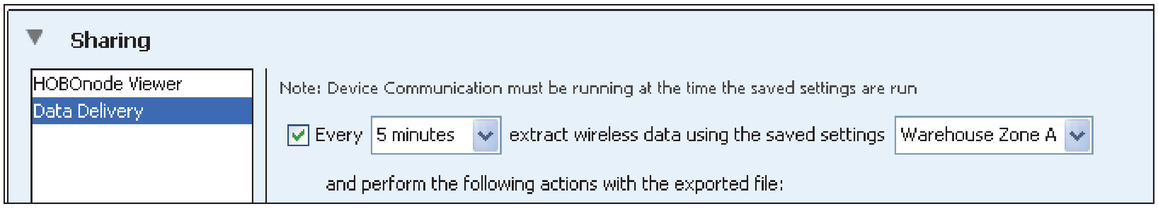


3. Select Sharing, and then select Data Delivery.



Note: If you have not yet selected the sensors you wish to export, then you will see a message indicating you need to create and save a settings file. You must select the sensors in Plot/Export Wireless Data before continuing.

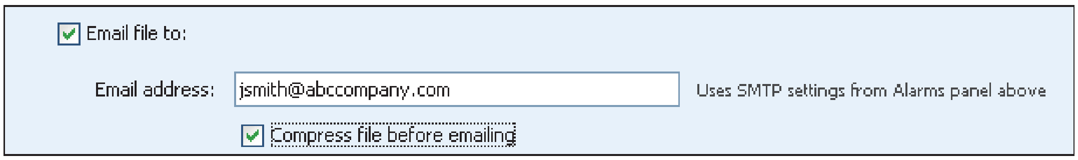
4. Select how often you want to save the data from your network, from 1 minute to 7 days. This will determine what schedule you use to share the data.



5. Select the name of the saved settings that you created in Plot/Export Wireless Data, such as "Warehouse Zone A" in the example above.
6. Select how you would like to share the file: via email, FTP, or saved to a computer or network location. You may select more than one method of sharing the file.

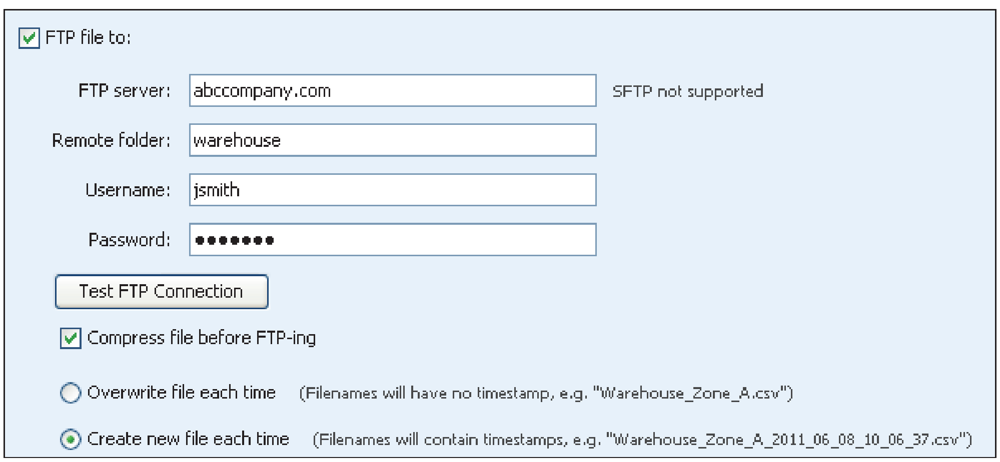
Email:

Type the email address where you want to send the file and select the checkbox if you want to compress the file before emailing it. **Note:** Data delivery uses the same email settings configured for alarm email notifications. If you have never configured an alarm email, you must do that first, even if you don't plan on setting any alarms.



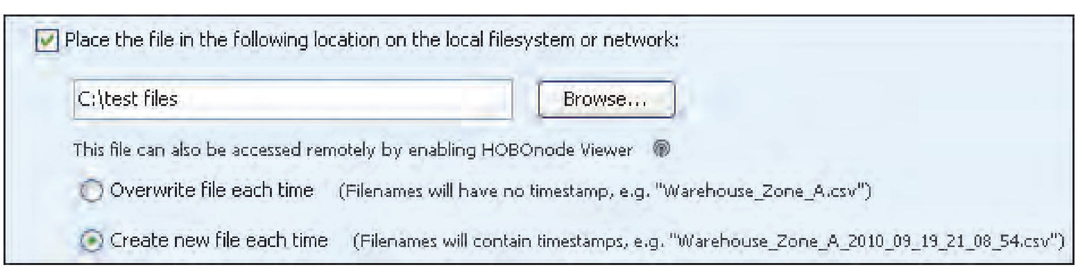
FTP:

Enter the FTP server name, the directory name (remote folder), username, and password for the FTP location where you want to place the file. Test the FTP Connection to make sure it successfully delivers the file to the specified location. Select the checkbox if you want to compress the file before delivering it via FTP. Choose whether you want to overwrite the existing file at that FTP location each time a new file is transferred, or if you want to create a new time-stamped file each time.

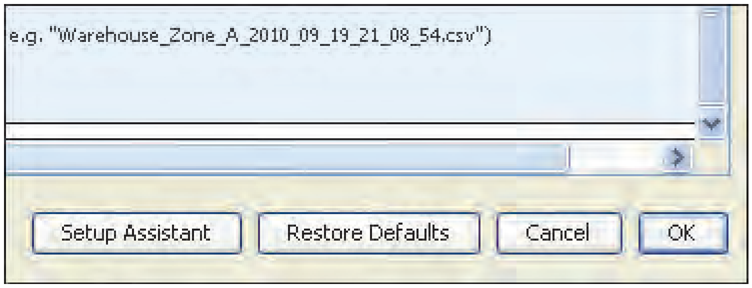


Saving it to a hard drive or network:

Select the directory where you want to save the files. Choose whether you want to overwrite the file each time a file is saved, or if you want to create a new file each time.



When you are done configuring your data delivery settings, click **OK** in the main Preferences window.

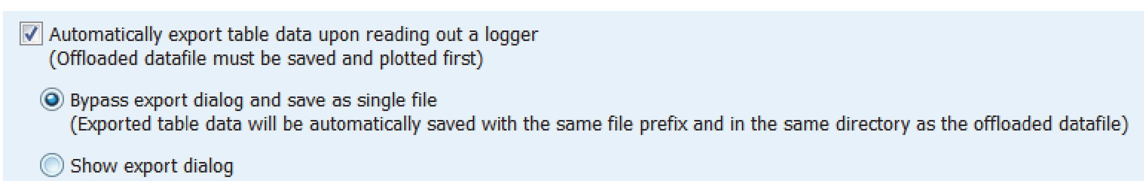


The sensor data from your data network will then be saved and shared on the schedule that you selected. The data will be saved as a .txt, .csv, or .xls file that you can import into HOBOware, Microsoft Excel, and other programs for analysis. The file type is determined by the export settings in Preferences.

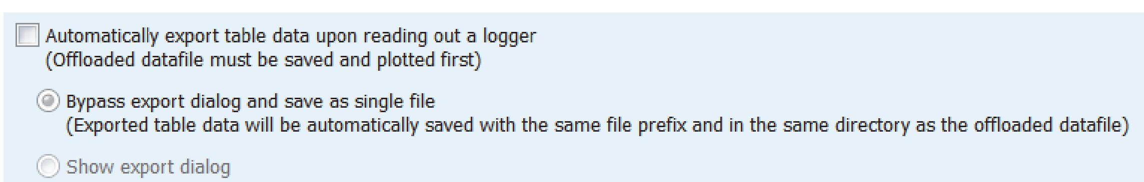
Notes:

- Data delivery will not run unless device communication is also running. This means if you opt to stop device communication when you close HOBOnode Manager, then data delivery will also stop. Once you restart the device communication, then data delivery will commence again on the previously configured schedule.
- The preferences for data delivery may include the names of settings files from old network deployments. If you enable data delivery and use the saved settings from an old deployment, you will see a message indicating "No data found for selected sensors." Choose a settings file from the current deployment, or create a new one with Plot/Export Wireless Data.

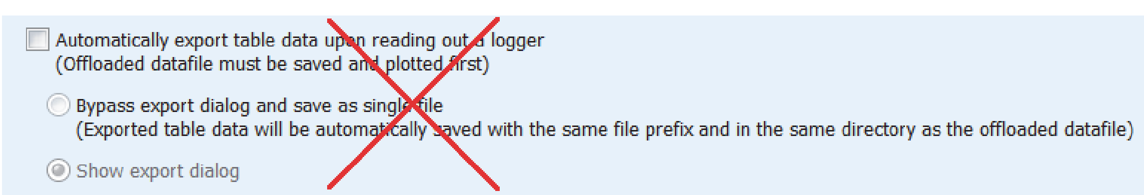
Important: Data Delivery will not work properly if the "Show export dialog" setting is selected in the export preferences. To disable this setting, select Preferences from the File menu in Windows or the HOBOware menu in Macintosh. In the General category, select Export Settings. Make sure "Show export dialog" is not selected. Even if the "Automatically export table data upon readout of logger" option is disabled, the "Show export dialog" must not be selected for Data Delivery to work properly. Your preferences must look like this:



or this:



but not like this:



for Data Delivery to work correctly.

Tip: You can also share data from your HOBO data node network by enabling a HOBOnode Viewer webpage. When data delivery is configured to save files to your computer or a network drive, the files will also be available on the

Data tab in HOBOnode Viewer. Note that if you change the file directory used for data delivery when HOBOnode Viewer is enabled, you will need to restart HOBOnode Manager before you can access the files from the Data tab.

Data Storage Location

The HOBOnode Manager database is stored in the directory shown in the Data Storage Location field. This database includes all data recorded by the data nodes, settings for all deployments, alarm information, and other details related to your data node network.

Onset recommends that you periodically back up the database to secure your data in case of a database or computer failure. You can back up the database to an external hard drive or network server using third-party backup software. You will also be asked to back up your database before running the HOBOnode Manager Database Upgrade Utility in HOBOware 3.2.2 or later.

Important: The database must be closed during a backup or restore. Before copying or restoring a database, close HOBOware, HOBOnode Manager, and Device Communication. Right-click (Windows) or left-click (Macintosh) the HOBOware system tray icon and select Stop Device Communication.

The database is stored at the following location, as shown in the Data Storage Location field:

- Windows 7 and Windows 8

  C:\Users\<user name>\AppData\Local\OnsetComputerCorporation\cosmos\db

- Windows XP

  C:\Documents and Settings\<user name>\Application Data\Local\OnsetComputerCorporation\cosmos\db

- Macintosh OS 10.5 and 10.6

  /Users/<user name>/Documents/OnsetComputerCorporation/cosmos/db

Be sure to back up the entire "db" directory.

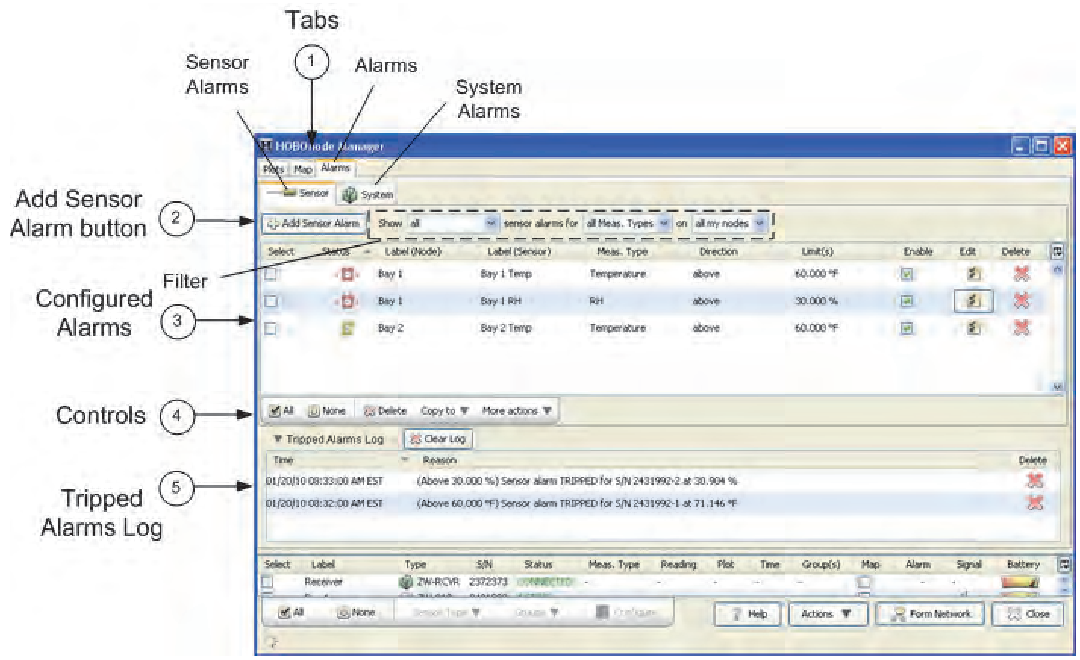
To restore the database:

1. Obtain the "db" directory from your backup source.
2. Replace the "db" directory as shown in the Data Storage Location field with the backup copy.

Alarms

There are two types of alarms in HOBOnode Manager: sensor alarms and system alarms. With sensor alarms, you can set an alarm to trip when a sensor reading is out of a range you specify. With system alarms, you can set an alarm to trip when a node is missing from the network or has a low battery. You can also configure a heartbeat alarm, which periodically notifies you the receiver is active and communicating with the nodes in the network. You can also set alarm actions, or notifications, to alert you via email, text, and/or audible/visual cue on your computer when an alarm trips. **Note:** When an alarm trips, HOBOnode Manager is opened, if it is not already.

Click the Alarms tab to access the following:



1. Tabs. Click the Sensor tab to set or view sensor alarms. Click the System tab to set Missing Node, Heartbeat, and Low Battery alarms.

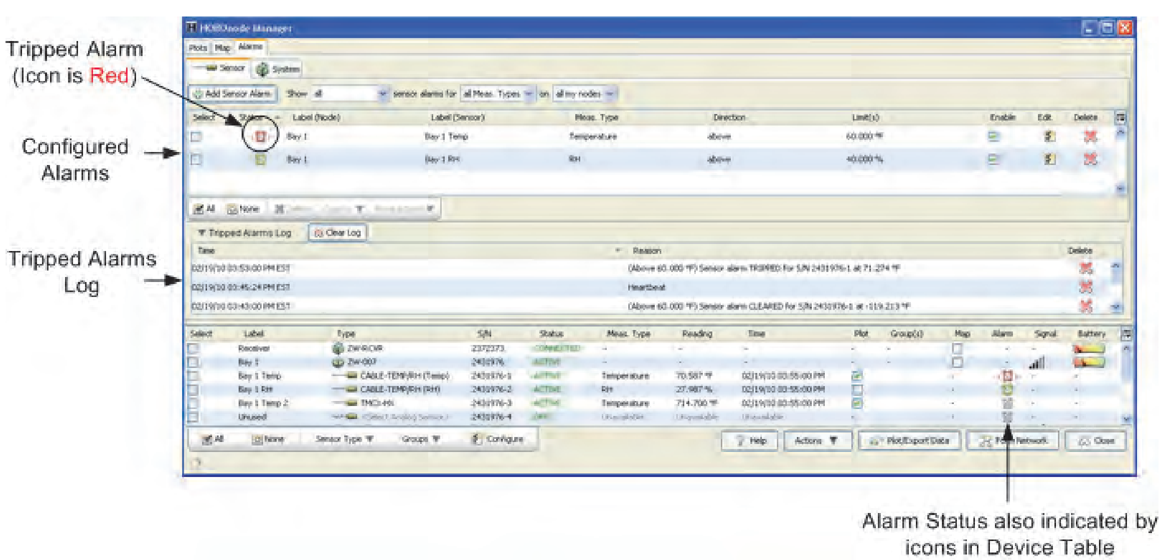
2. Add Sensor Alarm button (Sensor tab only). Click this button to go to the Add Sensor Alarms window.

3. Configured Alarms. Configured sensor alarms appear here. Use the filter to control what alarms shown in the sensor alarms pane. **Note:** If an alarm you configured is not appearing in the Alarms window, make sure the filter is set to show all.

4. Controls (Sensor tab only). Use the controls to apply an action to multiple alarms, including delete, copy, enable/disable, and apply default actions.

5. Tripped Alarms Log. All tripped alarms appear here. Click the Clear Log button to delete all tripped alarms.

Alarms that have been configured, but not tripped, display as green alarm clock icons in both the Sensor and Systems tab as well as the Device Table (sensor alarms only). Once the alarm is tripped, the alarm clock icon changes to red.



Adding a Sensor Alarm

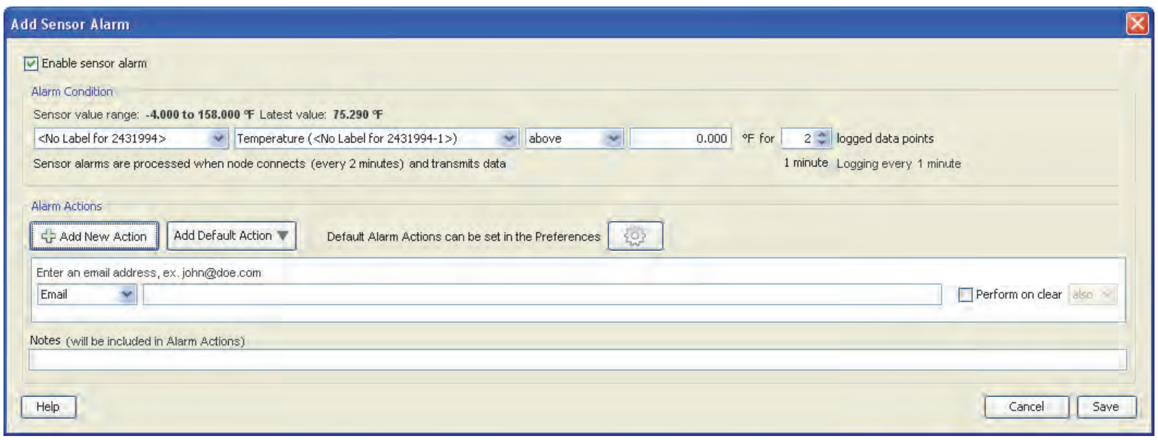
A sensor alarm trips when a sensor reading is outside a threshold that you configure. You can set up actions so that you are notified by email, text message, or by an audio or visual alarm in HOBOnode Manager when a sensor alarm trips. Once you create an alarm, you can copy it to multiple sensors of the same measurement type or the same measurement type and group.

Note: Sensor data is sent to the receiver periodically (based on the Connection Interval) and not continuously. Therefore, there is a delay between the time the alarm condition occurs and is recorded by the sensor and when you are alerted by any notifications you have configured. The default Connection Interval is 10 minutes. For critical applications, you may want to decrease the Connection Interval so that you are alerted to alarm conditions more frequently. See Changing the Logging Interval and Connection Interval.

Opening the Add Sensor Alarm window

The first time you add an alarm for a sensor, you can click the alarm icon for the sensor in the Device Table. This will open the Add Sensor Alarm window with the sensor already selected.

Otherwise, click the Alarms tab, then the Sensor tab, and then the Add Sensor Alarm button. With this method you will then need to select the sensor from a drop-down list.

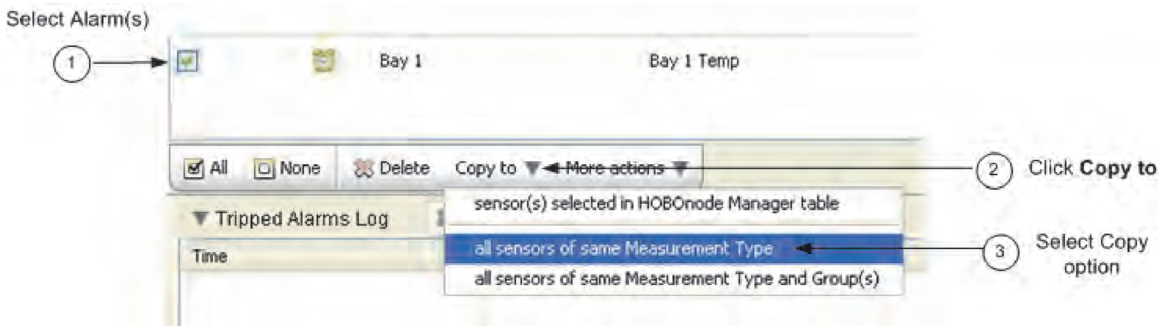


1. Make sure the "Enable sensor alarm" checkbox is selected.
2. Select the sensor (if not already selected). If you accessed the Add Sensor Alarm window by clicking on the alarm icon in the Device Table, the sensor will automatically be populated. Otherwise, select the sensor you want to add the alarm to.
3. Configure Alarm Parameters.
    a. Select the threshold: Above, Below, or Outside Range.
    b. Enter the value for the alarm.
    c. Enter the Number of Data points. This is the number of readings that must be outside of the limits for the alarm to be tripped or cleared.
4. Configure Alarm Actions (Notifications).
5. Click Save.

Note: Any time you edit an existing alarm, the alarm state is reset to untripped and the logged data points are reset to zero.

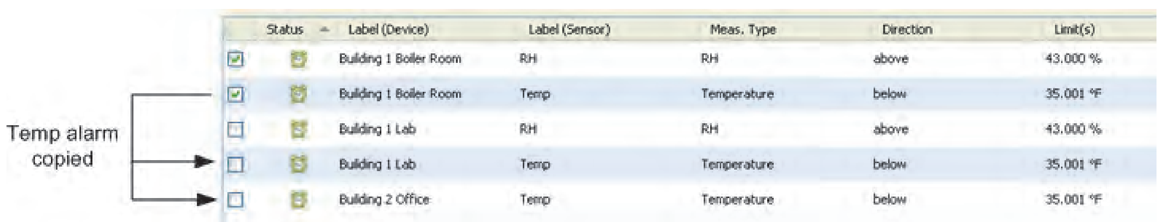
Copying an Alarm to Other Sensors

To copy an alarm to other sensors:



1. Select Alarm(s). Select the alarms you want to copy. You can select alarms for multiple measurement types and each alarm will only be copied for sensors of that type.
2. Click the **Copy to** button.
3. Select the copy option. You can copy the alarm to all sensors of the same Measurement Type, or to Measurement Type and Group(s).

The alarms are copied to the sensors, as shown below.

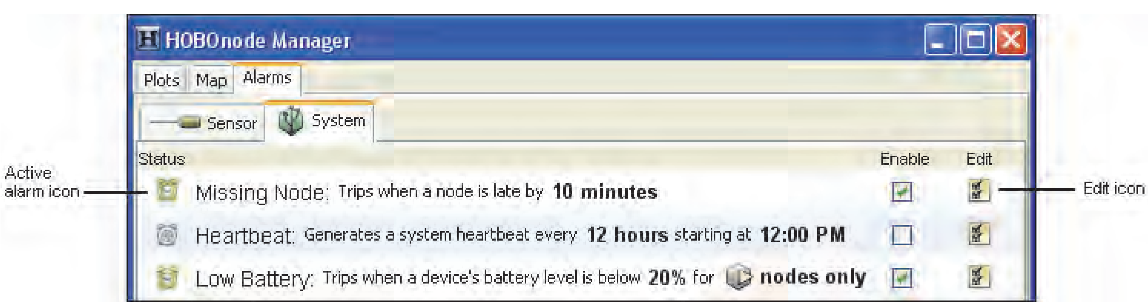


Enabling a Missing Node Alarm

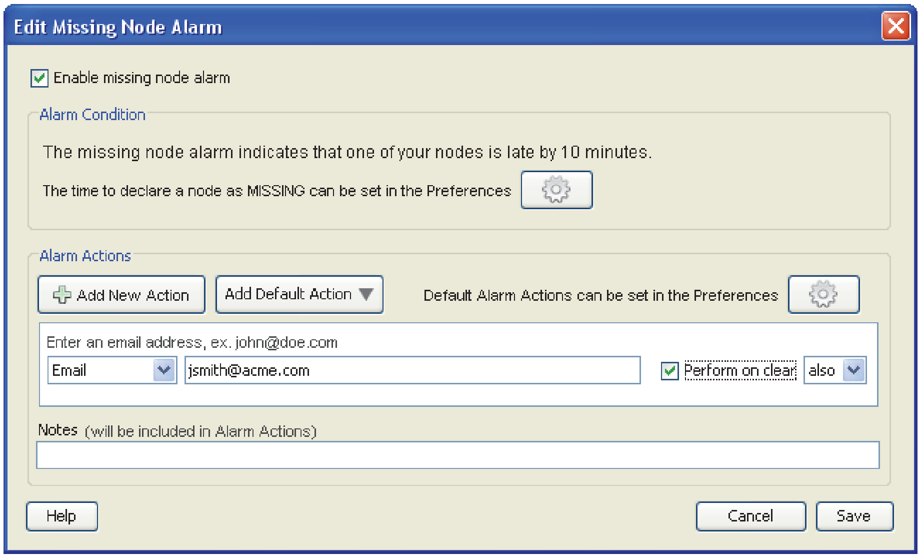
A Missing Node alarm trips when a data node has not connected to the receiver within the specified timeframe. The default period to determine that a node is missing is 10 minutes. You can change this in the Preferences.

To enable a missing node alarm:

1. Click the Alarms tab.
2. Click the System tab and select the checkbox in the Enable column for Missing Node. If alarm actions have already been configured by a previous edit, then the Status icon for Missing Node will change to an active alarm icon (green) as shown below. This means the alarm is enabled. If an Edit Missing Node Alarm dialog box appears or you wish to make additional changes to this alarm, then proceed to next step.



3. An Edit Missing Node Alarm dialog box may open automatically. If it does not and you wish to change the settings, then click the Edit icon for Missing Node as shown above.



4. Make sure the "Enable missing node alarm" checkbox is selected.
5. By default, the alarm will trip after the node is missing for 10 minutes. Click the Preferences button if you wish to change the default time period.
6. Add one or more alarm actions, which is how you will be notified when the alarm trips. You can be notified via email or text, or by a visual cue or audible sound on the computer where HOBOnode Manager is running.
7. Click **Save**. The changes you made to the missing node alarm are displayed on the System tab.

Note: Nodes may temporarily go missing after upgrading their firmware as described in Upgrading the Firmware for a Receiver or Single Data Node or Updating the Firmware for Multiple Data Nodes. In most instances, the node will not be reported as missing after upgrading its firmware. However, depending on how long the upgrade process takes and the length of the connection interval, the node may occasionally be reported as missing. If a node is reported as missing after updating its firmware, wait one or two connection intervals for the node to reappear. For example, if the connection interval is set to 20 minutes, wait for 40 minutes to make sure the node reappears. If the node is then still reported as missing, add it back to the network by following these steps:

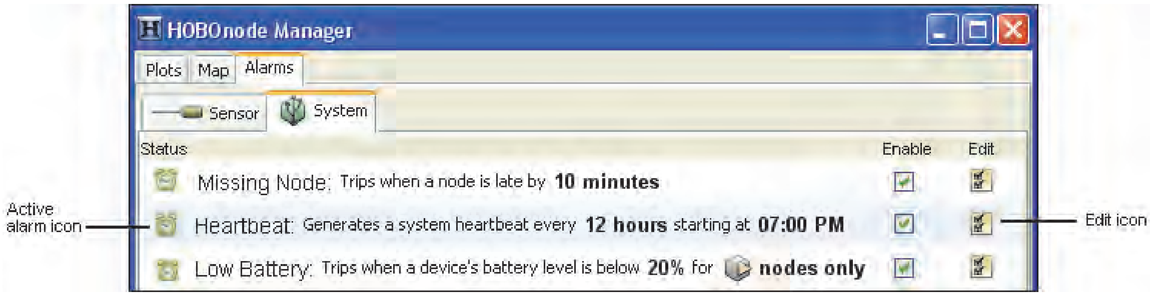
1. Click the Form Network button in HOBOnode Manager.
2. Press the reset button with a quick 1-second push to reactivate the data node.
3. Verify that the data node appears in the HOBOnode Manager table and is identified as a router or data node as expected (see Determining Data Node Type). To change the type of data node, see Converting an End-Point Node to a Router Node or Converting a Router Node to an End-Point Node.

Enabling a Heartbeat Alarm

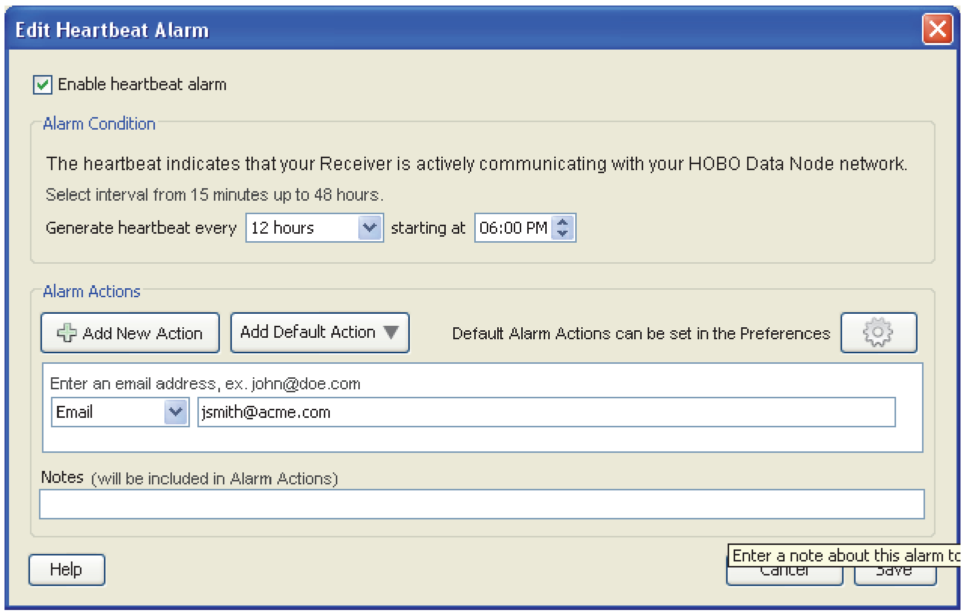
If you enable a Heartbeat alarm, a heartbeat is generated every 12 hours (configurable) to let you know that the system is up and running. If you do not receive a heartbeat notification, check the status of your receiver and restart HOBOware if necessary.

To configure a heartbeat alarm:

1. Click the Alarms tab.
2. Click the System tab and select the checkbox in the Enable column for Heartbeat. If alarm actions have already been configured by a previous edit, then the Status icon for Heartbeat will change to an active alarm icon (green) as shown below. This means the alarm is enabled. If an Edit Heartbeat dialog box appears or you wish to make additional changes to this alarm, then proceed to next step.



3. An Edit Heartbeat dialog box may open automatically. If it does not and you wish to change the settings, then click the Edit icon for Heartbeat as shown above.



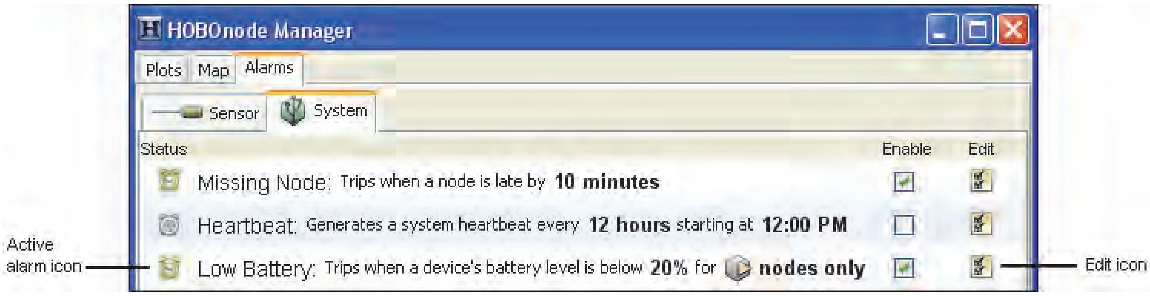
4. Make sure the "Enable heartbeat alarm" checkbox is enabled.
5. Select how often you want to generate a heartbeat and what time you want to start.
6. Add one or more alarm actions, which is how you will be notified when the alarm trips. You can be notified via email or text, or by a visual cue or audible sound on the computer where HOBOnode Manager is running.
7. Click Save. The changes you made to the heartbeat alarm are displayed on the System tab.

Enabling a Low Battery Alarm

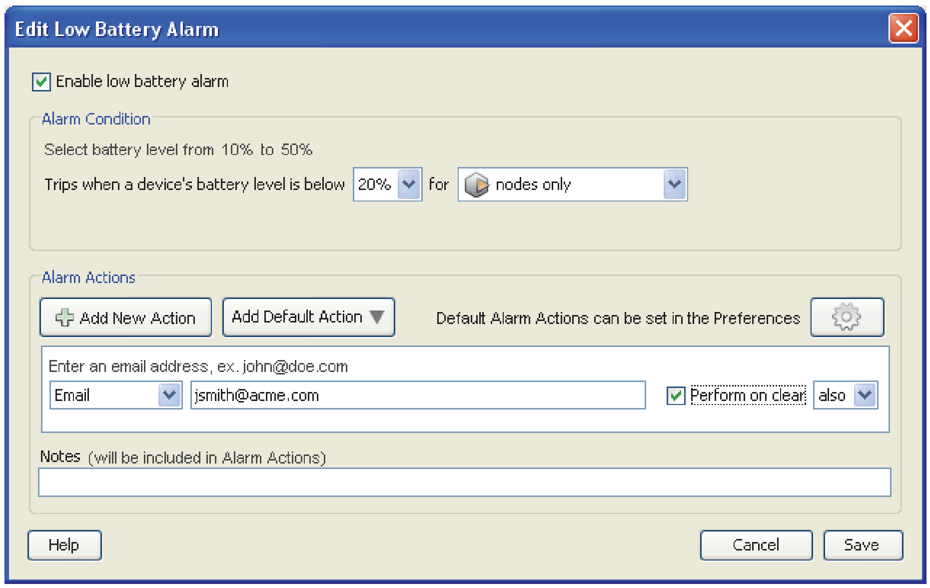
You can set an alarm to trip when the battery level in a data node or a router drops below a specific threshold. This can help you determine when it is time to change the batteries for devices in your network. The low battery alarm is a system-wide alarm, which means it applies to all devices (either all nodes or all nodes and routers) in the network. You cannot set a low battery alarm for some nodes and not others.

To configure a low battery alarm:

1. Click the Alarms tab.
2. Click the System tab and select the checkbox in the Enable column for Low Battery. If alarm actions have already been configured by a previous edit, then the Status icon for Low Battery will change to an active alarm icon as shown below. This means the alarm is enabled. If an Edit Low Battery dialog box appears or you wish to make additional changes to this alarm, then proceed to next step.



3. An Edit Low Battery dialog box may open automatically. If it does not and you wish to change the settings, then click the Edit icon for Low Battery as shown above.



4. Make sure the "Enable low battery alarm" checkbox is enabled.
5. Select the battery level at which you want the alarm to trip, from 10 to 50%. For example, if you choose 20%, then the alarm will trip once the device's remaining battery power drops below 20%.
6. Select whether the battery alarm should trip for nodes only or for both nodes and routers. **Notes:** You cannot set a low battery alarm for a receiver because it should always be powered by an AC adapter. In addition,you should not set a low battery alarm for routers that do not have batteries installed. If your routers are powered by AC adapters only and do not have backup batteries installed, then you should set the battery alarm for nodes only.
7. Add one or more alarm actions, which is how you will be notified when the alarm trips. You can be notified via email or text, or by a visual cue or audible sound on the computer where HOBOnode Manager is running.
8. Click Save. The changes you made to the low battery alarm are displayed on the System tab. **Note:** If the low battery alarm was previously configured and had tripped, then clicking Save will clear the tripped state. If the newly saved settings result in an alarm condition, then the alarm will trip at the next connection interval.

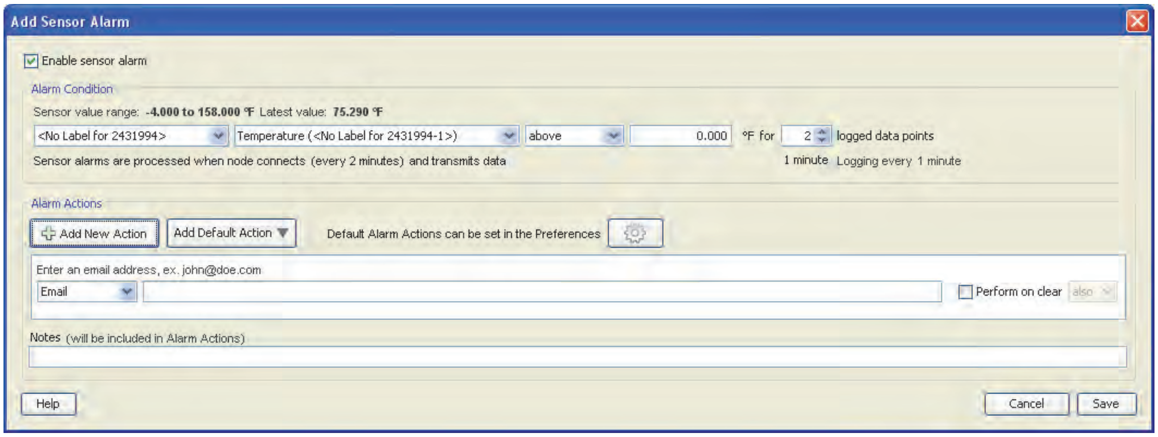
Adding Alarm Actions (Notifications)

An alarm action is a notification when an alarm trips or and/or clears. You can configure the alarm action to notify you in four ways:

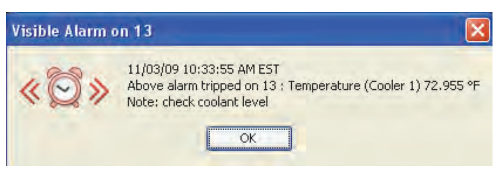
- Via email

- Via text message
- With a visible message on your computer
- With a sound on your computer

Before you set up email or text notifications, you must configure your SMTP settings. See Setting Alarm Preferences.



1. Click the Add New Action button. A new action is added. **Tip:** To save time, you can configure default alarm actions. See Setting Alarm Preferences for information.
2. Select the type of notification: Email, Text Message, Visible, or Audible.
3. Enter information or make a selection depending on the type of notification. **Note:** If you add an email or text notification and you have not already set up your SMTP settings, you will be prompted to do so.
   - Email: Enter the email address where you want the alarm notification sent.
   - Text Message: Enter the email address where you want the alarm notification sent.
   - Visible: No further configuration required. A pop-up window will appear in HOBOnode Manager if the alarm trips.

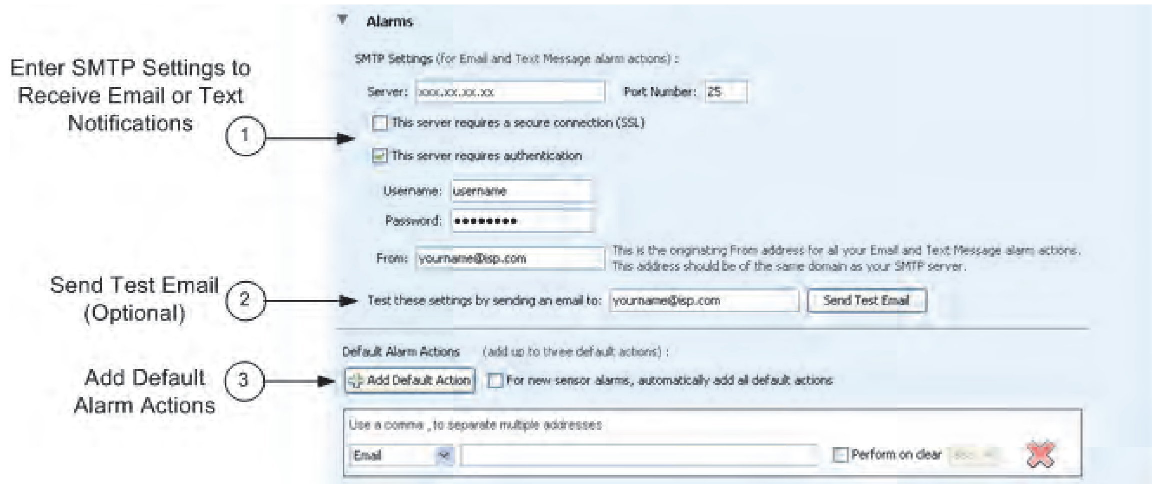
   - Audible: Select the sound that you want to play when an alarm trips. Click the Play icon to hear the alarm.

   Note: If multiple audible alarms are set, only the most recent will play. Any other actions configured for the alarm will be sent.
4. Check the "Perform on clear" box if you want a notification when the alarm clears. If you only want a notification when the alarm clears and not when it is tripped, change the drop-down selection to "only."
5. Add Notes to be included in the alarm notification (optional).
6. Click Save.

To add another action, repeat the procedure.

Setting Alarm Preferences

Before you add sensor alarms, set up your Alarm Preferences for email notifications and create default actions (notifications). To open the Preferences window, click Actions at the bottom of the HOBOnode Manager window and select Edit Data Node Preferences.

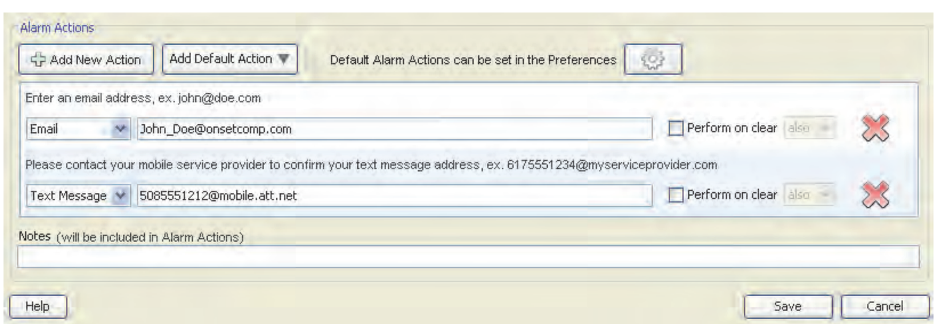


1. Enter SMTP settings for email or text notifications. To receive email or text message alarm notifications, enter the Server IP Address for your mail server, and enable SSL or authentication if required by your network. See your Network Administrator or your Internet Service Provider for information; see also Alarm Email/Text Configuration for more information.

2. Send a test email. Enter your email address and click the Send Test Email button to verify that your settings are correct. Make sure you check your Junk Mail or Spam folder for the email if it is not in your email inbox.

3. Add default alarm actions (optional). Entering default alarm actions simplifies alarm configuration. For example, instead of entering the same email address for every alarm, you can select an address from a list of drop-down entries when you add the alarm action. For more details on alarm actions, see Adding Alarm Actions.

If you check "For new sensor alarms, automatically add all default actions" when you click the Add Sensor Alarm button, the alarm actions you configured are automatically added, as shown below. This is helpful if you want the same actions for every alarm.



Alarm Email/Text Configuration

You must configure the SMTP Settings to allow email from the data node network to get to your email recipients. If your data node network is within a corporate network environment, you should contact your Network Administrator (IT/MIS dept.) for this information. Also, they may need to add the receiver to a White List to allow it to relay email through the corporate email server.

If you use a private mail account such as Yahoo or Google, or if you do not know your corporate information, you can get the outgoing mail parameters from your mail provider. Search the Internet for "SMTP Settings for <provider name>."

Sending an Alarm to a Cell Phone

To send an email to your cell phone when an alarm occurs, enter the email address for your cell phone. These are the formats for some cell phone providers. For others, contact your provider.

AT&T

[10-digit phone number]@txt.att.net

Example: 2125551212@txt.att.net

Boost Mobile

[10-digit phone number]@myboostmobile.com

Example: 2125551212@myboostmobile.com

Sprint

[10-digit phone number]@messaging.sprintpcs.com

Example: 2125551234@messaging.sprintpcs.com

T-Mobile

[10-digit phone number]@tmomail.net

Example: 4251234567@tmomail.net

Verizon

[10-digit phone number]@vtext.com

Example: 5552223333@vtext.com

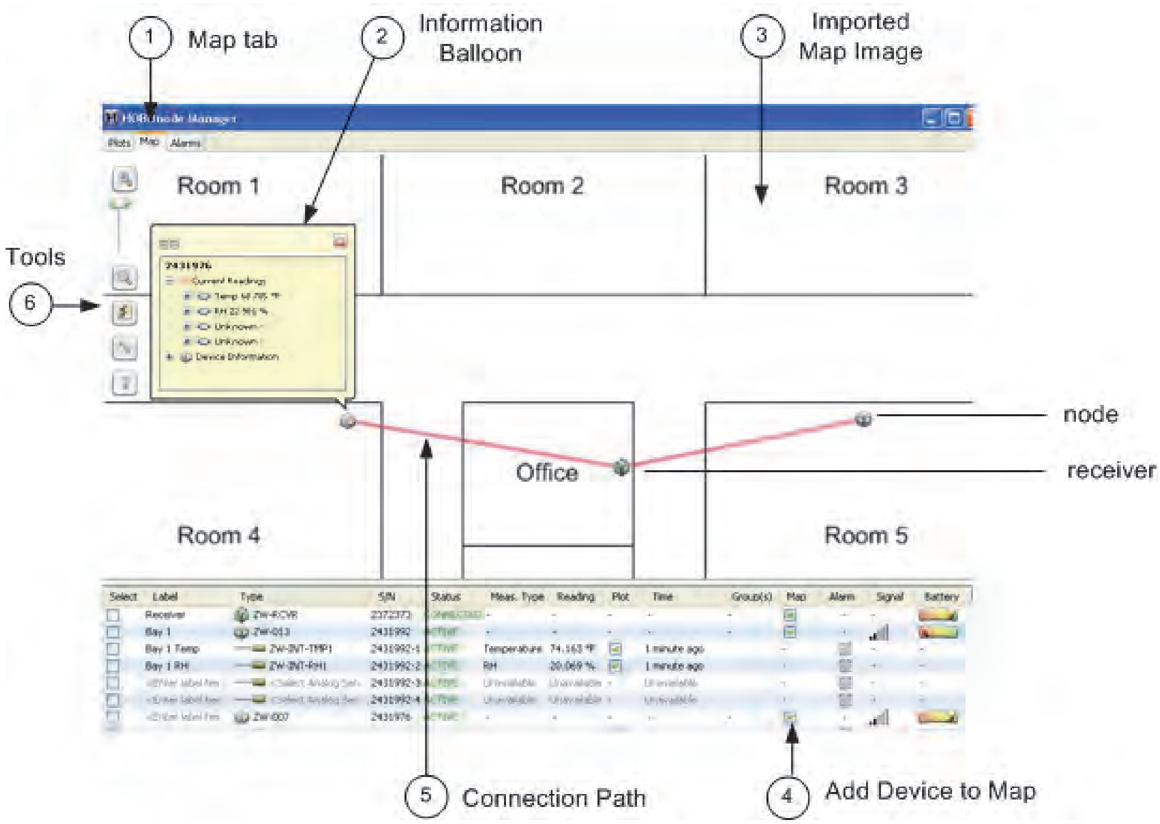
Virgin Mobile USA

[10-digit phone number]@vmobl.com

Example: 5551234567@vmobl.com

The Network Map

Place icons on the Network Map to help you keep track of your devices. You can expand Information Balloons on the device to view status information and sensor readings. You can also import a custom background image, such as a floor plan.



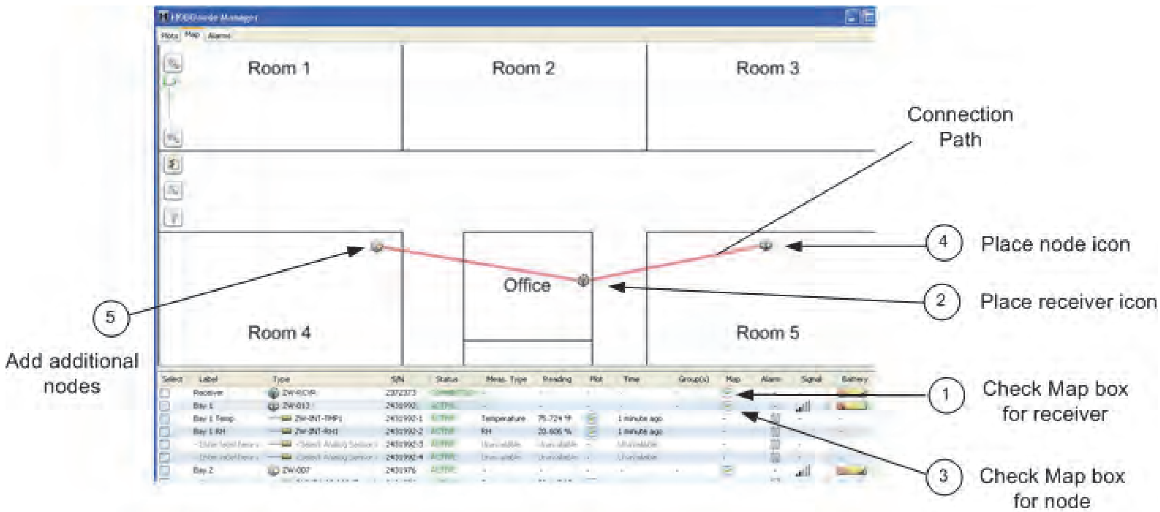
1. Map Tab. To view the Network Map, click the Map tab.
2. Information Balloons. Click a device in the Network Map to open a pop-up that shows current readings and other device information. To have pop-ups appear automatically, click the Configure Map icon and select "Show Information Balloon when adding new data nodes and on startup." You can also adjust how much information is included in the balloon. See Configuring the Network Map for more information.
3. Imported Map Image. To customize your map background image, see Customizing the Network Map Background.
4. Add Device to Map. To add a device to the map, check the Map box in the Device Table and then click in the map where you want to place the icon.
5. Connection Path. Lines on the map show the path each device takes to the receiver. You can monitor the communication between a data node and the data receiver by checking the connection paths between devices. If a device has missed a scheduled connection, the path will become a dotted line. To change the path color, see Configuring the Network Map.
6. Tools. Use the Zoom tools to zoom in and out of the map. Click the Configure Map button to access additional map settings. Use the Refresh Network Paths button to see the latest path that the devices are taking to get to the receiver. Paths can change if a data node is moved or because the original path was obstructed.

Note that if an alarm has tripped on a node, the node icon on the network map will have a red ring around it like this: 

Adding a Device to the Network Map

To add a device to Network Map.

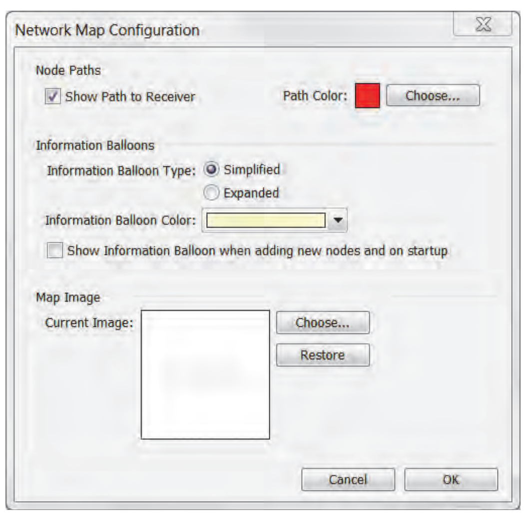
1. In the Device Table, check the Map box for the receiver to add it to the map.
2. Move the icon to the location of the receiver and click the left mouse button.
3. Check the Map box for a node to add it to the map.
4. Move the icon to the location of the device and click the left mouse button.
5. Repeat steps 3 and 4 for each node you want to add to the map.



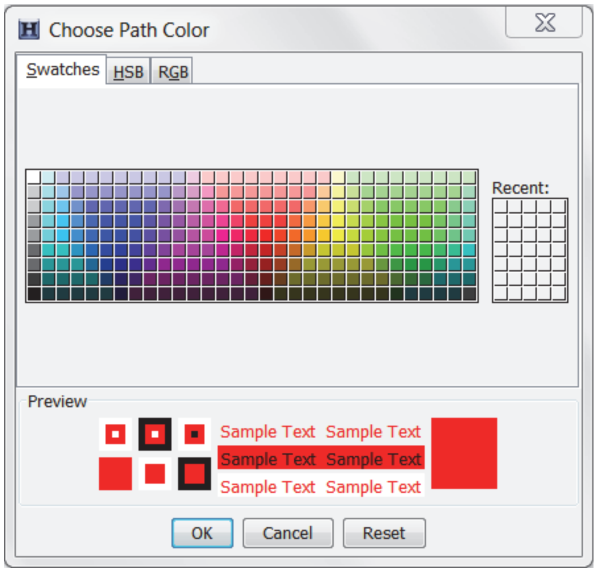
Configuring the Network Map

You can customize the paths and information balloons on the Network Map, and you can use your own

Click the Configure icon  in the top left of the Network Map to open the Network Map Configuration window.

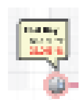


In the Node Paths pane, select the Show Path to Receiver checkbox Paths to show or hide connection paths between nodes. To change the path color, click the Choose button. Select a new color from the Swatches tab, or enter HSB or RGB values and click OK.

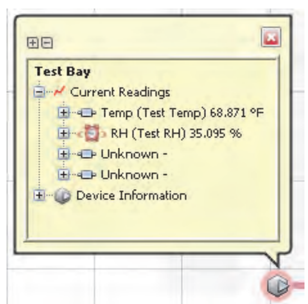


In the Information Balloons pane, select the Information Balloon Type, as either:

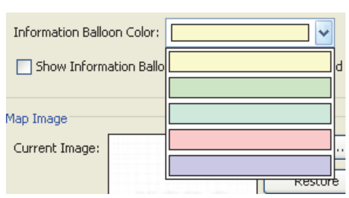
- Simplified to show only label and readings, or



- Expanded to show all device information.



To change the background color on the balloon, click the Information Balloon Color drop-down arrow and select a color.

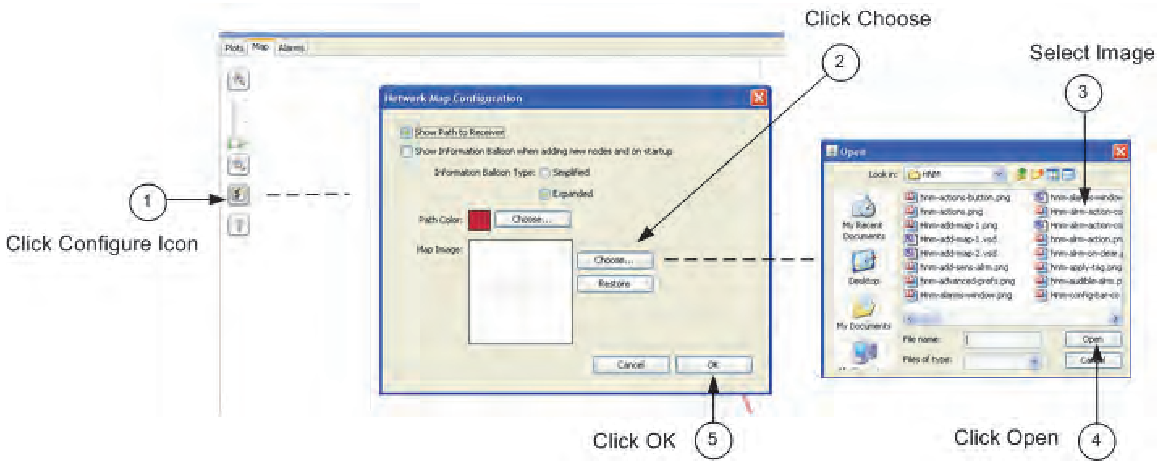


Select the "Show Information Balloon when adding new data nodes and on startup" checkbox to automatically display the balloons any time you open HOBOnode Manager or add a new icon to the map.

To change the map image, see Customizing the Network Map Background.

Customizing the Network Map Background

You can upload a custom image to the Network Map to represent your floor plan.



1. Click the Configure icon in the top left corner of the map.
2. Click the Choose button in the Network Map Configuration window.
3. Select the image file from the Open window.
4. Click Open.
5. Click OK to close the Network Map Configuration window and display the new image.

To revert to the default image, click Restore.

If you don't have an image to upload, you can create one using any drawing program following these guidelines:

- There are 3 scale levels available for an image in the Network Map, depending on the size of the image you upload. The larger the size, the more zoom levels you will have.
    - 1,000 x 1,000 (minimum size) - 1 zoom level
    - 2,000 x 2,000 - 2 zoom levels
    - 3,000 x 3,000 (maximum size) - 3 zoom levels
- All images are converted to squares in the Network Map, so for best results your overall image should be a square.
- Inside the main square, add a smaller square or rectangle to roughly represent your building.
- Add squares or rectangles to represent rooms in your building where you will place nodes. Add descriptive labels to each room such as "Office," "Cooler," or "Boiler Room." Some programs will also have other images you can add to the room such as desks and computers to help you narrow the location of the node.
- Set the properties of the image to your desired resolution. For best results enter 4,000 x 4,000 pixels.

Maintenance & Troubleshooting

Once your ZW Wireless Data Node Network is running, refer to the following topics for maintenance and troubleshooting tips:

- Changing External Sensor Type
- Moving or Removing a Data Node
- Converting a Router Node to an End-Point Node (Switching from AC Power to Battery Power)
- Converting an End-Point Node to a Router Node (Switching from Battery Power to AC Power)

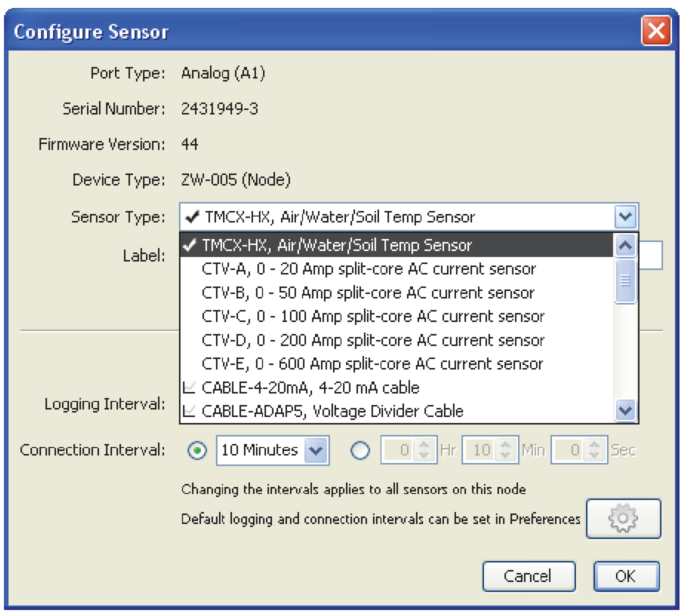
- Database Backup and Restore
- HOBOnode Manager Database Upgrade Utility
- Creating a New Deployment
- Updating Firmware for a Receiver or Single Data Node
- Updating Firmware for Multiple Data Nodes
- Troubleshooting

Changing External Sensor Type

Many types of HOBO data nodes can be configured with external sensors. One of the benefits of using external sensors is that you can swap them out when necessary for different ones if you want to modify your wireless network. Or, you can disable the external sensor channel if you don't need it for your current network deployment.

To change the type of external sensor associated with a data node:

1. Double-click the external sensor you wish to change in the HOBOnode Manager device table.
2. Select the sensor from the Sensor Type drop-down list.

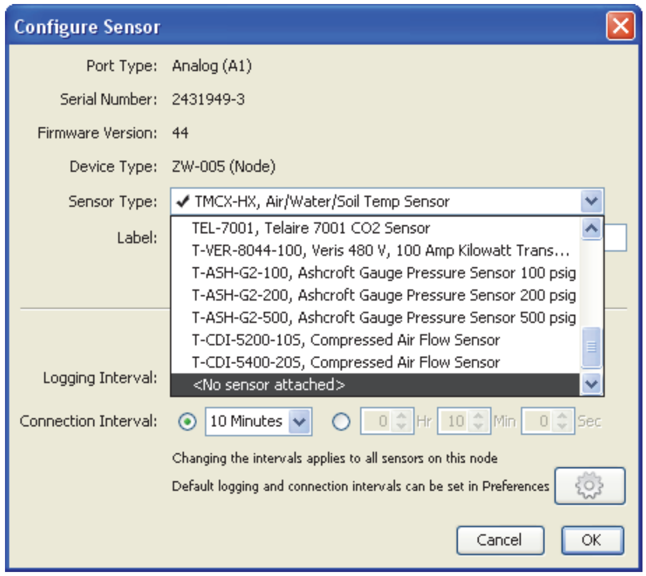


3. Make any other changes as necessary and click OK.

Note: While the HOBOnode Manager device table will display the change to the sensor type immediately, data for the new sensor will not display until the next connection interval .

To deselect, or turn off, an external sensor:

1. Double-click the external sensor you wish to change in the HOBOnode Manager device table.
2. Scroll to the end of the Sensor Type drop-down list and select <No sensor attached>.



3. Make any other changes as necessary and click OK.

The HOBOnode Manager device table will then change the status for that external sensor to OFF as shown below. Any plots and alarms associated with that sensor will also be removed from HOBOnode Manager.

Type	S/N	Status
ZW-RCVR	2372376	CONNECTED
ZW-005	2431949	ACTIVE
CABLE-TEMP/RH (Temp)	2431949-1	ACTIVE
CABLE-TEMP/RH (RH)	2431949-2	ACTIVE
<Select Analog Sensor>	2431949-3	OFF

Shortcut: In the device table, click the checkbox next to the external sensor, then click the Sensor Type button and select the sensor from the list. This can be done for many sensors at once by selecting more than one sensor at a time in the device table.

For details on setting up a HOBO data node with an external sensor for the first time, see Setting Up an External Sensor. For details on scaling sensor data, see Configuring Scaling on a Sensor.

Moving or Removing a Data Node

If you will not be using a data node for an extended period of time, you may want to deactivate it to stop measurements and save batteries. To deactivate a data node, use a paper clip to press the Activate button as shown in the photo below for 5 seconds until the red LED starts flashing.

To later reactivate the data node, select Form Network from HOBOnode Manager and briefly depress the Activate button on the node.

If you do not want a data node to appear in HOBOnode Manager, double-click the device row in the Device Table and then click Remove Node in the Configure Node window.

If you move a data node to a new location, make sure the green LED is still blinking once per 10 seconds to indicate that the node still has a connection to the receiver. If the red LED is blinking, the connection path is broken. Try adjusting the orientation of the data node or moving it closer to the receiver to minimize obstructions. You may need to add a router to re-establish a connection.

If moving a data node changes the primary power source, see the following:

- Switching from AC Power to Battery Power
- Switching from Battery Power to AC Power

Converting a Router Node to an End-Point Node (Switching from AC Power to Battery Power)

If you initially power up a node using an AC adapter, it will operate as a router node. If you need to convert the router node into an end-point node that operates on battery power only, follow this procedure.

1. Deactivate the data node by pressing the reset button on the data node with a paper clip until the red LED starts flashing repeatedly (about 5 seconds).
2. Disconnect the data node from AC power.
3. If batteries are installed, remove them.
4. Wait at least 30 seconds to clear the memory.
5. Reinstall the batteries. Do not plug in the AC adapter.
6. Click Form Network in HOBOnode Manager.
7. Press the reset button with a quick 1-second push to reactivate the data node.
8. Verify that the data node appears in the HOBOnode Manager table and is identified as a node (no routing capabilities). See Determining Data Node Type.

Converting an End-Point Node to a Router Node (Switching from Battery Power to AC Power)

If you initially power up a node using batteries, it will operate as an end-point node with no routing capabilities. If you need to convert the end-point node into a router node that operates on AC power, follow this procedure so that HOBOnode Manager recognizes the data node as having routing capabilities.

1. Deactivate the data node by pressing the reset button on the data node with a paper clip until the red LED starts flashing repeatedly (about 5 seconds).
2. Remove the batteries from the data node.
3. Wait at least 30 seconds to clear the memory.
4. Plug the data node into an AC power outlet.
5. Click Form Network in HOBOnode Manager.
6. Press the reset button with a quick 1-second push to reactivate the data node.
7. Verify that the data node appears in the HOBOnode Manager table and is identified as a router. See Determining Data Node Type.
8. Reinstall the batteries for backup purposes.

Database Backup and Restore

It is recommended that you periodically back up your database to secure your data in case of a database failure. You can back up your database to an external hard drive or network server using third-party backup software.

If you should ever need to restore your database, simply replace the primary database with the backup.

Important: The database must be closed during a backup or restore. Before copying or restoring a database, close HOBOware, HOBOnode Manager, and Device Communication. Right-click (Windows) or left-click (Macintosh) the HOBOware system tray icon and select Stop Device Communication.

The database is stored at the following location:

- Windows 7 and Windows 8

  c:\Users\<user name>\AppData\Local\OnsetComputerCorporation\cosmos\db

- Windows XP

  c:\Documents and Settings\<user name>\Application Data\OnsetComputerCorporation\cosmos\db

- Mac OS 10.5 and 10.6

  /Users/<user name>/Documents/OnsetComputerCorporation/cosmos/db

To rename the database, modify the name of the db folder by adding the deployment location or the date (example: "db-11-10"). **Note:** HOBOnode Manager will be empty after renaming the database. You will need to form a new network.

HOBOnode Manager Database Upgrade Utility

HOBOnode Manager databases created in HOBOware 3.2.1 or earlier must be upgraded with the HOBOnode Manager Database Upgrade Utility to improve performance and response time. This utility is automatically opened the first time you access the HOBOnode Manager database in HOBOware 3.2.2 or later.

Before you can upgrade the database with the utility, you must first go to the data storage location to back up the database (and the entire db directory). After the backup is complete, click Start in the utility to begin the upgrade process. Progress will be displayed while the upgrade takes place.

Important: The larger your database, the longer it will take the upgrade to complete. Please be prepared for the utility to run for an hour or more. You will not be able to access any features in HOBOnode Manager or HOBOware while the utility is running. Any data recorded while the upgrade is running will be saved and available in HOBOnode Manager once the upgrade is complete. In addition, this utility requires free disk space equivalent to double the size of the current database. For example, if your database is 450 MB, then you will need at least 900 MB free disk space on the computer for the utility to complete its process. Once the upgrade is complete, the database will be close to its original size.

Creating a New Deployment

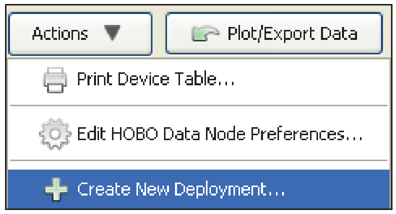
The first time you form a HOBO data node wireless network, the initial deployment, or network configuration, is created automatically for you. This first deployment can continue indefinitely. However, you also have the option to create a new deployment if you need to move your current network to a new location or if you'd like to configure a different set of sensors in a new network, for example. This allows you to more easily distinguish between two separate networks or deployments of nodes when they are plotted or exported from HOBOware.

You have the option of either creating a new deployment that is an exact copy of the previous one (all devices, alarms, and settings will be copied as currently configured) or consists of a new network (only system alarms and alarm logs are copied).

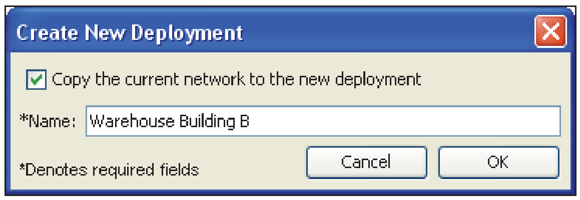
Note: Creating a new deployment does not create a new database. All data recorded in the previous deployment is saved and can be accessed through Plot/Export Data.

To create a new deployment:

1. Click the Actions button in HOBOnode Manager and select Create New Deployment.



2. Type a name for the new deployment. Select the Copy the current network to the new deployment checkbox if you want to use the current deployment as the basis for the new deployment (HOBOnode Manager will automatically be filled in with your current network devices, alarms, and settings). If you do not copy the current network, then you will need to form a new network (only system alarms and alarm logs will appear in HOBOnode Manager). Click OK.

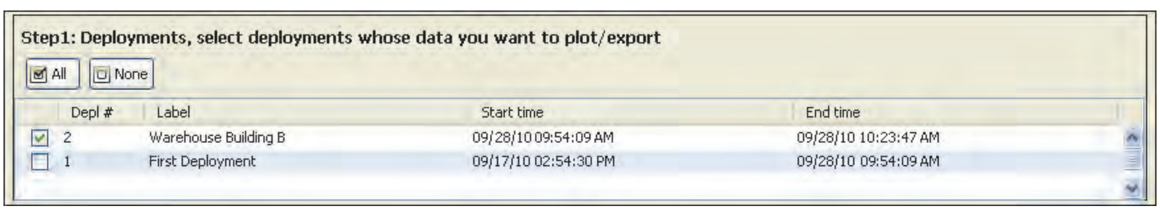


3. A message appears indicating that the current network deployment will end and a new deployment will be started. Click Yes to continue, or click No to return to the Create New Deployment dialog.

4. From the Device menu in HOBOware, select Manage HOBO Data Node Network to restart HOBOnode Manager.

5. If you chose to copy the current network to the new deployment, then HOBOnode Manager opens with all devices listed. Plots will begin displaying the new network data at the next scheduled connection interval. If you did not copy the old network, then you will be prompted to form a new network.

Both the newly created deployment and the previous deployment are listed in the Plot/Export Wireless Data window. Click the Plot/Export button in HOBOnode Manager to see the deployment list as shown in the example below.



Deployments are listed from newest to oldest. The initial deployment is labeled "First Deployment" by default. Any subsequent deployments are listed with the name you entered in the Create New Deployment dialog.

The start time for the current deployment (the deployment at the top of the list) is the time the new deployment was created, which is also the end time for the previous deployment on the list.The end time for the current deployment is the current time.

Updating Firmware for a Receiver or Single Data Node

Occasional firmware updates may be necessary for the devices in your network. Follow these steps if you are directed by Onset Computer to upgrade the firmware in the receiver or a single data node. To update several data nodes in the network at once, see Updating Firmware for Multiple Data Nodes.

Important Notes Before you Begin:

- Updating the firmware generally takes two to three minutes for a receiver and four to six minutes for a data node. You cannot cancel the update process once it starts.
- If you need to update both the receiver and data nodes, update the receiver first to provide the best network performance. After the receiver update is complete, wait for HOBOnode Manager to display the latest data from all the nodes. Once each node has communicated with the newly updated receiver and the latest data appears in the device table, then you can continue with updating the firmware in the nodes.
- When updating the receiver firmware, the entire network will automatically shut down and restart.
- A data node should be powered the same way as it was when it was originally configured to ensure it remains a part of the network once the update is complete. This means a router node must be plugged into an AC adapter and an end-point data node must have batteries installed and not be plugged into an AC adapter. See Determining Data Node Type for details on identifying routers and end-point nodes in HOBOnode Manager.

To update firmware:

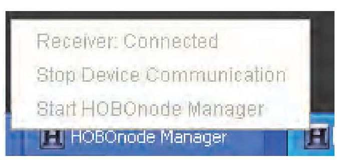
1. Place the firmware .hex file(s) in the appropriate directory. Do not rename the files.

   For Windows 7 and Windows 8: C:\Users\Public\Documents\HOBOware Public Files\FWUpdates

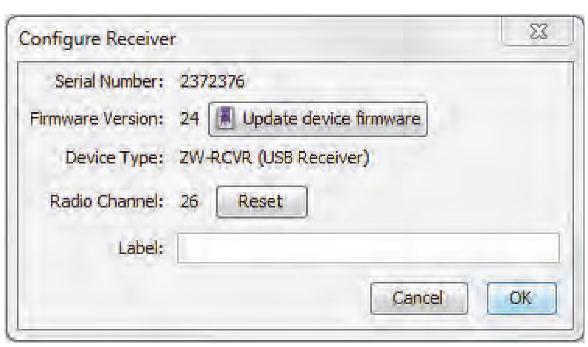
   For Windows XP: C:\Documents and Settings\All Users\Shared Documents\HOBOware Public Files\FWUpdates

   For Macintosh: /Users/<user>/Documents/HOBOware/FWUpdates

2. HOBOware, HOBOnode Manager, and ZW Device Communication must be restarted to correctly identify the firmware files. Close HOBOware and HOBOnode Manager if open. If prompted to leave the device communication running in the background, click No. If HOBOware and HOBOnode Manager were already closed, but device communication was running, right-click (or left-click on a Mac) the HOBOware icon in the system tray select Stop Device Communication.



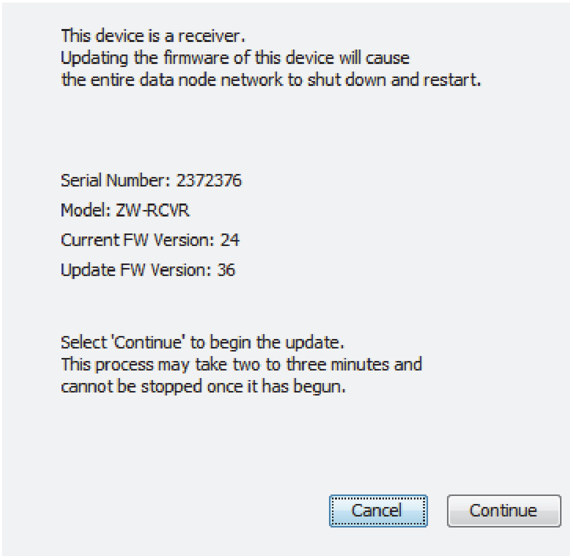
3. Open HOBOware and HOBOnode Manager again. Wait for new data to be updated in HOBOnode Manager.
4. In HOBOnode Manager, double-click the receiver (ZW-RCVR) or node you want to update in the Device Table (or select the receiver or node and click Configure).
5. Click the "Update device firmware" button in the Configure Receiver or Configure Node window (Configure Receiver is shown in the following example).



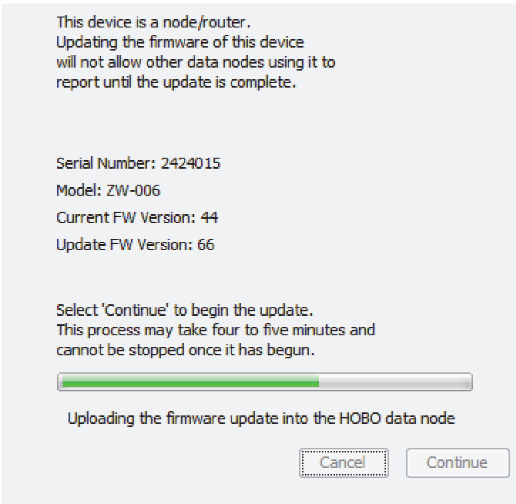
Notes:

- If the "Update device firmware" button is disabled, HOBOnode Manager is still being updated after its restart. Keep the Configure window open and wait for a few more minutes for the button to become enabled.
- If the "Update device firmware" button does not appear, double-check that the firmware .hex file is in the correct directory as described in Step 1.
- A battery-powered end-point node with a current firmware version of 64 must be temporarily converted to an AC-powered router node before you can update the firmware. If a message displays indicating you cannot complete the update, follow the steps in Converting an End-Point Node to a Router Node first and then repeat Steps 2 and 3 again.

6. A message appears listing details about the device and any notes about the update process. Click Cancel if you do not want to update the device at this time. Otherwise, click Continue.



7. The firmware is updated in the device; check the progress on the screen during the update as shown in the following example of a node being updated.



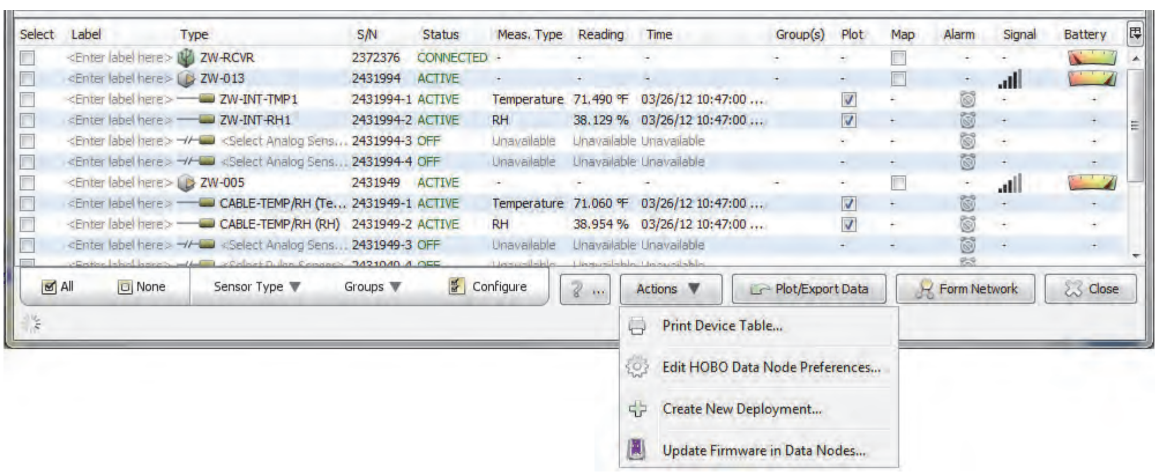
When the firmware is saved to the device, the LED will flash red on the receiver and green on a data node. A message appears at the end when the update is successfully completed.

Notes:

- After a data node has been updated, it may to take one or two connection intervals before new data is displayed in HOBOnode Manager. For example, if the connection interval is set for 10 minutes, it may take two connection intervals, or about 20 minutes, for new data to appear. If new data still isn't appearing after two connection intervals have passed, power cycle the data node (unplug the adapter and/or remove the batteries then plug the adapter back in and/or reinstall the batteries).
- If HOBOnode Manager still is not displaying data after power cycling the data node as described above or if the data node is listed as missing in HOBOnode Manager after updating the firmware, add it back to the network by following these steps:
  1. Click the Form Network button in HOBOnode Manager.
  2. Press the reset button with a quick 1-second push to reactivate the data node.
  3. Verify that the data node appears in the HOBOnode Manager table and is identified as a router or data node as expected (see Determining Data Node Type). To change the type of data node, see Converting an End-Point Node to a Router Node or Converting a Router Node to an End-Point Node.

Updating Firmware for Multiple Data Nodes

Occasional firmware updates may be necessary for the data nodes in your network. If new versions of firmware files are detected in the HOBOware FWUpdates directory (exact location described below), then an Update Firmware in Data Nodes option appears in the Actions drop-down menu in HOBOnode Manager as shown below.



Follow these steps if you are directed by Onset Computer to upgrade the firmware in multiple data nodes. To update the firmware in the receiver or in a single data node at a time, see Updating Firmware for a Receiver or Single Data Node.

Important Notes Before you Begin:

- Firmware .hex files must be present in the appropriate directory. (Do not rename the files.)

  For Windows 7 and Windows 8: C:\Users\Public\Documents\HOBOware Public Files\FWUpdates

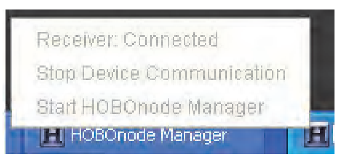
  For Windows XP: C:\Documents and Settings\All Users\Shared Documents\HOBOware Public Files\FWUpdates

  For Macintosh: /Users/<user>/Documents/HOBOware/FWUpdates
- If you need to update the firmware in both the receiver and data nodes, update the receiver first for best network performance. Follow the steps in Updating Firmware for a Receiver or Single Data Node. After the receiver update is complete, wait for HOBOnode Manager to display the latest data from all the nodes. Once each node has communicated with the newly updated receiver and the latest data appears in the device table, then you can continue with updating the firmware in data nodes.

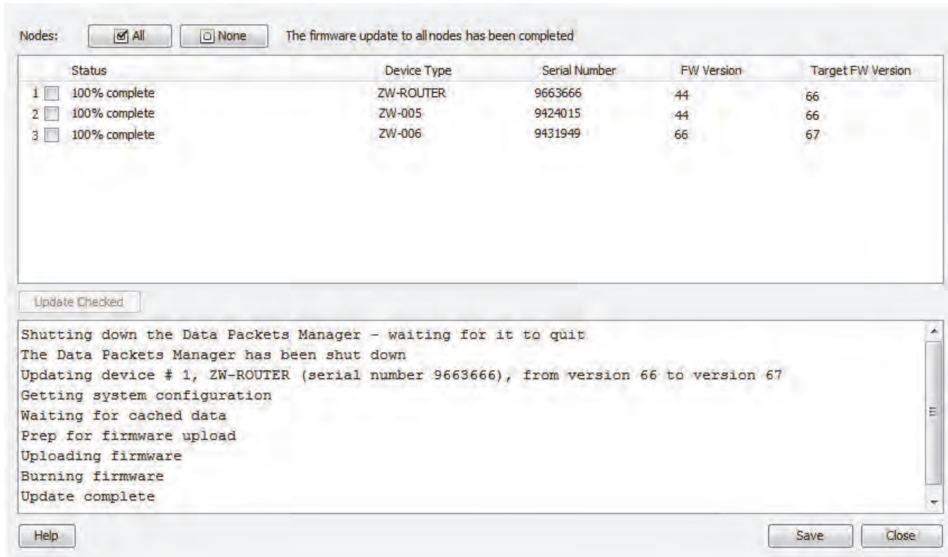
- A data node should be powered the same way as it was when it was originally configured to ensure it remains a part of the network once the update is complete. This means a router node must be plugged into an AC adapter and an end-point data node must have batteries installed and not be plugged into an AC adapter.
- A battery-powered end-point node with a current firmware version of 64 must be temporarily converted to an AC-powered router node before you can update the firmware. These nodes will not be displayed in the list of data nodes waiting for an update. Follow the steps in Converting an End-Point Node to a Router Node first, then update the firmware in each of these nodes one at time as described in Updating Firmware for a Receiver or Single Data Node.
- Although data will continue to be transmitted and stored in the receiver while this upgrade takes place, it will not be available in HOBOnode Manager until after the upgrade is complete. Therefore, select a time to perform the upgrade when you do not need real-time access to your data.
- Nodes may be temporarily reported as missing after being upgraded. If you have enabled the Missing Node alarm for any nodes in your network, consider only upgrading a few nodes at a time to minimize the potential for nodes to be reported as missing and the Missing Node alarm to trip.

Steps

1. Once the firmware .hex files are in the correct location as described in the Important Notes Before you Begin, you must restart HOBOware, HOBOnode Manager, and Device Communication. Close HOBOware and HOBOnode Manager if open. If prompted to leave the device communication running in the background, click No. If HOBOware and HOBOnode Manager were already closed, but device communication was running, right-click (or left-click on a Mac) the HOBOware icon in the system tray select Stop Device Communication.



2. Open HOBOware and HOBOnode Manager again. Wait for new data to be updated in HOBOnode Manager.
3. From the Actions menu in HOBOnode Manager, click Update Firmware in Data Nodes. If this option does not appear in the menu, wait for a few more minutes for HOBOnode Manager to finish updating in Step 2. If it still does not display, double-check that the firmware .hex files are in the correct directory and repeat Steps 1 through 3 again.
4. A list of all nodes waiting to be updated is displayed. Click the checkbox next to each node you want to update or click Select All to choose all the nodes in the list.
5. Click the Updated Checked button to start the update process for all the nodes selected in the list. Each node will be updated one by one, with the progress displayed next to the node and a detailed progress listed in the bottom pane of the window. **Important:** Clicking Cancel will not immediately stop all updating. When you click Cancel, the node update in progress will continue until finished. The Cancel button will also change to read "Cancel requested." Once the update is complete for that node, the update for the remaining nodes will be canceled. Click the Update button to restart the update process for the remaining nodes.



6. Once the update is complete, click the Save button to save the log detailing the update procedure to a text file called "FirmwareUpdateLog.txt" (saved in C:\Users\<User Name>\Documents on Windows and in the <User Name> folder on Mac). Click Close to return to HOBOnode Manager.

Notes:

- After a data node has been updated, it may to take one or two connection intervals before new data is displayed in HOBOnode Manager. For example, if the connection interval is set for 10 minutes, it may take two connection intervals, or about 20 minutes, for new data to appear. If new data still isn't appearing after two connection intervals have passed, power cycle the data node (unplug the adapter and/or remove the batteries then plug the adapter back in and/or reinstall the batteries).
- If HOBOnode Manager still is not displaying data after power cycling the data node as described above or if the data node is listed as missing in HOBOnode Manager after updating the firmware, add it back to the network by following these steps:
  1. Click the Form Network button in HOBOnode Manager.
  2. Press the reset button with a quick 1-second push to reactivate the data node.
  3. Verify that the data node appears in the HOBOnode Manager device table and is identified as a router or data node as expected (see Determining Data Node Type). To change the type of data node, see Converting an End-Point Node to a Router Node or Converting a Router Node to an End-Point Node.

Troubleshooting

General Network Connection Issues

If you are having problems connecting data nodes to the receiver, or they are losing a connection after they have been joined to the network, you may be experiencing issues with a conflicting wireless device. To reset the radio channel, double-click the receiver row in the Device Table and in the Configure Receiver window click the Reset button. You will then need to form the network again.

Receiver Will Not Connect to HOBOnode Manager

Make sure the USB plug is secure on both ends. Try unplugging and plugging the receiver back in.

Data Node Cannot Join Network

Positioning: If you are having trouble getting a data node to join the network, try repositioning the node within the space. Move the data node away from any obstacles (such as metal walls, stairwells, elevator shafts) that may exist between it and the receiver.

Distance: The data node may be too far from the receiver to obtain a signal. Try moving the data node closer to the receiver, or add a router or router/node between the data node and the receiver.

Make sure the receiver is in Form Network mode (RED and GREEN LEDs alternating).

Make sure you have pressed the button on the bottom of the node and that the RED and GREEN LEDs are alternating. Try pressing the button again.

Debugging

There are a number of debugging and logging options in HOBOnode Manager. If you are working with Onset Technical Support on an issue, you may be asked to enable debugging options and send a log file to Onset.

No readings for a sensor

For external sensors, make sure the connection to the data node is secure and that you have assigned a Sensor Type (does not apply to the External Temp/RH Sensor).

No Plot Appears for a Sensor

Make sure you have checked the Plot box in the Device Table for the sensor.

Extreme Sensor Readings

If you are seeing extreme sensor readings, make sure the sensor cable is securely plugged into the node.

Alarms

If an alarm you configured is not appearing in the Alarms window, make sure the filter is set to Show all.

Security Connection Messages on Macintosh

If the firewall setting is enabled in the security system preferences on a Macintosh, you may encounter a security warning message every time you open HOBOnode Manager. To turn off this message, go to System Preferences, select Security, and turn off the firewall. **Note:** Keeping the firewall turned on and adjusting the advanced settings to allow all incoming connections for HOBOware does not resolve the problem.

Firewall Messages on Windows

Windows Firewall must allow access to HOBOware.exe for HOBOnode Viewer to run properly. To allow HOBOware access, open Control Panel, go to Security, and select Allow a program through Windows Firewall (or click Windows Firewall and click the Exceptions tab on some versions of Windows). Make sure HOBOware is selected in the allowed access/exceptions list.

Changing Locale

The language in use at the time the original HOBO data node network database was created is the only language that can be used for that database. You cannot switch to another language. If you need to change the locale on the computer that contains your HOBO data node network database, you will need to:

1. Back up and then move or rename the database.
2. Change the locale on the computer.
3. Form a new network to create a database that operates in the new locale.

Chapter 7
Reference

- Setting Preferences
- Menus
- The Toolbar
- Tips for Working with Multiple Loggers
- Setting the Language Format on Your Computer
- Alarm & Readout Tool (**Note:** This tool is no longer supported as of HOBOware 3.5.)

Setting Preferences

You can change the default behavior of HOBOware in the categories listed below. Preference settings are unique for each user login on your computer. The following categories are available:

- **General**. Set preferences for Launch Time-Savings Options, Readout Time-Savings Options, Open File Time-Saving Options, Export Settings, Selecting Devices, File Associations, Startup, Data Verification, and Data Encoding.
- **Communications**. Set preferences for Device Types , Serial Ports, Device Speeds, and Other Options.
- **Plotting**. Set preferences for Fonts, Lines, Value Axis, Layout, Points Table and Details Pane, Gridlines, Plot Setup, Other Options, Undo & Redo.
- **Data Assistants**. Set show/hide preferences for HOBOware Data Assistants.
- **Display**. Set preferences for Default Unit System, Date/Time, and Series.
- **Warnings**. Set preferences for various warning types.
- **Data Nodes**. Set preferences for HOBOnode Manager, including General, Alarms, Real-Time Plots, Data Storage, and Sharing (HOBOware Pro only).
- **Alarms**. Set preferences for the Alarms & Readout Tool, including Alarm Conditions, Readouts, Notifications, Messages, and Warnings (HOBOware Pro only). **Important:** The Alarm & Readout Tool is no longer supported as of HOBOware 3.5.
- **Bulk Export**. Set YAML preference for Bulk Export Tool (HOBOware Pro only).

Some preferences have one of the following icons next to them, indicating a difference in behavior between HOBOware and HOBOnode Manager (HOBOware Pro only).

Takes effect on next plotted file
HOBOnode Manager: Takes effect on restart or next created plot

You can save preference settings and reload them as needed (HOBOware Pro only). Click the Save Preferences button at the top of the Preferences window and type a name in the pop-up field to save all currently selected preferences. You can then click the Load Preferences button and select the name you typed in to load those preference settings back into the Preferences window.

See also:

- Restoring Default Preferences

General Preferences

Use the General category within Preferences to control a variety of HOBOware behavior, including launching, reading out, opening files, exporting, selecting devices, and more.

To change these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the General category on the left and then click the subcategory you wish to change.
3. Adjust any of the settings described below and then click OK.

Launch Time-Saving Options (HOBOware Pro only)

- **When launching.** Select "Show launch screen" to display the Launch Logger window when you select Launch from the Device menu or click the Launch icon  on the toolbar, or select "Automatically launch" to bypass this window and launch the logger with the default settings. Selecting "Automatically launch" is particularly useful if you want to launch several loggers quickly without changing any settings. The default settings are determined by the "Fill launch window with contents of" preference.

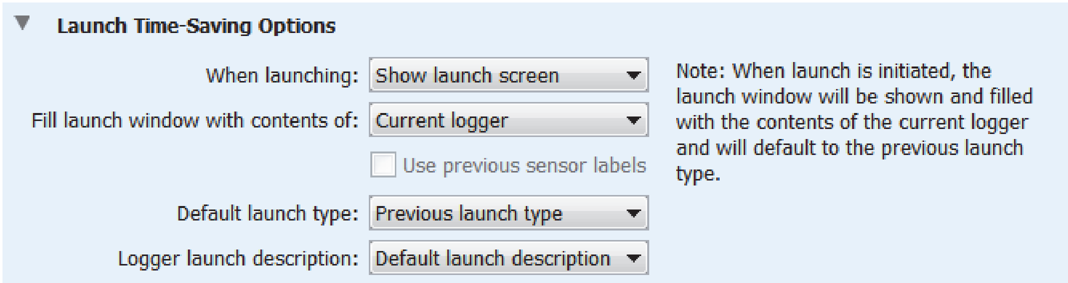
  For HOBOware Pro only: If you select "Automatically launch" and also set the Default Action from the Device menu to Launch, this feature allows you to launch several U-Series loggers in a row simply by connecting and disconnecting each logger to the computer.

- **Fill launch window with contents of.** Select "Current logger" to show the logger's most recent launch settings (as stored in the logger memory) in the Launch Logger window. Select "Previous launch" to show the same settings used in the most recent launch. This is helpful if you want to launch several loggers of the same type with similar settings or if you want to set up several loggers to start at the same time with the same logging interval. An indicator on the Launch Logger window will remind you when this preference is use. Note that "Previous launch" does not apply if you are launching different types of loggers; instead the settings in the logger's memory will be used. When "Previous launch" is selected, you also can select the "Use previous sensor labels" checkbox to automatically fill any sensor label fields with the labels from the previous launch.

- **Default launch type.** This preference controls what displays by default in the "Start logging" field in the Launch Logger window"Previous launch type" is selected, then the "Start logging" field will display the same setting used for the logger's last launch. For example, if the logger was last configured to start logging "Now" selected, then the "Start logging" field will default to "Now" for the next launch. Note that if the previous launch was set to start "At interval," the "Start logging" field will default to start "On Date/Time." If "Launch now," "Launch at interval," "On specified date/time," or "Button or coupler start" is selected, then that launch type will automatically be selected in the "Start logging" field in the Launch Logger window regardless of how the logger was previously launched. Note that if you choose "Button or coupler start" and the logger does not support that feature, then the "Start logging" field will default to "Now." **Important:** If you set the "Fill launch window with contents of" preference to "Previous launch," then the "Default launch type" preference will be ignored in favor of the "Start logging" setting used in the last launch.

- **Logger launch description.** This preference controls what displays by default in the Description field in the Launch Logger window. If you select "Default launch description," then the Description field will display the description used the last time the logger was launched. If you select "Logger S/N," then the logger serial number will automatically be listed in the Description field. Selecting "Logger S/N" can help to easily differentiate files when launching and reading out several loggers of the same type.

Note that whatever is listed in the Description field is also used as the default file name when reading out and saving the logger data.



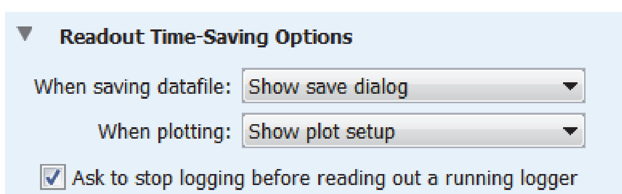
Readout Time-Saving Options (HOBOware Pro only)

- **When saving datafile.** This preference controls whether the Save window displays automatically when reading out a file. Select "Show save dialog" if you want the Save window to display every time you read out a logger and specify a location and name for the file, or accept the default file name. Select "Automatically save" if you do not want to display the Save window during the readout process. The file will automatically be saved with the default name (the description in the Launch Logger window) and in the default location (as described in Reading Out the Logger).

- **When plotting.** This preference controls the default plot behavior when reading out a logger. Select "Show plot setup" to display the Plot Setup window after reading out and saving the file. Select "Automatically plot" if you want to bypass the Plot Setup window and instead automatically plot the data after reading out and saving the file. This option is not recommended if you will be using Data Assistants, which are accessed through the Plot Setup window. Select "Do not plot" if you do not want to plot the data at all. This is useful if you are reading out several loggers and prefer to look at the plots later. You can always open the saved datafile and plot it at that time.

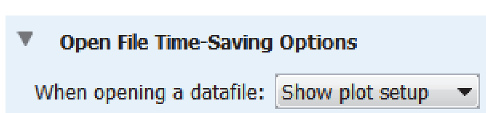
  For HOBOware Pro only: You can adjust the Readout Time-Saving Options and set the Default Action from the Device menu to Readout to quickly read out several U-Series loggers in a row by connecting and disconnecting each logger to the computer. To do this choose "Automatically save" for "When saving datafile," choose "Do not plot" for "When plotting," and deselect the "Ask to stop logging before reading out a running logger" checkbox.

- **Ask to stop logging before reading out a running logger.** When this checkbox is selected, a message appears every time you read out a logger that is still recording data. The message asks whether you want to stop the logger or let it continue logging data during the readout process. If you deselect this checkbox, a logger that is still recording data will automatically continue logging during readout.



Open File Time-Saving Options (HOBOware Pro only)

This preference controls whether the Plot Setup window is automatically displayed when opening a file. Select "Show plot setup" if you want the Plot Setup window to display every time you open a file. Select "Automatically plot" if you want to bypass the Plot Setup window and automatically generate the plot each time you open the file. This is not recommended if you will be using Data Assistants, which are accessed through the Plot Setup window.

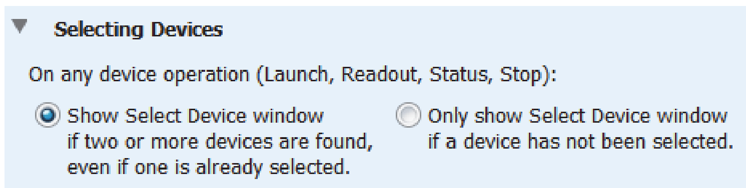


Export Settings

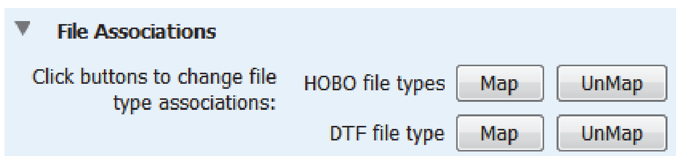
See Export Settings for details on the preferences in this subcategory.

Selecting Devices

This preference controls when the Select Device window is displayed. If you select "Show Select Device window if two or more devices are found, even if one is already selected," then the Select Device window will display any time more than one device is connected to the computer. This allows you to choose the device you want to work with any time you select Launch, Readout, Status, or Stop from the Device menu. If you select "Only show Select Device window if a device has not been selected," then the Select Device window will only display the first time you select Launch, Readout, Status, or Stop. That device will then remain selected until you change it with the Select Device icon on the toolbar.



File Associations

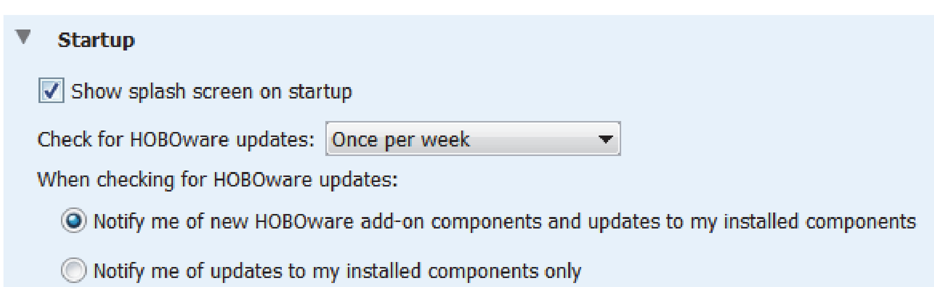


Use this preference to control the association of HOBOware file types on Windows. **Note:** You must have administrator privileges on the computer to change file type associations. To temporarily run HOBOware as an Administrator, right-click the HOBOware icon and select Run as Administrator. Enter the Administrator name and password as prompted.

By default, files with the extensions of .hobo, .hsec, and .hproj (HOBO files) and .dtf and .dsec (DTF files) are automatically associated with HOBOware. This means that these files are identified by a HOBOware icon and can be opened by double-clicking them. Click the Map or UnMap buttons to change the file type associations.

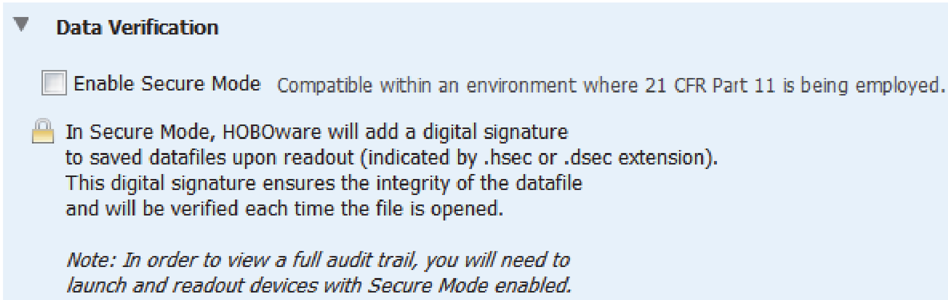
Startup

- **Show splash screen on startup.** This preference controls whether the HOBOware graphic, or splash screen, appears every time you open the software.
- **Check for HOBOware updates.** This setting controls how frequently, if it all, HOBOware automatically checks the Onset website for any software updates. The default setting is once per week.
- **When checking for HOBOware updates.** These settings control whether you are notified about all new software updates or only those that affect the currently installed components. The default is to check for any new updates.



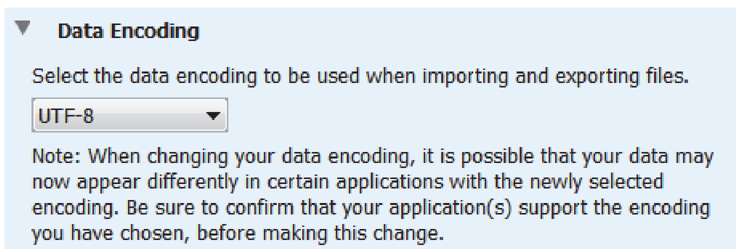
Data Verification (HOBOware Pro Only)

Select this option to enable Secure Mode and have HOBOware Pro add a digital signature to new datafiles when you read out loggers (for environments where 21 CFR Part 11 is being employed). The digital signature is indicated by a filename extension of .hsec for hobo files and .dsec for dtf files. The signature will be verified each time you open the datafile to ensure its integrity. This option is disabled off by default.



Data Encoding

Data encoding controls how special characters are displayed in files that are imported into and exported from HOBOware. The default is to use UTF-8, a common character encoding protocol for software. Select "Windows default" if characters are not displaying correctly in imported and exported files in Windows.



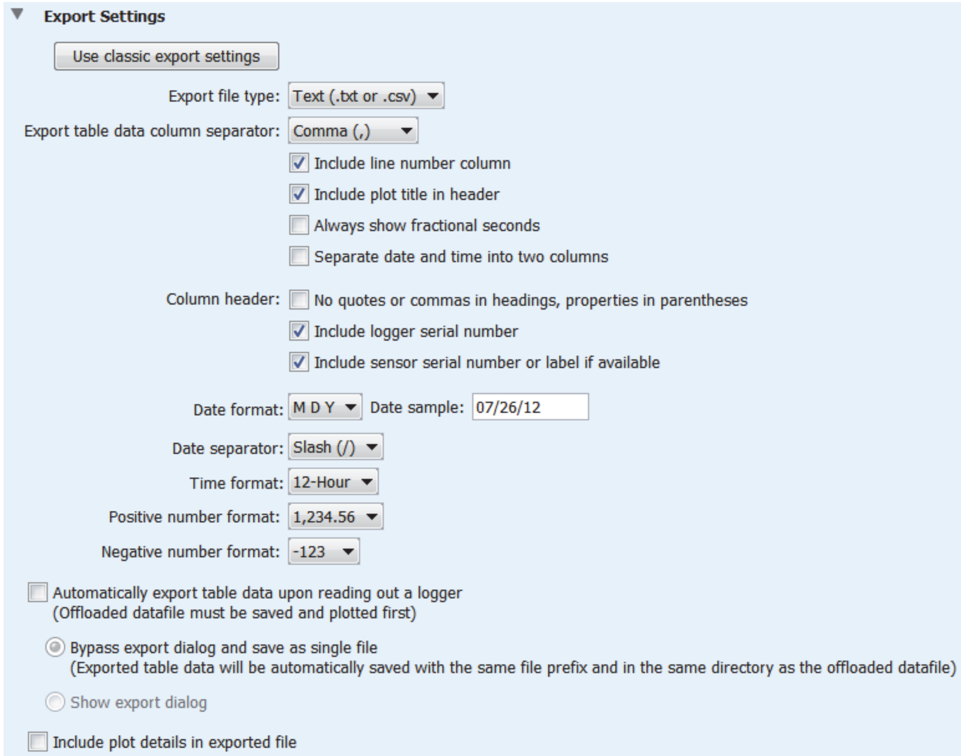
Send Metrics

When Send Metrics to Onset is enabled, information about HOBOware usage is sent to Onset for future software enhancements.

Export Settings

Use the Export Settings preferences to customize how data is formatted when you export the table data from a plotted HOBOware file, to set up automatic export upon readout, to include plot details in an exported file, and to set export ordering rules. To access these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the General category and then click Export Settings.
3. Adjust any of the settings described below and then click OK.



- **Use classic export settings.** Click this button to change the export settings to the default settings used with BoxCar Pro software, which is Onset legacy software released before HOBOware.

- **Export file type.** Select how you want exported data to be saved: either to a text file (.csv or .txt) or a Microsoft Excel file (.xls).

- **Export table data column separator.** This setting controls the column separator for exported text files. (If you selected Excel for the export file type, then this option is disabled.) Select Comma, Tab, or Semicolon. When Comma is selected as the column separator, the data will be saved to a .csv file that can be imported into Excel. When Tab or Semicolon is selected, the data will be saved to a .txt file.

- **Include line number column.** By default, exported files include line numbers. Uncheck this box if you do not want line numbers in the file (for example, to export in BoxCar Pro software format).

- **Include plot title in header.** Uncheck this box if you do not want the plot title included in the header of the exported file. This option is primarily for compatibility with the BoxCar Pro software format.

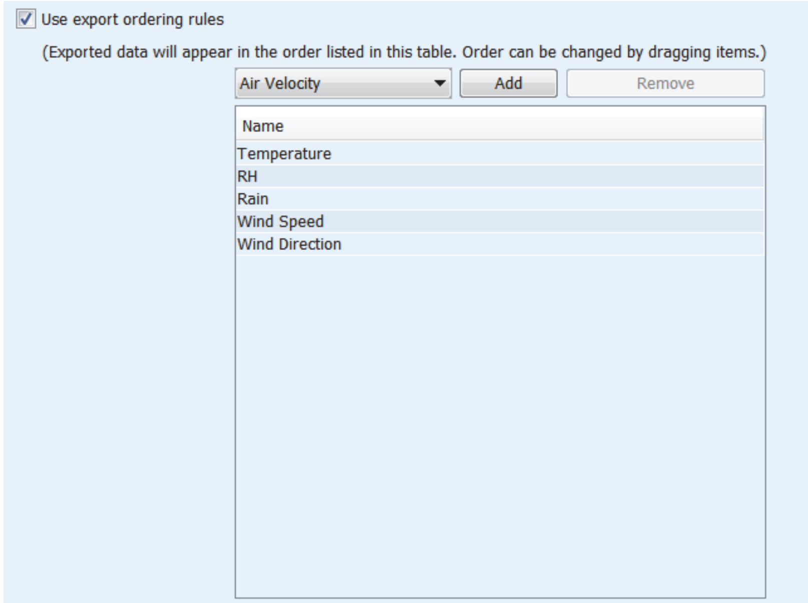
- **Always show fractional seconds.** Check this box to show fractional seconds in the time-stamped data points. This is primarily for compatibility with the BoxCar Pro software format.

- **Separate date and time into two columns.** By default, the date and time of a logged data point is exported as a single column to facilitate graphing in spreadsheet programs. Check this box to split the date and time into two columns.

- **No quotes or commas in headings, properties in parenthesis.** Check this box if you do not want quotations marks and commas in the exported file's column headers. Sensor properties, or units, (such as °F or RH) will be listed in parenthesis instead of quotation marks when this setting is enabled. This option is primarily for compatibility with the BoxCar Pro software format.

- **Include logger serial number.** When this setting is enabled, the logger's serial number will be listed in each column header in the exported file. This is useful if you are exporting data series that were copied and pasted from plots that originally came from different loggers.

- **Include sensor serial number, or label (if available).** When this setting is enabled, each sensor's serial number or label (if available) will be listed in each column header in the exported file. This is especially useful when exporting data from multiple sensors recording the same measurement type (for example, three temperature sensors). **Note:** If "No quotes or commas in headings, properties in parenthesis" is selected, the label (if available) will be added to the column header instead of the sensor serial number.
- **Date format.** Select the format in which you want the date to be shown (Month, Day, Year; Day, Month, Year; or Year, Month, Day).
- **Date separator.** Select either a slash (/) or a dash (-) to separate the months, day, and year in the date format.
- **Time format.** Select whether to show the time in a 12-hour or 24-hour format.
- **Positive number format.** Select the format in which positive numbers are displayed (for example: 1,234.56; 1 234,56; 1.234,56; or 1.234 56).
- **Negative number format.** Select the format in which negative numbers are displayed (for example: -123, 123-, or (123).
- **Automatically export table data upon reading out a logger.** Select this option if you want HOBOware to automatically create an export file each time you read out a logger (note that you must save and plot the data before the exported file will be created). When this setting is enabled, the default option is to export the data to a single file (as controlled by "Bypass export dialog and save as single file"). This will result in an exported file saved in the same directory as the datafile offloaded from the logger. Both files will also have the same prefix. If you do not want to save it to the default directory or use the default name, then select "Show export dialog" instead to select your own directory or name.
- **Include plot details in exported file.** When this setting is enabled, the information that appears to the left of the plot in the Details pane (series information, the type of logger, deployment information, etc.) will be included in the exported file along with the sensor data. This option only applies to text (.txt or .csv) file type exports, not Excel. It also requires that the file is saved and plotted before exporting. Therefore, it is not compatible with exports done via the Bulk Export Tool or HOBOnode Manager's Data Delivery and Plot/Export Wireless Data features. Finally, select a tab or semicolon for the "export table data column separator" when using this option. If you choose a comma separator, then details may span multiple cells.
- **Use export ordering rules.** Select this option to define the order that series are listed in the Export window by default. Select the measurement type from the drop-down list and then click Add to add it to the ordering rules list. In this example, we have set the order to temperature, RH, rain, wind speed, and then wind direction. This means the Export window will always show any temperature, RH, rain, wind speed, and then wind direction series first in the list, in that order, followed by any series that were not defined in the rules. (You can override this order as needed in the Export window by clicking the column header or dragging a row.) To delete an item from the ordering rules, click the measurement type and then click Remove. To change the order of items, drag them up or down.



Communications Preferences

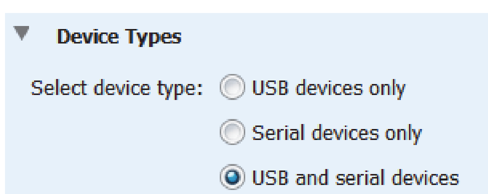
Use the Communications category within Preferences to set the default device type, serial port, device speed, and status window operation.

To change these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the Communications category on the left and then click the subcategory you wish to change.
3. Adjust any of the settings described below and then click OK.

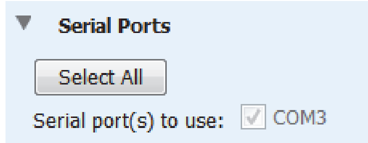
Device Types

This preference controls the type of devices HOBOware recognizes when connected to the computer: USB, serial, or both. If you only use USB loggers or serial loggers, select the corresponding preference. This will save time as HOBOware will only check the USB or serial port(s) for a connected device when selecting Launch, Readout, Status, or Stop from the Device menu. If you use both USB and serial loggers regularly, select "USB and serial devices." You can also quickly change this preference by using the pull-down menu next to the Select Device icon  on the toolbar.



Serial Ports

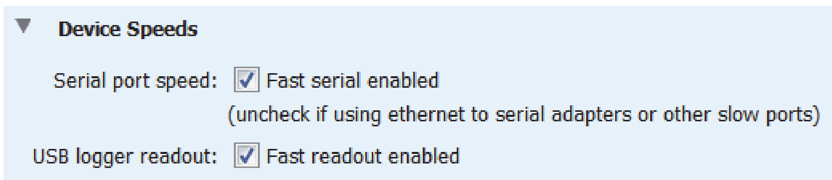
This preference controls which serial ports you want HOBOware to check for a connected device. Click Select All to check all serial ports displayed in this list or choose specific serial ports. Note that if you want to use only one port, you can have only one serial logger connected at a time. Alternatively, checking multiple serial ports can cause slow performance even when no loggers are connected.



Device Speeds

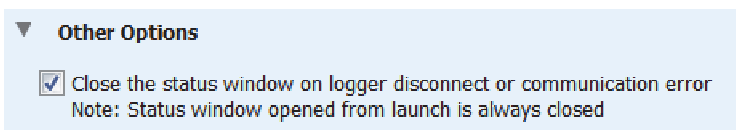
- **Serial port speed.** Select "Fast serial enabled" to read out a serial logger at a speed appropriate for most systems. Disable this option only if you are having communication problems with the logger, such as when the logger is connected via a slow serial-to-LAN bridge device. Communication between the computer and the logger is slower when this option is disabled.

- **USB logger readout.** Select "Fast readout enabled" to read out a USB logger quickly. Disable this option only if you are having communication problems with the logger. Communication between the computer and the logger is slower when this option is disabled.



Other Options

Select "Close the status window on logger disconnect or communication error" if you want the Status window to close automatically (on the next refresh) if it is open when you remove the interface cable, base station, or coupler from the logger, or if communication is interrupted for another reason. Deselect this option if you want to leave it open. Note that if the Status window was opened from the Launch Logger window, it will close automatically even if this option is not selected.



Plotting Preferences

Use the Plotting Preferences to control fonts, series lines, Y-axis, and several other plot elements.

To change these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the Plotting category on the left and then click the subcategory you wish to change.
3. Adjust any of the settings described below and then click OK.

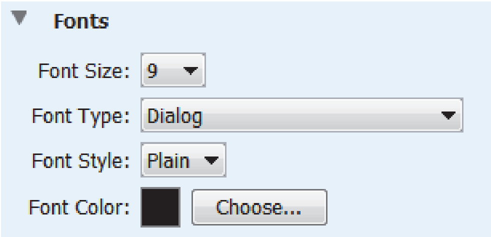
Notes:

- To apply certain preferences to a single series, double-click the series to open the Series Properties window.

- To apply changes to real-time plots in HOBOnode Manager, restart HOBOnode Manager or remove the plot for the sensor and then add it back (deselect the Plot checkbox for the sensor to remove it and then select the Plot checkbox again to add it back.

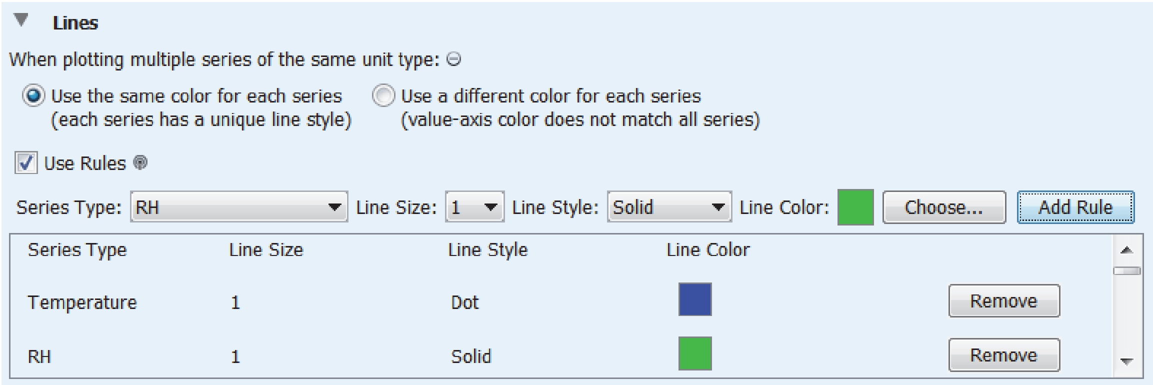
Fonts

Use the Fonts Preferences to control the font size, type, style, and color for most text on the graph (type, style, and color preferences available in HOBOware Pro only). Note that the plot title font will be two points larger than the selected font size.



Lines (HOBOware Pro only)

Use the lines preferences to define the appearance of lines in the plot for a specific series type. Rules added will appear in the panel at the bottom. Only one rule can be added per series type. To delete a rule, click the delete button on the row.

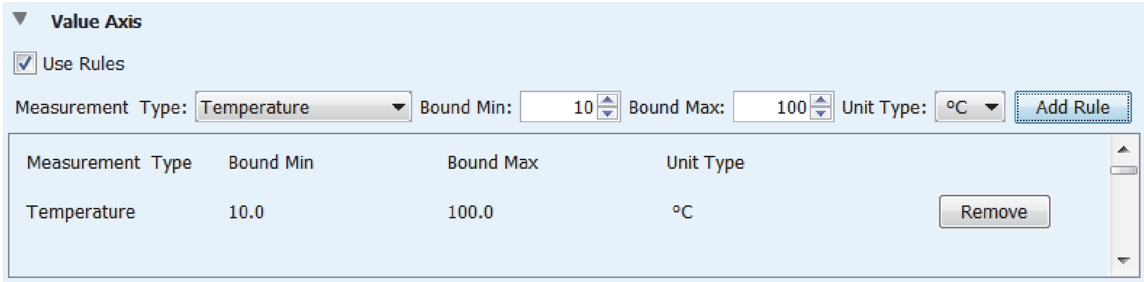


- **When plotting multiple rules of the same type.** If "Use the same color for each series" is selected, then multiple series of the same unit type (for example, multiple temperature series) are plotted with the same color, but with different line styles (solid, dashed, dotted, etc) to differentiate them. If "Use a different color for each series" is selected, then multiple series of the same unit type will be plotted in different colors. The series will still be attached to a single, common Y-axis, but only one series will match the axis color.

- **Use Rules.** Select this box to set up rules for series lines on the plots. Then select the series type for the rule you want to set up. Select the size and style of the series line. Click the Choose button to select a line color. Click the Add Rule button to create the rule. Line size, style, and color will be applied on series lines, the corresponding Y-axis (value axis), and its corresponding representation in the legend. This rule will be overridden by any changes you make in the Series or Axis Properties window. To add another rule, select a different Series Type, choose the settings, and then click Add Rule. To delete a rule, select it and click the Remove button.

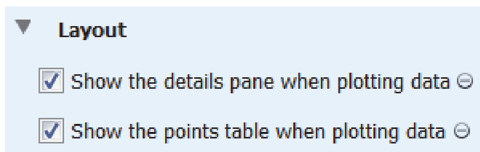
Value Axis (HOBOware Pro only)

Select the Use Rules box to set up rules about the minimum and maximum values used on the Y-axis (value axis) for a specific measurement type. Select the measurement type and then type in the minimum (Bound Min) and maximum (Bound Max) you want to use. Select the Unit Type and then click Add Rule to create the rule. This rule can be overridden by any changes you make in the Axis Properties window. To add another rule, select a different measurement type, choose the settings, and then click Add Rule. To delete a rule, select it and click the Remove button.



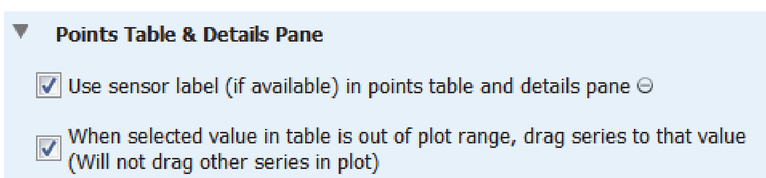
Layout

- **Show the details pane when plotting data.** Select this preference to automatically display the details pane with the plot.
- **Show the points table when plotting data.** Select this preference to automatically display the points table with the plot.



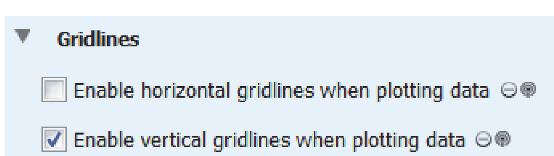
Points Table & Details Pane

- **Use sensor Label (if available) in points table and details pane.** Select this preference to display the sensor label (if available) as added in the Launch Logger window with corresponding column header in the points table and in the details pane. This is especially useful if there are multiple sensors of the same measurement type in the same file (for example, a HOBO Micro Station datafile with three temperature sensors).
- **When selected value in table is out of plot range, drag series to that value.** Normally, if the plot is zoomed in and you select a point in the Points table that is outside the zoom area, the plot will scroll so the marked point is in view, while retaining your zoom factor. Clear this box if you do not want to scroll to points outside of the current view.



Gridlines

- **Enable horizontal gridlines when plotting data.** By default, horizontal gridlines are not displayed when you open a plot. Enable this option if you always want a new plot to display gridlines for all value axes.
- **Enable vertical gridlines when plotting data.** By default, vertical gridlines are always displayed when you open a plot. Clear this checkbox if you never want a new plot to display gridlines for the time axis.



Plot Setup

- **Automatically select all data series for plotting.** By default, some series (such as Dew Point) are not selected for display in the Plot Setup window. Enable this option if you want every series to be selected automatically in the Plot Setup window.

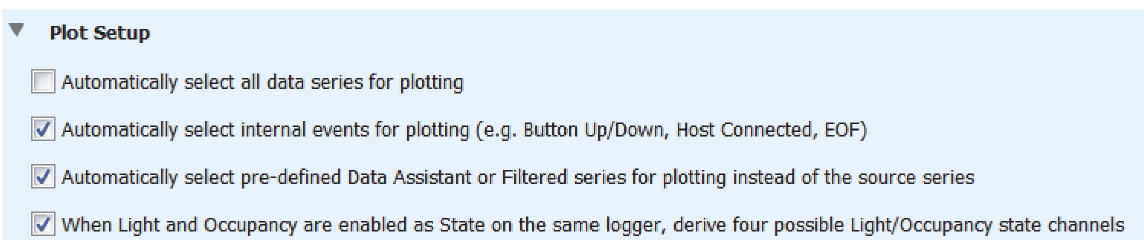
- **Automatically select internal events for plotting (e.g. Button Up/Down, Host Connected, EOF).** By default, all internal events are selected for display in the Plot Setup window. Disable this option if you do not want these events to be selected automatically in the Plot Setup window.

- **Automatically select pre-defined Data Assistants or Filtered series for plotting instead of the source series.** This option controls whether any series from Data Assistants and filters that you configured in the Launch Logger window are automatically selected in the Plot Setup window. Disable this option if you do not want these series selected automatically in the Plot Setup window.

- **When Light and Occupancy are enabled as State on the same logger, derive four possible Light/Occupancy state channels.** For UX90-005x and -006x series loggers, this option controls whether four additional data series are automatically calculated and available for plotting. These series are:

  - Lights on & occupied (Light On & Occ)
  - Lights on & unoccupied (Light On & Unocc)
  - Lights off & occupied (Light Off & Occ)
  - Lights off & unoccupied (Light Off & Unocc)

  Disable this option if you do not want these series to be generated when plotting data.

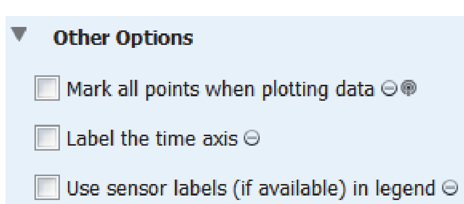


Other Options

- **Mark all points when plotting data.** This preference controls whether each data point is marked on the series. Point markers are not displayed by default (except for events and for a series with only one data point) to avoid cluttering the plot. Enable this option if you want all points to be marked on every series whenever you display a plot. Keep in mind, however, that marking all points on a large plot takes longer and consumes more system memory.

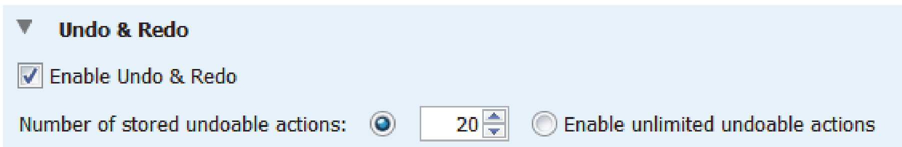
- **Label the time axis.** Select this option if you want the default label "Time" to be displayed with the time axis (X-axis).

- **Use sensor labels (if available) in legend.** Select this option if you want any available sensor labels as added in the Launch Logger window to appear in the legend with the series name.



Undo & Redo

This preference controls whether you can undo and redo the changes you make to plots. When the Undo & Redo preference is enabled, you can specify how many changes to plots will be stored within HOBOware. If you select "Number of stored undoable actions," then there will be a limit to the number of changes to the plots that you can undo. For example, if you choose to store 25 undoable actions, then you will be able to undo the last 25 changes that you made to the plots, but not the 26th. You can configure HOBOware to store from 1 to 50 undoable actions (changes to the plot) with this setting. If you select "Enable unlimited undoable actions," then there will be no limit to the number of changes to the plots that you can undo. Note that storing an unlimited number of actions can impact HOBOware performance on slower computers.

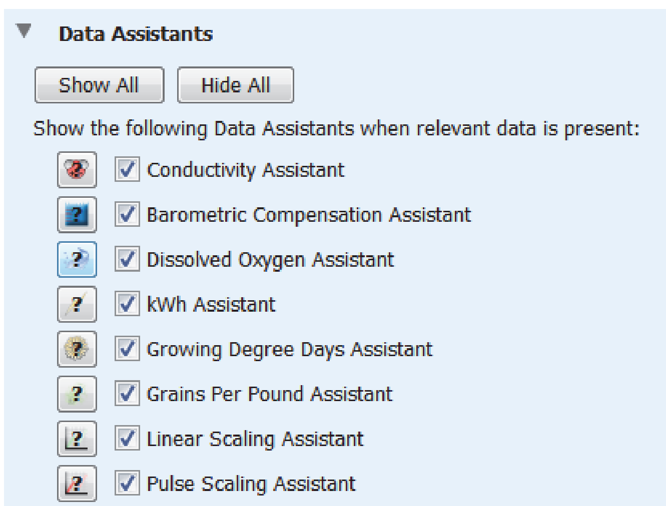


Data Assistant Preferences

Use the Data Assistant category within Preferences to control which Data Assistants are displayed in the Plot Setup window.

To change these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the Data Assistant category on the left and then click the Data Assistants subcategory.
3. Adjust any of the settings described below and then click OK.



When you read out a logger or open a datafile, all compatible Data Assistants are listed in the Plot Setup window by default. Deselect the checkboxes for any assistants that you do not want to display in the Plot Setup window. Or, click Show All to display all compatible assistants in the Plot Setup window or Hide All to display none of them.

Display Preferences

Use the Display category within Preferences to control the default units, date/time format, and series options displayed in plots.

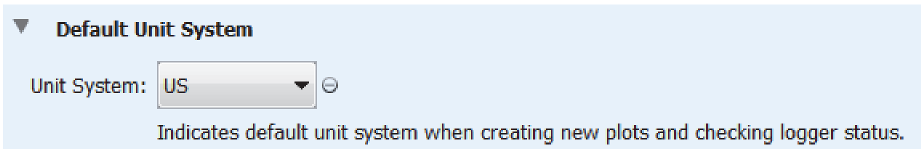
To change these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.

2. Select the Display category on the left and then click the subcategory you wish to change.
3. Adjust any of the settings described below and then click OK.

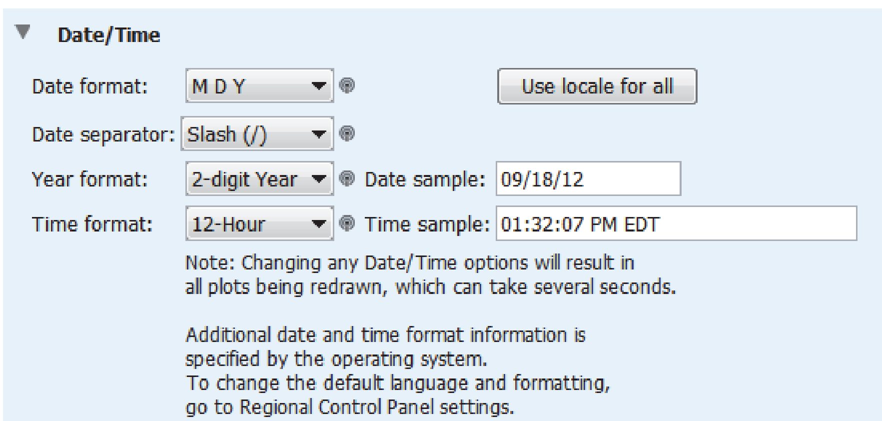
Default Units

This preference controls the units used throughout HOBOware: either US or SI (Metric). This will change the units shown on the axis, legend, points, and details the next time you display a plot. This will also change the current readings the next time you open the Status window.



Date/Time

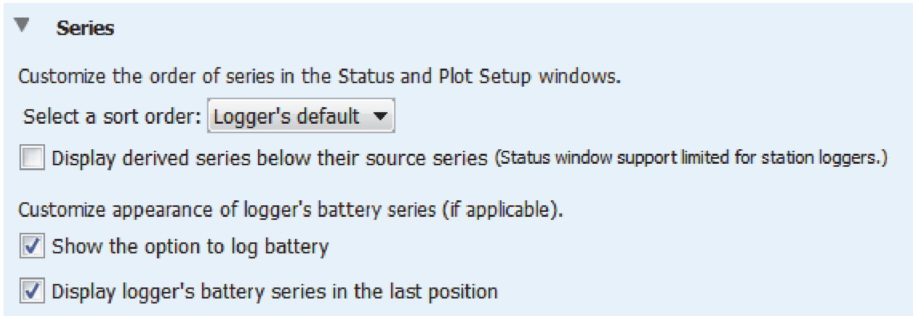
These settings control how the date and time appears in HOBOware. Changes you make are shown in the date and time sample. Any plots that may be open when you make changes to the date and time display will require the plots to be redrawn, which may take several seconds. As noted in the preferences, date and time formatting beyond what is specified in these settings are determined by the computer operating system. **Note:** When you export a file, the date and time are exported as determined by the Export Settings in Preferences (except for year format, which is only controlled by these Date/Time settings in the Display category. If you open the file in Excel, the dates and times may be automatically reformatted to Excel's default date and time format, which you may customize within Excel.



- **Date format.** This controls how the date is displayed: Month, Day, Year; Day, Month, Year; or Year, Month, Day.
- **Date separator.** This controls what character is displayed between the month, day, and year: a slash (/) or a dash (-).
- **Year format.** This controls whether the year is listed as two of four digits.
- **Time format.** This controls whether the time is shown in 12- or 24-hour format.
- **Use locale for all.** Click this button to use the default settings for the current locale as configured in the operating system.

Series

Use the Series preferences to customize how data series are sorted in the Status and Plot Setup windows and to set battery series options.



- **Select a sort order.** Choose one of the following four ways to sort the series displayed in the Status and Plot Setup windows:
    - Logger's default: Series are sorted the same way they were listed in the Launch Logger window.
    - Enabled: All series selected, or enabled, for logging are displayed at the top of the list.
    - Label: Series are sorted by their label name, if available. Labels can be sorted in ascending or descending order (alphabetically or numerically depending on the label entered).
    - Measurement: Series are sorted by measurement type alphabetically in ascending or descending order.
- **Display derived series below their source series.** A derived series is one that is calculated rather than recorded by a sensor. Some loggers have the capability to create datafiles that not only have logged sensor data, but also additional derived series automatically calculated in relevant units. One example is a logger with a temperature/RH sensor. The logger records a data series for temperature and another for humidity (two source series), which are used to calculate a dew point data series (the derived series). In addition, some loggers support filtering at launch time and using data assistants before or after launch, which also results in derived series. Select this option if you want any derived series to be displayed immediately following its source series in the Status and Plot Setup windows. By default, this option is disabled, which means all derived series are displayed at the bottom of the data series list. Note that status window support is limited for station loggers, such as the U30 Station.
- **Show the option to log battery.** This setting controls whether you have the option to enable or disable the battery series in the Launch Logger window when applicable. You can configure some loggers to record the battery voltage at every logging interval. When this option is selected, you can choose whether to record the battery voltage at launch time. If this setting is not selected, then you cannot record the battery voltage and it will not be shown in the Launch Logger window. This setting is enabled by default.
- **Display logger's battery series in the last position.** This setting controls whether the optional battery series is displayed at the bottom of the data series list in the Launch Logger, Status, and Plot Setup windows regardless of any other series settings. If this setting is not enabled, the position of the battery series in the data series list will vary based on other preferences. This setting is enabled by default.

Warnings Preferences

Use the Warnings Preferences to disable warning pop-ups that you do not want to appear. Before you do so, however, keep in mind that the warnings are intended to help prevent mistakes and inadvertent data loss. Review each warning carefully before disabling it. To re-enable a warning, re-select the check box.

To disable all of the warnings in a group, click the **Select None** button for that group.

To enable all of the warnings in a group, click the **Select All** button for that group.

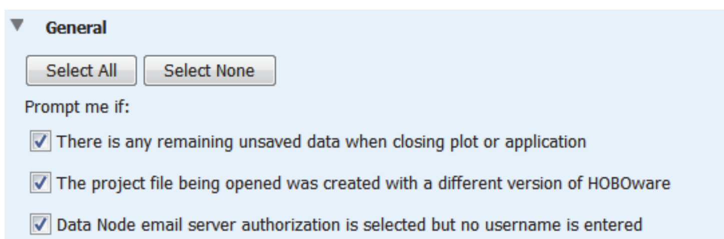
You access the Warnings Preferences by going to File > Preferences > Warnings.

To change these settings:

1. From the File menu on Windows or the HOBOware menu on Macintosh, select Preferences.
2. Select the Warnings category on the left and then click the subcategory you wish to change.
3. Adjust any of the settings described below. To disable all the warnings in a group, click the Select None button for that group. To enable all the warnings in a group, click the Select All button for that group. Click OK in the Preferences window to save changes.

General

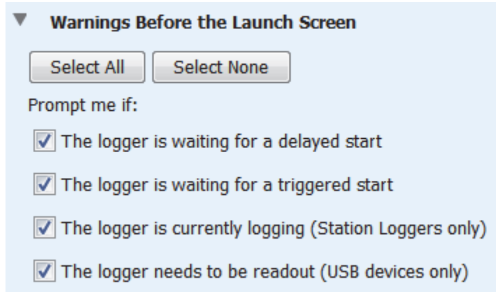
- **There is any remaining unsaved data when closing a plot or application.** This warning reminds you when you made changes to a plot, but haven't saved the changes to a project file.
- **The project file being opened was created with a different version of HOBOware.** This message warns you if you are opening a project file that was saved in different version of HOBOware than you are currently using. In some instances, there may be differences in software versions that could affect the project file.
- **Data Node email server authorization is selected but no username is entered.** When setting up HOBOnode Manager alarm preferences, this message warns you if there is no username entered when you selected the option "This server requires authentication."



Warnings Before the Launch Screen

These preferences control warnings that appear when the logger is connected to the computer and you select Launch from the Device menu or the Launch icon from the toolbar. If enabled, these warnings will display before the Launch Logger window is opened.

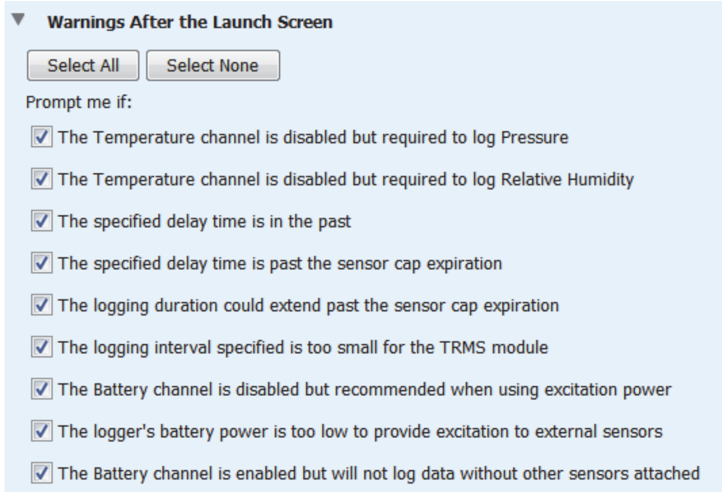
- **The logger is waiting for a delayed start.** This warning indicates that the logger has already been configured to start logging on a specific date and time; logging has not begun.
- **The logger is waiting for a triggered start.** This warning indicates that the logger has already been configured to launch with a push button or triggered start, but logging has not begun.
- **The logger is currently logging (Station Loggers only).** This warning indicates the a station-type logger (U30, HOBO Weather Station, HOBO Micro Station) is currently recording data.
- **The logger needs to be readout (USB devices only).** This warning indicates the data on the USB logger (U-Series) has not been offloaded, or read out, yet.



Warning After the Launch Screen

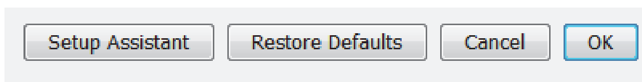
These preferences control warnings that appear after you click the Start button in the Launch Logger window.

- **The Temperature channel is disabled but required to log Pressure.** For some loggers that record barometric pressure data, the temperature must also be logged. This message warns you if you selected the pressure sensor or channel in the Launch Logger window, but not temperature.
- **The Temperature channel is disabled but required to log Relative Humidity.** For some loggers that record relative humidity data, the temperature must also be logged. This message warns you if you selected the relative humidity sensor or channel in the Launch Logger window, but not temperature.
- **The specified delay time is in the past.** This warning indicates that you have selected a start date or time for logging that is in the past instead of the future.
- **The specified delay time is past the sensor cap expiration.** This warning indicates that the date or time you selected for the launch to begin is past the U26 Dissolved Oxygen logger sensor cap expiration date.
- **The logging duration could extend past the sensor cap expiration.** This warning indicates that projected logging duration (the amount of time it takes for the logger's memory to fill) lasts beyond the U26 Dissolved Oxygen logger sensor cap expiration date.
- **The logging interval specified is too small for the TRMS module.** This warning indicates that the logging interval (how often the logger records data) is not supported by the TRMS module in a U30 station logger.
- **The Battery channel is disabled but recommended when using excitation power.** This warning indicates that the battery channel in the Launch Logger window has not been selected on a U30 or FlexSmart logger configured to use excitation power.
- **The logger's battery power is too low to provide excitation to external sensors.** This warning indicates the battery is too low for a U30 or FlexSmart logger that has been configured to power excitation to external sensors.
- **The Battery channel is enabled but will not log data without other sensors attached.** This warning indicates that you have only selected the battery channel in the Logger Launch window and no other sensors.



Restoring Default Preferences

To return all preferences to their original settings in both the Preferences and custom-defined Launch Logger window settings (State Description, % or Time, Logging Interval), open the Preferences window (click the File menu in Windows or the HOBOware menu on Macintosh and select Preferences). Click the Restore Defaults button.



A message appears asking if you are sure you want to restore all preferences to their default values. Click Yes to restore the default preferences. In addition to the options configured in the Preferences window, the following settings are also affected:

- **Data File Folder Locations.** When you restore the preference defaults, the default folder locations for datafiles, text files, and project files is reset to:
  - C:\Documents and Settings\<user>\My Documents\HOBOware (for Windows XP)
  - C:\Users\<user>\Documents\HOBOware (for Windows 7, Windows 8, or Windows 10)
  - Users/<user>/Library/Application Support/HOBOware (for Macintosh OS X)
- **FlexSmart modules or Analog Sensor Ports channel names and units.** Any custom-defined channel names and units for FlexSmart modules or Analog Sensor Ports are removed from the pull-down menus in the Configure Channel window. However, this will not affect customized channel names and units that you saved in configuration files (.hcfg).
- **HOBOware software updates.** The date and time of the most recent check for HOBOware software updates will not be retained. A message will appear next time you reopen HOBOware asking if you want to check for updates.
- **Custom-defined Launch Logger window menus.** Any custom-defined Launch Logger window settings, such as State Description, % or Time, Logging Interval, will be cleared.

Menus

The following menus are available in HOBOware:

- HOBOware (on Macintosh)
- File
- Device
- Edit
- View
- Tools
- Window
- Help

The HOBOware Menu

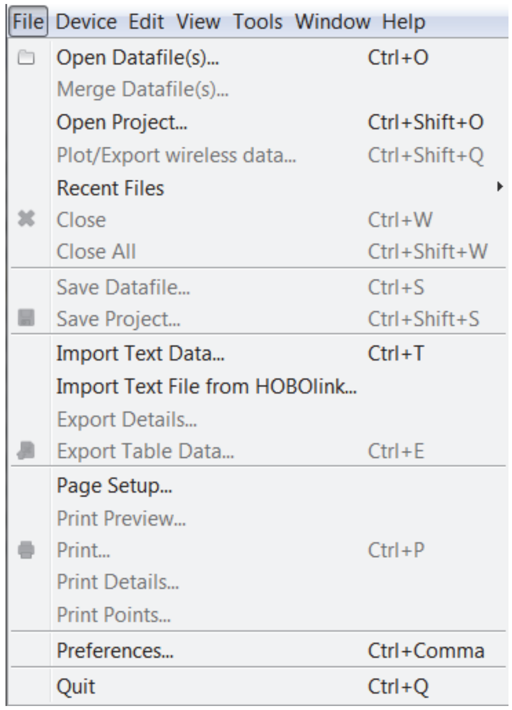
The HOBOware menu is available on Macintosh only. Some of the menu options available from the File menu in Windows are displayed here instead on Macintosh.

The HOBOware menu options are:

- **About HOBOware.** Select this option to open a compatible datafile. See Opening Files for more information.
- **Preferences.** Select this option to open the Preferences window where you can change the default settings in HOBOware. See Setting Preferences for more information.
- **Services.** This is a Macintosh operating system menu option.
- **Hide HOBOware.** This option hides HOBOware from view.
- **Hide Others.** This option hides all currently open programs except for HOBOware from view.
- **Show All.** This option displays all currently open programs.
- **Quit.** Select this option to close HOBOware.

The File Menu

From the File Menu, you can open and close datafiles and projects, import and export data, and print plot elements.



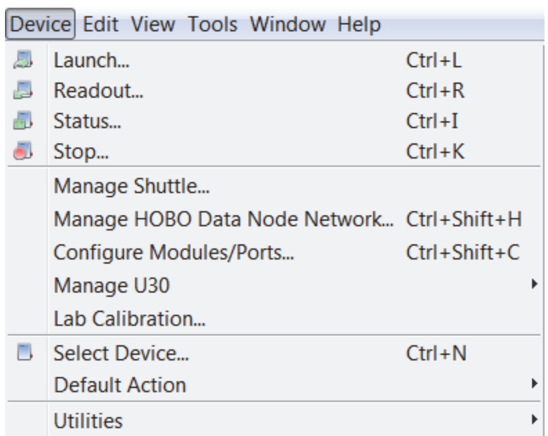
The File menu options are:

- **Open Datafile(s).** Select this option to open a compatible datafile. See Opening Files for more information.
- **Merge Datafile(s).** Select this option to add a datafile to the end of another datafile. See Merging Datafiles for more information.
- **Open Project.** Select this option to open a HOBOware project. See Opening Files for more information.
- **Plot/Export Wireless Data.** This applies to a ZW series wireless network and is only available in HOBOware Pro. See Plotting or Exporting Wireless Data for more information.
- **Recent Files.** Select this option to quickly access the last 10 files you opened.
- **Close.** Select this option to close the active file or project.
- **Close All.** Select this option to close all open files and projects.
- **Save Datafile.** Select this option to save the data of the active plot to a datafile (only available as an option if you selected to not save the datafile when reading out a logger).
- **Save Project.** Select this option to save the active project.
- **Import Text Data.** Select this option to import and graph non-HOBOware data in certain text files (available in HOBOware Pro only). See Importing Text Files for more information.
- **Import Text File from HOBOlink.** Select this option to open a text file generated by HOBOlink for a HOBO U30 Station.
- **Export Details.** Select this option to export the information in the Details Pane into a text file that can be opened in any text editor or imported into many other types of programs (word processors, spreadsheets, etc.). See Exporting Details for more information.

- **Export Table Data.** Select this option to export the points shown in the Points table to a text file (.csv or .txt) or Microsoft Excel (.xls) file. See Exporting Table Data for more information.
- **Page Setup.** Select this option to set up the paper size, margins, and orientation for printing a plot.
- **Print Preview.** Select this option to preview the page for printing a plot.
- **Print.** Select this option to print a prot.
- **Print Details.** Select this option to print the Details Pane.
- **Print Points.** Select this option to print the Points Table.
- **Preferences.** Select this option to open the Preferences window where you can change the default settings in HOBOware. See Setting Preferences for more information. Note that Preferences is available from the HOBOware menu on Macintosh.
- **Quit.** Select this option to close HOBOware. Note that this is available from the HOBOware menu on Macintosh.

The Device Menu

Use the Device menu to launch, read out, and stop loggers as well as access HOBOnode Manager and work with other features for specific devices.



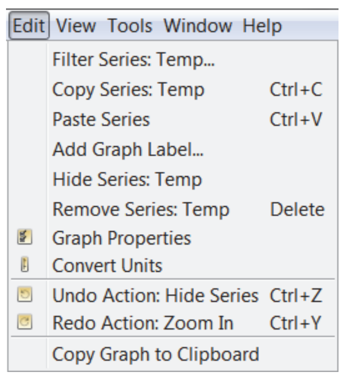
The Device menu options are:

- **Launch.** Select this option to open the Launch Logger window where you can set launch settings and start the logger.
- **Readout.** Select this option to offload, or read out, data from the logger to your computer, allowing you to save the data in a datafile and view the plot in HOBOware.
- **Status.** Select this option to view the current status of the logger, including current readings (for some sensors), remaining battery, and logger memory.
- **Stop.** Select this option to stop a device.
- **Manage Shuttle.** Select this option to manage a HOBO shuttle (available for HOBOware Pro only). See Working with a Shuttle for more information.
- **Manage HOBO Data Node Network.** Select this option to open the HOBOnode Manager where you can manage a ZW series wireless network (available for HOBOware Pro only).
- **Configure Modules/Ports.** Select this option to configure analog sensor ports on the HOBO U30 station logger or FlexSmart modules.

- **Manage U30.** Select this option to access features specific to the HOBO U30 Station. From this menu option, select Control U30 Relay to configure the default state of a relay or to activate or deactivate the relay for testing. See Controlling the Relay on the HOBO U30 Station for more information. Or, select Configure U30 Alarms to set up alarms on the HOBO U30 Station.
- **Lab Calibration.** Use this option to open the Lab Calibration tool used with the HOBO U26 Dissolved Oxygen Logger.
- **Select Device.** Use this option to select a device currently connected to the computer.
- **Default Action.** Select this option to set up HOBOware to perform the same action (Launch, Readout, or get Status) every time a logger is connected (available for HOBOware Pro only). See Repeating an Action on Multiple U-Series Devices for more information.
- **Utilities.** Use the Utilities submenus to select one of the three Force Offload options only if you are having problems reading out your device or as directed from Onset Technical Support.

The Edit Menu

Use the Edit menu to modify the plot, including filtering series, removing series, setting properties, and converting units.



The Edit menu options are:

- **Filter Series.** Select this option to create a new series based on statistical analysis of an existing series over specified periods of time. See Filtering a Series for more information.
- **Copy Series.** Select this option to copy a series and then paste it into another plot. See Copying a Series to another Plot for more information.
- **Paste Series.** Select this option to paste a series into another plot. See Copying a Series to another Plot for more information.
- **Add Graph Label.** Select this option to access the Graph Label Properties window to add labels to a plot that identify specific points or call attention to a region of the graph. See Adding Labels to a Graph for more information.
- **Hide/Show Series and Show All Hidden Series.** Select Hide to hide a series from the plot and the Points table (it will be grayed out in the Details pane). To show an individual series that was previously hidden, select a grayed out series in the Details pane and then select Show Series from this menu. To show all series that were previously hidden, select Show All Hidden Series.
- **Remove Series.** Select this option to remove series from a plot after you have selected it in the graph or the Details pane. If you remove a series, it can only be recovered by reopening the original datafile or a saved project file that contains the series.

- **Graph Properties.** Select this option to access the Series Properties window. See Setting Series Properties for more information.

- **Convert Units.** Select this option to access the Convert Plot window, which allows you to convert some or all of the series on the currently focused plot to other units (for example, from degrees Fahrenheit to degrees Celsius). Note that changing the units will result in the entire plot being redrawn. See Converting Units for more information.

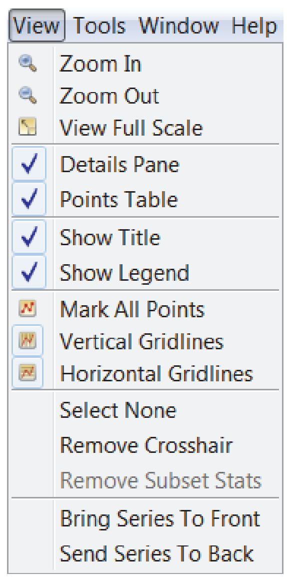
- **Undo Action.** Select this option to undo the last change made to the current plot. The most recent change is listed after the Undo Action menu choice. In this example, the most recent change to the plot was to "Zoom Out." See Undo and Redoing Plot Changes for more information.

- **Redo Action.** Select this option to redo the last change that was previously undone. See Undo and Redoing Plot Changes for more information.

- **Copy Graph to Clipboard.** Select this option to copy the graph to the clipboard to paste it into another application.

The View Menu

Use the View menu to change the appearance of the plot, including zooming, showing or hiding components, marking points, and setting gridlines.



The View menu options are:

- **Zoom In.** Select this option to zoom in on the plot.

- **Zoom Out.** Select this option to zoom out on the plot.

- **View Full Scale.** Select this option to view the plot in full scale.

- **Details Pane.** Select this option to show or hide the Details Pane.

- **Points Table.** Select this option to show or hide the Points Table.

- **Show Title.** Select this option to show or hide the title of the plot.

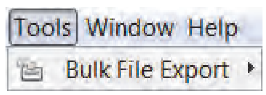
- **Show Legend.** Select this option to show or hide the plot legend.

- **Mark All Points.** Select this option to mark all points on the plot.

- **Vertical Gridlines.** Select this option to show or hide vertical gridlines on the plot.
- **Horizontal Gridlines.** Select this option to show or hide horizontal gridlines on the plot.
- **Select None.** Select this option to deselect all elements in the plot.
- **Remove Crosshair.** Select this option to remove crosshairs from the graph.
- **Remove Subset Stats.** Select this option to remove subset statistics from the plot.
- **Bring Series To Front.** Select this option to bring a series to the front on the plot on top of all other series.
- **Send Series To Back.** Select this option to send a series to the back of the plot behind all other series.

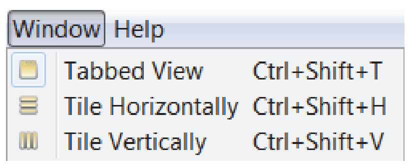
The Tools Menu

Use the Tools menu to access the Bulk File Export tool, which allows you to export numerous datafiles at one time (HOBOware Pro only). See the Bulk Export Tool for more information.



The Window Menu

Use the Window menu to organize several plots.



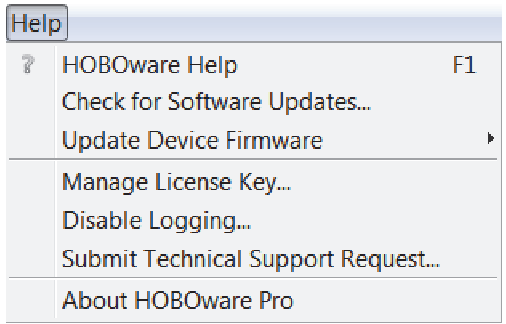
The Window menu options are:

- **Tabbed View.** With this option, plots are layered as tabs so you can see the file name of each open plot (or "Untitled*" for an unsaved datafile). You can also get to this view by clicking the Tabs icon in the lower left of the window.
- **Tile Horizontally.** Select this option to arrange up to five plots horizontally. If six or more plots are open, they will be tiled as a grid. You can also get to this view by clicking the Horizontal Tile icon in the lower left of the window.
- **Tile Vertically.** Select this option to arrange up to five plots vertically. If six or more plots are open, they will be tiled as a grid. You can also get to this view by clicking the Vertical Tile icon in the lower left of the window.

Tip: You can open the same datafile multiple times to create different views of the graph, then use the Tile commands on the Window menu (or resize and move the windows manually) to see all of them at once. This is helpful if you want to zoom in on several different areas and view them side-by-side, see the detail of a small area while the full graph is still in view, or view each series in a different window.

The Help Menu

Use the Help menu to get more information about HOBOware, upgrade the software and certain devices, and request help from Onset Technical Support.

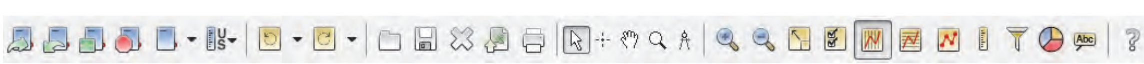


The Help menu options are:

- **HOBOware Help.** Select this option to open the help system, displaying the full table of contents.
- **Check for Software Updates.** Select this option to check if there are any HOBOware updates available on the Onset website. You can also set the general startup settings in Preferences to automatically check for software updates on a schedule that you select.
- **Update Device Firmware.** Select this option to check if there are firmware updates available for certain devices. This option is only enabled when either a HOBO U-Shuttle or HOBO UX/MX series logger is connected to the computer. Select the appropriate submenu for your device, either "Update U-DT-1/U-DT-2 Firmware" for a HOBO U-Shuttle or "Update UX/MX Series Logger Firmware" for a logger. You likely will only need to do this as directed by Onset Technical Support. Note that firmware updates for HOBO ZW series receivers and data nodes are completed within HOBOnode Manager.
- **Manage License Key.** Select this option if you need to enter a new license key. This is only necessary if you are upgrading from HOBOware to HOBOware Pro.
- **Enable/Disable Logging.** Select this option to turn on or off logging within HOBOware. When logging is enabled, a series of text files will be generated and saved every time you use HOBOware. It is recommended that you only enable logging when requested to do so by Onset Technical Support, who may need additional files to troubleshoot any technical problems you may be having with the software.
- **Submit Technical Support Request.** Select this option if you are having a problem with HOBOware and would like to request help from Onset Technical Support. Fill in all the requested information in the form, including your name, email address, logger/device model name and serial number, and a detailed description of the problem you are encountering.
- **About HOBOware.** Select this option to see which version of HOBOware you are using in Windows. This option is available from the HOBOware menu on Macintosh.

The Toolbar

The toolbar, located at the top of the main HOBOware window, allows point-and-click access to the most frequently used functions. Pause the pointer over each icon on the toolbar for a description of each tool.



Launch -  - Opens the Launch window.

Readout -  - Opens the Readout window.

Status -  - Opens the Status window, which displays the logger's state and current readings.

Stop -  -Stops a logging logger.

Select Device - - Opens the select Device window, which displays available devices. The accompanying pull-down menu allows you to specify whether you want HOBOware to look for USB devices, serial devices, or both.

Set Default Units - - Change the default unit type between US and SI. Any changes you make will take effect with the next plotted file.

Undo Action - - Undoes the most recent change made to the plot.

Redo Action - - Redoes the most recent change that was undone to the plot.

Open - - Launches the Open window, from which you can open HOBOware files.

Save - - Opens the Save window, from which you can save the plot as a project (.hproj) file.

Close - - Closes the currently focused plot.

Export - - Opens the Export Options window, from which you can configure settings for exporting a text file of the data (in .csv or .txt format) for use in spreadsheet and other applications.

Print - - Prints the graph as it appears on your screen.

Arrow - - Launches the Arrow Tool, which you can use to point to and select items on the graph to edit their properties.

Crosshair - - Launches the Crosshair Tool, which you can use to display values for points on the graph and cross-references them to cells in the Points pane.

Hand Drag - - Launches the Hand Drag Tool, which you can use to scroll an axis or the entire graph.

Zoom - -Launches the Zoom Tool, which you can use to adjust the scaling of an axis or the entire graph.

Subset Statistics - -(HOBOware Pro Only) Launches the Subset Statistics Tool, which you can use to view statistics for a particular time span.

Zoom In - - Launches the Zoom In Tool, which allows you to zoom in on a smaller area of the graph.

Zoom Out - - Launches the Zoom Out Tool, which allows you to zoom out to a larger area of the graph.

Show Graph at Full Scale - - Resets the scale of a graph to accommodate all of the displayed data.

Graph Properties - - Opens the properties window for the element currently selected (such as series, legend, axis).

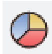
Vertical Gridlines - - Toggles vertical gridlines on or off.

Horizontal Gridlines - -Toggles horizontal gridlines on or off.

Mark Points - -Toggles point markers on or off.

Convert Units - -Opens the Convert Units window, which allows you to convert some or all of the series on the currently focused plot to other units (for example, from degrees Fahrenheit to degrees Celsius).

Filter Series - -You can create a new series based on statistical analysis of an existing series over specified periods of time.

Pie Chart -  -Opens the Pie Chart window in which you can view, print, and save a pie chart for plotted state series.

Add Graph Label -  -Opens the Graph Labels Properties dialog, which allows you to add a label to the plot or to a specific series, and change the appearance of that label.

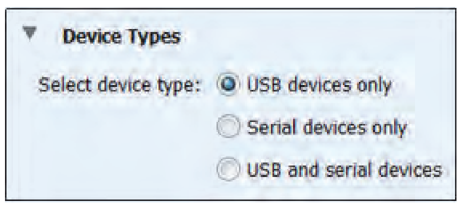
Help -  - Opens the Help.

Tips for Working with Multiple Loggers

HOBOware Pro has several built-in features that allow you to bypass some of the repetitive work of launching and reading out multiple loggers. These features not only will save you time, but also will help ensure your loggers are launched with consistent settings. Follow these tips if you plan to launch or read out many numerous loggers of the same type with identical settings.

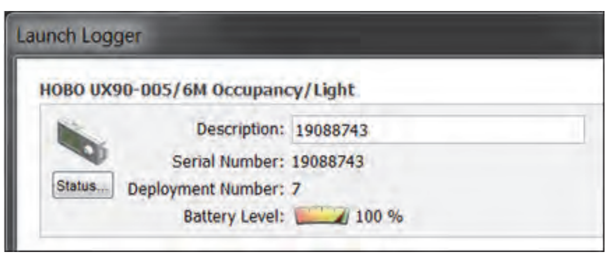
General Settings

- **Change the Device Types preference to one device type.** Depending on the selections you made when installing HOBOware, it may be configured to search for both serial and USB devices. If you are only using USB devices you can bypass the Select Device Type and save time. To bypass the Select Device Type window, select Preferences from the File menu. Under the Communications preferences, select Device Types. Choose either "USB devices only" or "Serial devices only."



Launching Multiple Loggers

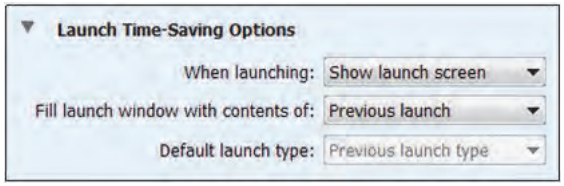
- **Check the Description name.** Use a logger serial number or your own unique identifier in the Description field in the Launch Logger window as shown in the example below. The name of the launch description is important because it is also used as the default file name when you read out the logger. Using unique names here will eliminate the need to individually name files during readout.



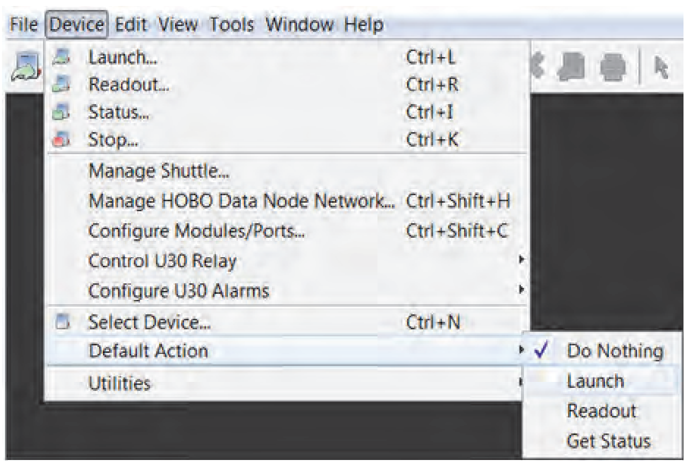
- **If you plan on launching multiple loggers of the same type with the same settings (i.e. start time, logging interval, etc.), set up and start one logger first.** To do this, open the Launch Logger window for one logger. Enter your settings for the launch. Double-check that they are correct and then start the launch. Setting and starting this one logger will create a model for all the other loggers of the same type to follow. The key to success is making sure the settings are exactly as you want so be sure to double-check or even triple-check them. You want to be certain the first logger is right!

- **Set the Launch Time-Saving preferences to use the previous logger's launch settings.** From the File menu, select Preferences. Select General and then click Launch Time-Saving Options. Under

"When launching," select "Show launch screen" and under "Launch with contents of," select "Previous launch" to use the same launch settings from the last logger that was launched (same logger model only).

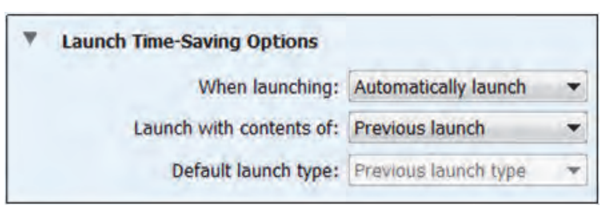


- **Change the Default Action option (USB devices only).** Under the Device menu in HOBOware, change the Default Action from "Do Nothing" to "Launch." If you also set the launch time-saving preferences to "Automatically launch," then this allows you to launch numerous U-Series loggers in a row simply by plugging and unplugging individual loggers. If you set the launch time-saving preferences to "Show launch screen," this will still save you the step of manually selecting Launch from the toolbar or the Device menu for each logger. Change this back to "Do Nothing" when you're done. Note: If this is the first time you have used the logger on the computer, you may have to plug the logger in, unplug it, and then plug it back in.



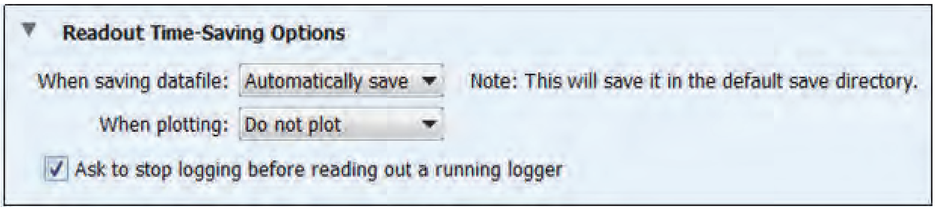
- **Test that your changes have taken effect.** Connect a different logger of the same type to the computer. The Launch Logger window for that logger should immediately open the settings should match what you set up in the first logger. Press Enter or click the Start button in the Launch Logger window and the logger will start (note that the wording on the Start button may vary depending on when logging is scheduled to begin). You can do this repeatedly for loggers of the same type.

- **Optional: Set the preferences to skip the launch window.** If you are comfortable with the previous steps, you can also set up HOBOware to bypass the Launch Logger window entirely. From the File menu, select Preferences. Select General and then click Time-Saving Options. Under "When launching," select "Automatically Launch" to skip the launch window. Note: If you need to change the launch description for each logger, then select "Show launch screen" instead.

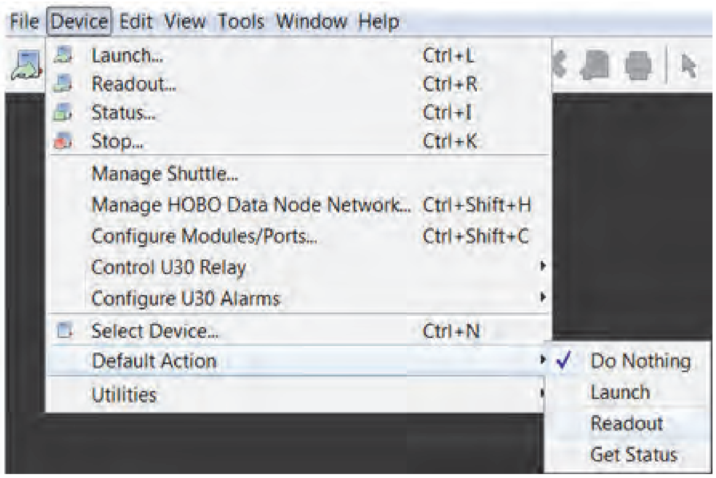


Reading Out Multiple Loggers

- **Set the Readout Time-Saving preferences.** From the File menu, select Preferences. Select General and then click Readout Time-Saving Options. Under "When Saving datafile," select "Automatically save" instead of "Show save dialog." Under "When plotting," select "Do not plot." This bypasses the save dialog that normally appears during readout and automatically saves the data file to the default directory without plotting the data. Note: If you also want the logger to continue logging after readout, uncheck the "Ask to stop logging before reading out a running logger" checkbox. If you need to stop the logger, keep that option checked. You'll then see a prompt to stop the logger during each readout.



- **Change the Default Action option.** Under the Device menu in HOBOware, change the Default Action to "Readout." This feature will automatically initialize the Readout sequence every time you connect a logger to the computer (with HOBOware open). This will still save you the step of manually selecting Readout from the toolbar or the Device menu for each logger.



Setting the Language/Format on Your Computer

The HOBOware user interface has been translated from English into several languages, which are supported by specific formats. These languages and formats are: Chinese (China), French (France), German (Germany), Japanese (Japan), Portuguese (Portugal), and Spanish (Spain). To change the language displayed in the HOBOware user interface, you must change the language/format settings on your computer as described below.

Notes:

- The supported languages only work with the specific format or country listed above. For example, Portuguese is supported in the Portugal format only and not with Brazil.
- The HOBOware Help and all related documentation are available in English only.
- **If you are using HOBOnode Manager:** The language in use at the time the original HOBO data node network database was created is the only language that can be used for that database. You cannot switch to another language. If you need to change the locale on the computer that contains your HOBO data node network database, you must first back up and then move or rename the database before changing the locale on the computer. Then, form a new network to create a database that operates in the new locale.

On Windows 10:

1. Close HOBOware.
2. From the Start menu, select Settings> Time & Language.
3. Select Region & Language.
4. Select your country or region.
5. Reopen HOBOware.

On Windows 7 and Windows 8:

1. Close HOBOware.
2. Open the Control Panel and select "Region and Language."
3. Under the Formats tab, select the desired language/format and click OK to save the changes.
4. Reopen HOBOware.

On Macintosh OS X:

1. Close HOBOware.
2. Open System Preferences and access the "Language & Text" Preferences.
3. Under the Language tab, drag the desired language to the top of the list. If the desired language does not appear in the list, click the "Edit List…" button to add it.
4. Under the Formats tab, ensure the correct Region is selected in the drop-down menu. Example: For Spanish (Spain), Spanish must be first in the Language list, and Spain must be selected under the Region drop-down menu.
5. Reopen HOBOware.

Alarm & Readout Tool

IMPORTANT: The Alarm & Readout Tool is not supported with HOBOware 3.5 or later. For questions or assistance, refer to www.onsetcomp.com/support.

HOBOware® Pro Barometric Compensation Assistant User's Guide

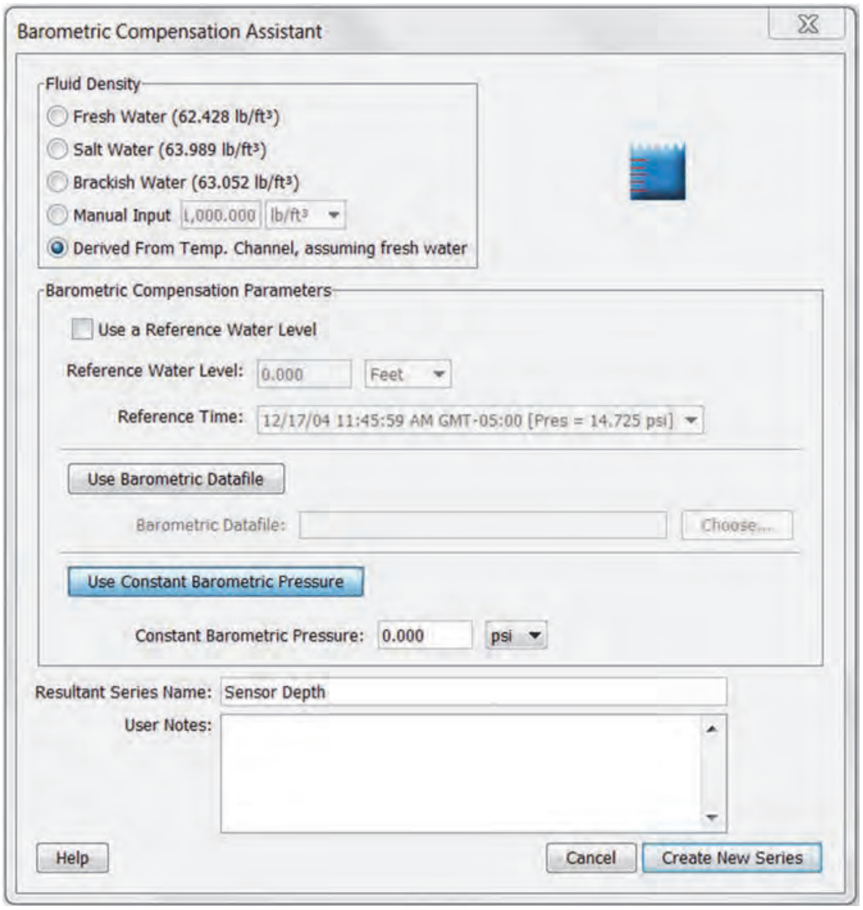
HOBO Data Loggers

The Barometric Compensation Assistant uses water pressure data from a HOBO U20 or U20L Water Level Logger and additional information from you to compensate for barometric pressure and create a water level or sensor depth series.

After you use the assistant and display the plot, you may apply filters to the new series.

To create a water level or sensor depth series:

1. Read out a logger or open a datafile that contains water pressure data from a U20 or U20L Water Level Logger.
2. From the Plot Setup window, select Barometric Compensation Assistant and click Process.
3. Provide Fluid Density information by choosing a water type (fresh, salt, or brackish), entering a specific constant value, or using the temperature series (if logged) to use temperature-compensated density assuming fresh water.



4. To enter a reference water level, check the Use a Reference Water Level box, enter the water level, and indicate whether it is in feet or meters.
   - Enter the water level as a positive number if it is measured upward from a reference point below the water's surface, such as the water's height above sea level.
   - Enter the water level as a negative number if it is measured downward from a reference point above the water's surface, such as a well cap.

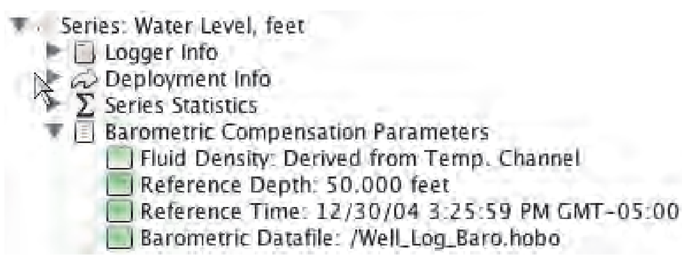
   Then, from the drop-down, select the logged time and value that is closest to the time when you measured the water level.

   - When selecting a logged value and time to link to the reference level, make sure the logger readings have stabilized. When a logger is first deployed in water, it takes some time for its temperature to reach equilibrium. You will get the best accuracy if you link your reference reading to a stabilized logger reading.

- When using a reference water level, the resulting series data will contain water level values relative to this reference level. If you do not use a reference water level, the resulting series data will contain values for absolute sensor depth.

5. You can either use a barometric data file from another source, or enter a fixed barometric pressure. For the most accurate water level results, use a reference water level and a barometric data file. The barometric data can come from another HOBO U20 or U20L Water Level Logger in air; a HOBO Weather Station, HOBO Micro Station, HOBO U30, or HOBO Energy Logger; or a text file from another source.
   - To use another file to provide barometric information, click the Use Barometric Datafile button and enter (or browse to) the name of a .hobo, .hsec, .dtf, .dsec, .csv, or .txt file that contains a barometric pressure series from an overlapping time period. You will have the option to display this series on the plot. **Important:** To use a .txt file, refer to the *HOBOware Pro User’s Guide* for information on how this file must be formatted.
   - To use a constant pressure value, click the Use Constant Barometric Pressure button. Enter the constant value and indicate whether it is in psi or kPa. (You cannot use a constant pressure value in combination with a reference water level.)
6. Keep the default Resultant Series Name, or enter a new one. You may also enter User Notes concerning the series you are creating.

   Note: Your settings are retained, so you do not need to re-select your density and barometric file each time you use the Barometric Compensation Assistant as long as they still apply to the new water level data set.
7. Click Create New Series. The new series is listed and selected in the Plot Setup window. You can click Process on the Plot Setup window again to create another series using different barometric compensation parameters.
8. Click the Plot button. The scaled series will appear in the plot and the settings for the scaled series are listed in the Details pane:

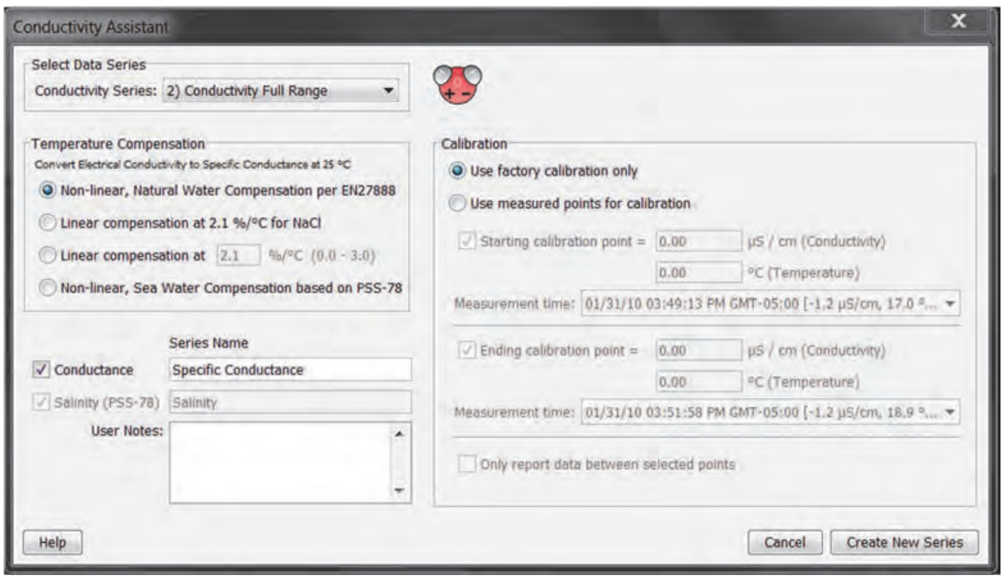


After the plot is displayed, you may apply minimum, maximum, and average filters to the new water level or sensor depth series as you would for any sensor data series in HOBOware Pro.

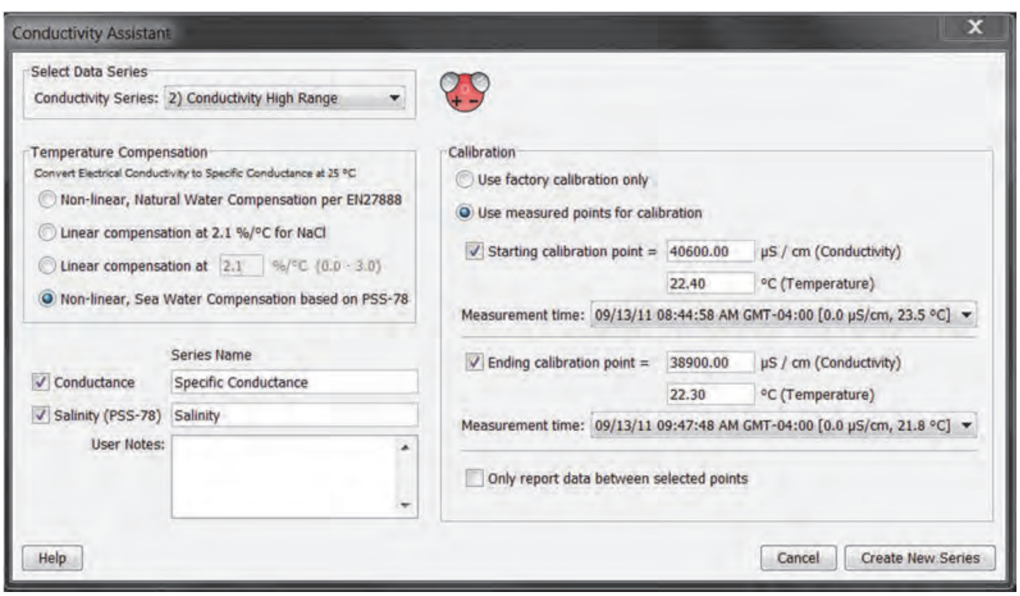
HOBOware® Pro Conductivity Assistant User's Guide

The Conductivity Assistant converts raw conductivity data from a U24 logger to Specific Conductance and/or Salinity. You can also use it to enter field calibration measurements recorded at the beginning and end of a deployment for calibration and to compensate for drift and sensor fouling effects.

1. Read out a U24 series logger or open a datafile from a U24 logger.
2. From the Plot Setup window, select the Conductivity Assistant and click the Process button.
3. In the Conductivity Assistant window, select the conductivity series that corresponds to the range of your data. **Note:** If you only selected one range at launch time, only one series will be listed.
   - For the U24-001 logger, select either Conductivity Low Range when the data is always less than 1,000 µS/cm or select Conductivity Full Range (default) when the data goes above 1,000 µS/cm as shown below.

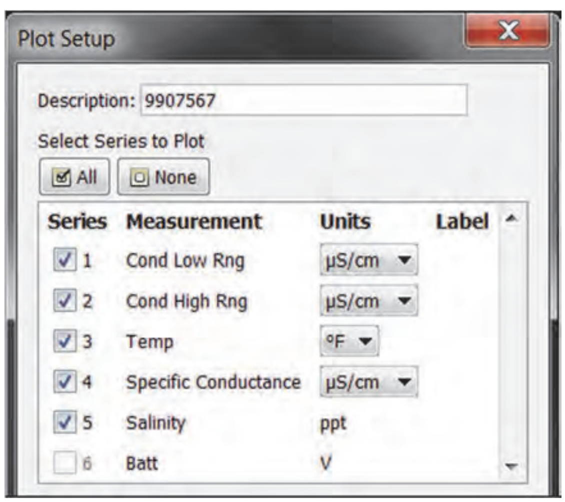


   - For the U24-002-C logger, select either Conductivity Low Range when the data is always less than 10,000 µS/cm or select Conductivity High Range (default) when the data goes above 10,000 µS/cm as shown below.

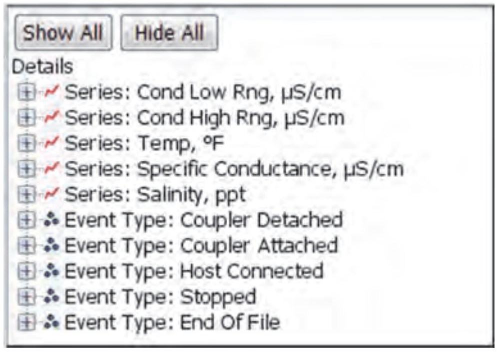


4. Select your desired Temperature Compensation method.
   - Use "Non-linear, Natural Water Compensation per EN27888" for freshwater lakes and streams.
   - Use "Linear compensation default at 2.1 %/°C" or "Linear compensation at <your own value> for NaCl solutions or other linear solutions.
   - Use "Non-linear, Sea Water Compensation based on PSS-78" for salt water or salt marshes.
5. Select a Calibration Method. By default, data is calibrated using the factory calibration. To enter your own calibration values, select "Use measured points for calibration" and then enter temperature and actual conductivity (not specific conductance) values from your calibration readings taken with a field meter. These field measurements will be used to provide calibrated conductivity and salinity data series by adjusting the data as a percentage of the reading. See *Calibration* below for more information.
   - Starting and Ending Value: This method calibrates your data and adjusts for sensor drift or fouling. This assumes there is a linear change in calibration adjustment required.
   - Starting value only: All readings are adjusted up or down by a fixed percentage of the reading based on this calibration point.
   - Ending Value Only: The factory calibration value is used as the starting point. This assumes there is a linear change in calibration adjustment required.

   Note: You cannot use a zero-point calibration solution for starting and ending values. The first data point cannot be used as the ending value; consider using that as the starting value instead.
6. Select the Only Report Data Between the Selected Points checkbox if you want readings from before or after the calibration points to be removed from the resulting series.
7. In the Series Name field, keep the default name or type a new one.
8. Type any User Notes concerning the series you are creating (optional).
9. Click the Create New Series button.
10. The Plot Setup dialog lists a series called Specific Conductance (or the name you entered for Series Name). The default units are microSiemens/cm (µS/cm). You can change the units to milliSiemens/cm (mS/cm) if desired. The default units for salinity are ppt (parts per thousand) and this cannot be changed.



11. Click **Plot** to plot the data. The Details Pane will show the series selected in Plot Setup:



    After the plot is displayed, you may apply minimum, maximum, and average filters to the scaled series as you would for any sensor data series in HOBOware Pro.

12. Save this plot as a Project to preserve this processed data.

Calibration

It is important to take temperature and conductivity calibration readings with a portable conductivity meter at both the beginning (launchtime) and end of a deployment (readout) because these readings are necessary for data calibration and to compensate for any measurement drift during deployment. The conductivity calibration readings should be the actual conductivity values (not in specific conductance at 25°C), and should be recorded in a notebook with the time and location of the reading. See the logger manual for details on different methods to record these values.

1. Once the logger is deployed and logging, record in a notebook the temperature and actual conductivity meter readings along with the date and time which will be entered into the Conductivity Assistance to correct the field data.
2. Before you remove the logger and read out its data, take another temperature and conductivity reading with the meter and record the exact date and time.
3. Enter these values under the "Use measured points for calibration" option in the Conductivity Assistant.

Notes:

- Whenever a logger is removed for downloading data, clean the sensor window using a cotton swab with a mild detergent and rinse.
- If the water in the field is not accessible to the conductivity meter sensor, such as in a deep well, a bailer can be used to fetch a water sample for testing. See the logger manual for more details.

Product Cleaning Reference Guide

Onset products are built with a variety of materials, each carefully chosen to best suit the environment where the loggers and sensors will be deployed. Because of the wide range of materials in use, there are different recommended cleaning methods for each product. Refer to the following chart to determine the compatible cleaning methods for your product based on its wetted materials. This guide lists safe cleaning methods for select loggers and sensors only; additional details on cleaning and maintenance for your device may also be available in the product manual. **Note:** When instructions call for warm soapy water, use a few drops of dish soap (such as Dawn®) or biodegradable soap.

Part Number(s)	Product Name	Wetted Materials	Cleaning Guidelines
U12-008	HOBO® U12 4-Channel External Data Logger	ABS	Briefly submersible for cleaning only. Clean housing and sensor cables with warm soapy water. To protect the logger electronics, do not fully submerge in water for an extended period of time.
U12-015, U12-015-02	HOBO U12 Stainless Temperature Data Logger	316 stainless steel	Completely submersible. Clean with 10% bleach solution, isopropyl alcohol, or warm soapy water.
U20-001-01, U20-001-01-TI, U20-001-02, U20-001-02-TI, U20-001-03, U20-001-03-TI, U20-001-04, U20-001-04-TI	HOBO U20 Water Level Data Logger	316 stainless steel, Viton®, acetyl, ceramic	Completely submersible. Clean with 10% bleach solution, isopropyl alcohol, or warm soapy water.
U20L-01, U20L-02, U20L-04	HOBO U20L Water Level Data Logger	Polypropylene, Viton, Buna-N, ceramic, acetyl, stainless steel	Completely submersible. Clean with isopropyl alcohol or warm soapy water.
U22-001, H20-001	HOBO Water Temp Pro v2 Data Logger	Polypropylene, EPDM, stainless steel	Completely submersible. Clean with isopropyl alcohol or warm soapy water.
U23-001	HOBO U23 Pro V2 Temperature/RH Data Logger	Styrene, polypropylene, Buna-N, vinyl, polyethersulfone	Not submersible. Clean logger housing with warm soapy water, but do not submerge in water.
U23-002	HOBO U23 Pro V2 External Temperature/ RH Data Logger	Styrene, polypropylene, Buna-N, vinyl, PVC, polyethersulfone	Logger is briefly submersible for cleaning only, but the sensor probe is not. Clean logger housing with warm soapy water and clean the probe with a damp cloth. To protect the logger electronics, do not fully submerge in water for an extended period of time.
U23-003, U23-004	HOBO U23 Pro v2 External Temperature Data Logger	Styrene, polypropylene, Buna-N, vinyl, PVC, polyethersulfone	Briefly submersible for cleaning only. Clean logger housing and sensor probe with warm soapy water. To protect the logger electronics, do not fully submerge in water for an extended period of time.
U24-001, U24-002-C	HOBO Conductivity Data Logger	Acetal, polypropylene, EPDM, stainless steel, epoxy, titanium pentoxide	Completely submersible; clean with a few drops of dish soap or biodegradable soap in a cup of warm tap water. Use vinegar and water to dissolve crusty deposits on the conductivity sensor.
U26-001	HOBO Dissolved Oxygen Logger	Delrin®, PVC, EPDM, silicon bronze	Completely submersible. Wipe the sensor cap with a soft-bristled brush or soft cloth to remove biofouling. Gently scrub the logger body with a plastic bristle brush or nylon dish scrubber. Use Alconox® to remove grease. Soak in vinegar to remove mineral deposits and then rinse with deionized (DI) water.

Part Number(s)	Product Name	Wetted Materials	Cleaning Guidelines
UA-001-08, UA-001-64, UA-002-08, UA-002-64, UA-003-64	HOBO Pendant® Data Logger	Polypropylene, 18-8 stainless steel, Buna-N	Completely submersible. Clean with isopropyl alcohol or warm soapy water.
UTBI-001, TBI32-05+37, TBI32-20+50, TBIB-40+75 IS, TBXT08-20+70	TidbiT v2 Water Temperature and StowAway TidbiT Temperature Data Loggers	Epoxy, Mylar®	Completely submersible. Clean with warm soapy water.
WTA-08, WTA-32	Optic Stowaway Temp	Polycarbonate	Completely submersible. Clean with isopropyl alcohol or warm soapy water.
H08-030-08, H08-031-08, H08-008-04	HOBO H08 Temp Loggers and Outdoor 4-Channel External	PVC	Briefly submersible for cleaning only. Clean logger with isopropyl alcohol or warm soapy water. Clean sensor probe and cable with warm soapy water.
S-SMC-M005, S-SMD-M005	EC-5 and 10HS Soil Moisture Smart Sensors	PVC, polycarbonate, fiberglass, EPDM	Briefly submersible for cleaning only. Clean sensor probe and cable with warm soapy water. To protect the sensor electronics, do not fully submerge in water for an extended period of time.
S-TMA-M002, S-TMA-M006, S-TMA-M017, S-TMB-M002, S-TMB-M006	8-Bit and 12-Bit Temperature Smart Sensors	PVC, polycarbonate, EPDM	Briefly submersible for cleaning only. Clean sensor probe and cable with warm soapy water. To protect the sensor electronics, do not fully submerge in water for an extended period of time.
TMC1-HD, TMC20-HD, TMC50-HD, TMC6-HD	Air/Water/Soil Temperature Sensors	PVD, stainless steel 316 or 304, polyolefin	Briefly submersible for cleaning only. Clean sensor probe and cable with warm soapy water. The sensor probe and cable can be submerged in water, but the connector end is not intended for prolonged exposure.
TMC6-HC	Stainless Steel Temperature Probe	PVD, stainless steel 316 or 304, polyolefin	Briefly submersible for cleaning only. Clean sensor probe and cable with warm soapy water.
TMC6-HE	Temperature Sensor	PVD, stainless steel 316 or 304, polyolefin	Briefly submersible for cleaning only. Clean sensor probe and cable with warm soapy water.
W-TMB	HOBOnode Temperature Wireless Sensor	PVC, polycarbonate, EPDM	Briefly submersible for cleaning only. Clean node housing, sensor probe, and cable with warm soapy water. To protect the node electronics, do not fully submerge in water for an extended period of time.
W-SMC	HOBOnode Soil Moisture Wireless Sensor	PVC, polycarbonate, fiberglass, EPDM	Briefly submersible for cleaning only. Clean node housing, sensor probe, and cable with warm soapy water. To protect the node electronics, do not fully submerge in water for an extended period of time.

National Park Service
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Natural Resource Stewardship and Science

Continuous Water Level Data Collection and Management Using Onset HOBO® Data Loggers

A Northeast Coastal and Barrier Network Methods Document

Natural Resource Report NPS/NCBN/NRR—2017/1370

ON THE COVER
Water level monitoring well in a Jamaica Bay salt marsh, Gateway National Recreation Area, New York.
Photograph by Jim Lynch

Continuous Water Level Data Collection and Management Using Onset HOBO® Data Loggers

A Northeast Coastal and Barrier Network Methods Document

Natural Resource Report NPS/NCBN/NRR—2017/1370

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U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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NPS 962/135920, January 2017

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Acknowledgments

This document borrows heavily from other documents, and I would especially like to acknowledge Geoff Sanders (author of *NCRN Continuous Water Monitoring Data Management SOP_v1.1.docx*), and Gwen Gerber (author of the document on which *Appendix B. HOBO® Quickstart* Guide is based). Dean Tucker authored numerous instructional videos and documents that are invaluable for aspiring Aquarius users; he has been very generous with his time and advice, and I've included text from -- and links to -- his materials. He also worked with Aquatic Informatics to create two custom Aquarius reporting tools described in Section 4.4.7. Special thanks are also due to Jim Lynch for numerous consultations and documents that he authored or contributed to, including *Appendix C. Water Level Logger Installation* Guide and *Appendix D. Water Level Logger Field Data* Sheet. Finally, Kelly Medeiros contributed valuable editing and content, especially in Section 4.

1. Purpose

The purpose of this paper is to document and standardize procedures for collecting, processing and archiving continuous water level data collected in the National Park Service Northeast Coastal and Barrier Network (NCBN) tidal wetlands and coastal areas. The procedures in this document pertain to data collection with the Onset HOBO® water level data loggers (Figure 1), and data processing and archiving with Onset's HOBOware Pro and Aquatic Informatics' Aquarius[1] software.

Figure 1. HOBO® U20 Water Level Data Logger. Photo from OnsetComp.com.

[1] Aquatic Informatics uses all capital letters to refer to their AQUARIUS software; this document capitalizes only the first letter (Aquarius).

2. Scope and Applicability

This document applies to the management of water level data collected using continuous data loggers. The NCBN currently uses HOBO® data loggers produced by Onset, so portions of this document will focus on using the HOBOware Pro software package to format the data from the loggers, to adjust the pressure readings to compensate for atmospheric pressure, and to calculate water depth values.

Much of the remaining content focuses on the use of Aquatic Informatics' Aquarius software package for performing quality control actions, creating derived data sets, creating reports, and archiving continuous water level data. To use Aquarius, users will have to establish an account and request an application shortcut (see Section 4.4.1).

The following data parameters will be archived in Aquarius (Table 1):

Table 1. Data parameters that will be archived in Aquarius

Parameter	Data Source
Date and Time	HOBO® Water Level Logger
Absolute Pressure	HOBO® Water Level Logger
Water Temperature	HOBO® Water Level Logger
Atmospheric Pressure	Atmospheric Logger (HOBO® Water Level Logger deployed in air)
Water Depth (from pressure)	Calculated in HOBOware Pro
Water Level Relative to Marsh Surface	Calculated in Aquarius
NAVD88 Water Levels	Calculated in Aquarius

3. General Considerations

This section of the document details the procedures and considerations pertaining to pre-deployment and deployment of the HOBO® data loggers, as well as how raw data collected from loggers will be handled and managed post-deployment.

3.1 Pre-deployment considerations

3.1.1 HOBO® water level data logger models

The Onset HOBO® water level data logger comes in several models. The HOBO® U20L series has a polypropylene housing, is significantly less expensive, and has a slightly lower accuracy specification than the U20 series, which comes with either a stainless steel or titanium housing. The polypropylene and titanium housings are approved for salt water use, while the stainless steel housing is recommended for fresh water only.

Both the U20 and U20L series have several models designed to operate in different depth ranges. For most wetland environments, the sensor with a depth range of 0-4 meters (0-13 ft) is appropriate. For deployments in areas with deeper water, sensors with depth ranges of 0-9 m (0-30 ft) and 0-31m (0-100 ft) are available.

3.1.2 Cleaning

The HOBO® U20 water level data logger can be cleaned with 10% bleach solution, isopropyl alcohol, or warm soapy water (Onset Product Cleaning Reference Guide). Pipe cleaners and/or syringe can be used to flush out fouling or debris from the pressure port.

3.1.3 Logger testing

Onset recommends testing their data loggers annually to insure that they are operating within specifications. Yearly testing by the manufacturer is expensive and may not be necessary, since these devices have a legacy of stability and reliability. A less expensive and more convenient method to test the general functionality of a water level logger is referred to as a bucket test (Figure 2). In this procedure, the water level logger is deployed in a bucket or similar container of water. After an equilibration period of approximately ten minutes, a manual water level reference measurement is made (e.g. distance between the water surface and top of bucket). After removing some of the water, a second reference level measurement is made. Data recorded on the logger are then compared to the reference measurements.

3.1.4 Duration of deployment and sampling interval

The data memory capacity of HOBO® data loggers is 64Kb, which is equivalent to approximately 21,700 samples. This is equivalent to 7.5 months (225 days) of data storage capacity at a 15-minute data collection interval, or 3 months (90 days) of data storage at a 6-minute collection interval. Once the data logger's memory is full, it stops collecting data. Data must be downloaded and the logger's memory cleared in order to resume data collection. The typical data collection interval for a National Oceanic and Atmospheric Administration (NOAA) tide station is 6 minutes. For NCBN's salt marsh monitoring, a typical collection interval is 15 minutes.

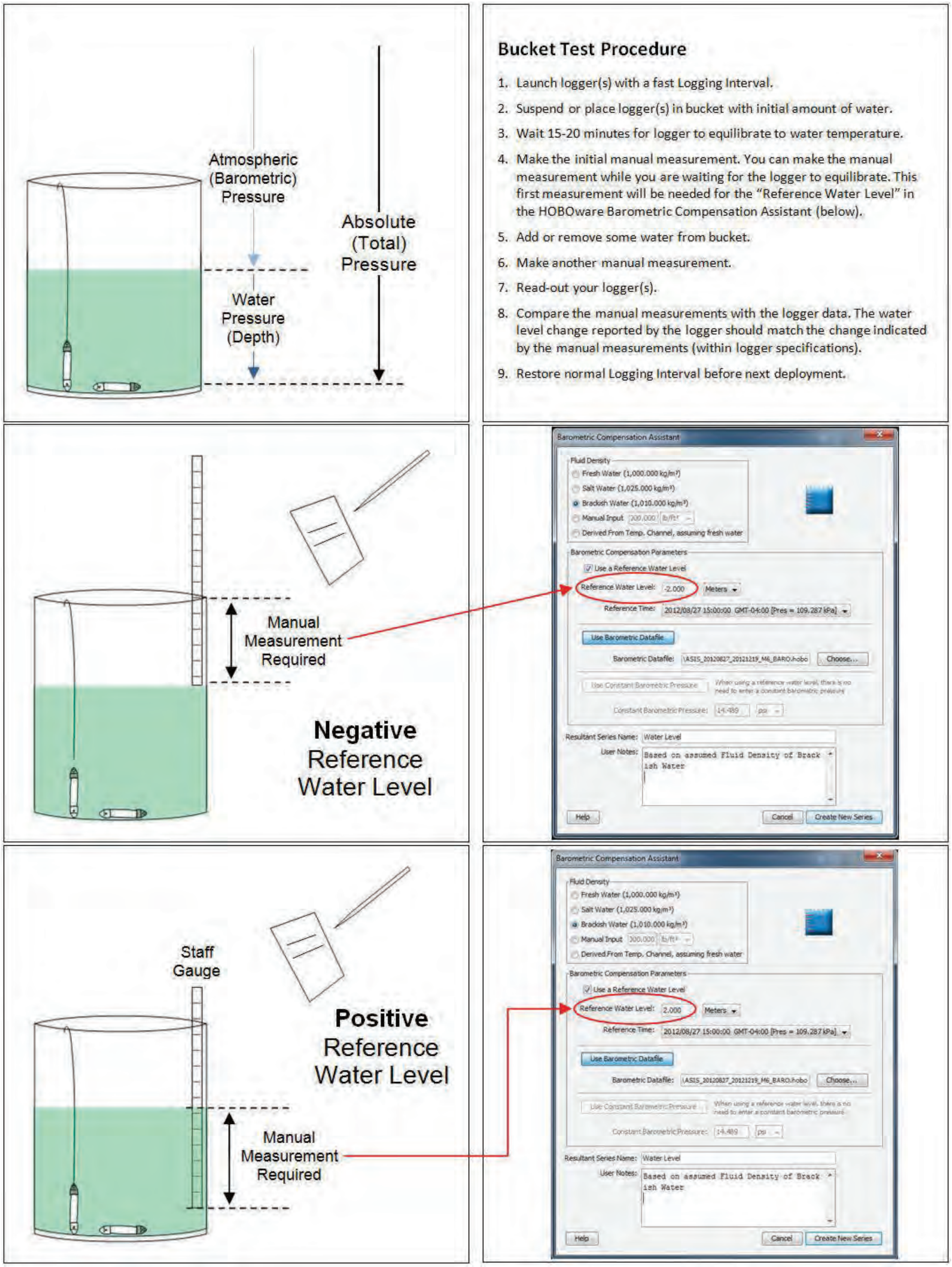

Figure 2. Bucket test procedure for testing water level data logger.

3.1.5 Atmospheric pressure

HOBO® water level loggers are sealed (non-vented), so they will record changes in pressure due to a combination of atmospheric and water level changes. To determine water depth, changes due to atmospheric pressure must be removed from the absolute pressure readings collected by the HOBO® logger.

Atmospheric pressure data can be collected by a separate air-deployed HOBO® data logger, or by a nearby meteorological station. A dedicated on-site HOBO® logger is preferred and recommended. Onset recommends that the barometric readings be collected within a 10-mile radius of the water level logger (Onset HOBO® U20 Logger Manual).

3.2 Deployment considerations

3.2.1 Site location

Site selection will be primarily driven by project objectives and what type of water body is being monitored. Water level data loggers can be deployed in wells that are set into a marsh surface, in tidal creeks, or in larger water bodies. Site selection factors to consider include accessibility, presence of a stable mounting structure, local water level regime, and probability of vandalism.

3.2.2 Mounting options

HOBO® sensors should be mounted low enough in the water to insure that they remain submerged during all tidal conditions. In open-water deployments with significant wave action, the water level loggers should be suspended inside a solid 2” PVC pipe with vented sections on the bottom and top to allow water and air into the pipe. Vents can be created with sections of slotted PVC or by drilling ¼” holes in top and bottom sections of the pipe. The PVC pipe acts as a stilling well to dampen the effects of chop and waves on the water level inside the pipe. The stilling well should be securely mounted to a stable structure, post, or piling, where the logger will remain submerged. If no structure is available, the logger could be anchored to the bottom inside a protective PVC tube. For year-round deployments in areas where surface ice formation is expected, the water logger should be mounted deeply enough to be below the ice, and the stilling well should be designed and secured to withstand the forces of ice formation and break-up.

Barometric loggers should be mounted on the north side (or otherwise shaded portion) of a post or structure to minimize heating and cooling fluctuations caused by varying sun exposure. Dramatic temperature fluctuations can affect pressure readings. Barometric loggers should be enclosed in a short section of PVC pipe to provide some protection from vandalism and changing environmental conditions.

See *Appendix C. Water Level Logger Installation* Guide for detailed data logger installation instructions in marsh and tidal creek settings.

3.2.3 Reference point(s)

A water level logger should have at least one vertically stable reference point. Reference pints serve several important functions. First, a vertically stable reference point allows one to monitor the stability of sensor and housing at a given site. Second, it allows water levels to be related to the elevations of nearby terrestrial features. Finally, it provides an effective way to monitor sensor drift during a deployment. The reference point could be an existing geodetic benchmark, a newly installed benchmark, or the top of a vertically stable well casing.

To monitor sensor drift in a well-deployed logger, a water level meter (cable with sensor) or a dipstick can be used to physically measure the distance from the top of the well casing or connection point to the water surface (see Figure 3). The water level determined by this measurement is then compared to the water level collected by the data logger. If the logger is mounted in a tidal creek or open water, an associated staff gauge or designated leveling point with a known and stable vertical offset from the sensor should be used for the reference measurements. A minimum of two reference measurements per deployment is recommended: one at the time of deployment and another at the end of the data series, just prior to downloading data from the logger. Supplementary reference measurements during the deployment provide additional quality control. Exact times of reference measurements must be recorded in order to associate them with the correct data logger readings. If readings are within logger specifications[2], the logger is considered to be calibrated and functioning properly. If there is a significant difference between the water level reference measurement(s) and the data logger reading(s), the logger should be sent to the manufacturer for laboratory testing and re-calibration.

There are various methods of determining the vertical relationship between the reference point and the data logger. Traditional surveying techniques involving the use of a benchmark with known vertical coordinates, total station, and digital leveling rod will yield the most precise and accurate results, but require a high level of technical ability and equipment. Several GPS-based methods including static occupations, real time kinematic (RTK) or post-processed kinematic (PPK) techniques provide more practical, though less accurate, solutions. GPS-based methods can be expected to yield an absolute vertical accuracy on the order of 1–2 cm. The methods used should be chosen based on project objectives, specifications and parameters.

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[2] See *Appendix 1. Reference Resources* for a link to the specifications of the HOBO® U20 and U20L water level loggers

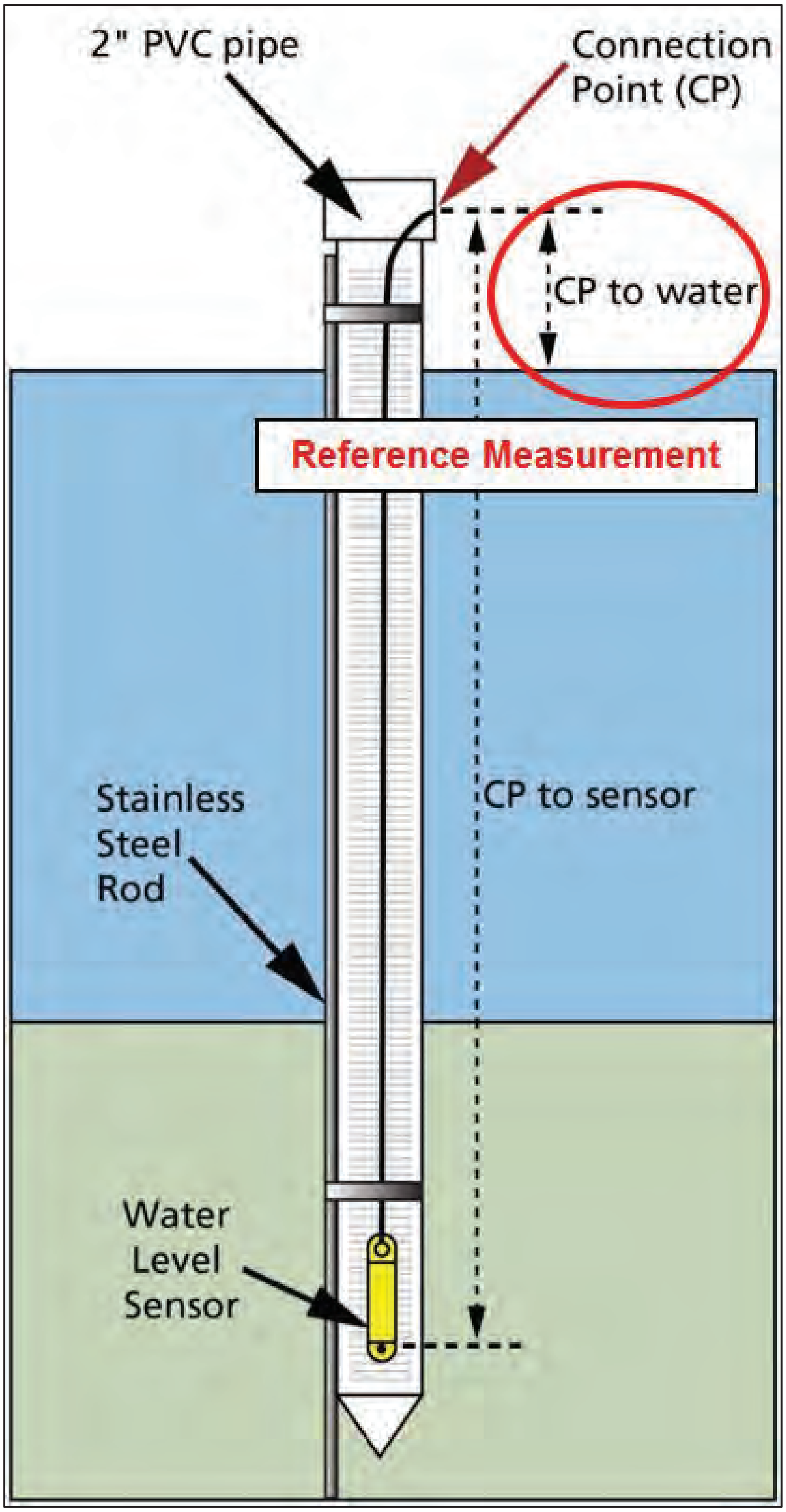


Figure 3. Well diagram showing CP to water distance, or reference measurement.

4. Data Processing

4.1 Electronic file naming standards

File naming should adhere primarily to the guidelines in the following document: *NCBN_20120525_Skidds_FileNamingStandards_SOP_Draft.pdf*. Additionally, the file name should include both a deployment start date and end date, instead of the single date recommended in the above document.

4.1.1 Raw HOBO® data files

HOBO® data logger file names should start with the park unit code, followed by the deployment start and end dates, author, location name (or code), and data type code (WL for water level data and BARO for barometric data). File names should contain no spaces, but use underscores to separate file name components:

Four-letter PARK CODE + StartDate (yyyymmdd) + End Date (yyyymmdd) +Author + Location Name (or Code) + Data Type.

Example for raw water level data collected by J. Lynch at in Fire Island National Seashore at Hospital Point:
FIIS_20130501_20130931_Lynch_HP_WL.hobo

Example for raw air-deployed barometric data collected by J. Lynch:
FIIS_20130501_20130931_Lynch_WH_BARO.hobo

If one barometric (air-deployed) file is used for multiple sites within a park, the location descriptor may not be necessary, as in the example below:
FIIS_20130501_20130931_Lynch_BARO.hobo

4.1.2 Processed HOBO® data files

Filenames for logger files that are processed in HOBOware Pro to apply atmospheric correction, and exported as a comma separated value (csv) file (described below) should maintain the same base file name as the original HOBO® file (as described above in Section 4.1.1):

Example for Hospital Point water level data collected by J. Lynch, after applying atmospheric correction:
FIIS_20130501_20130931_Lynch_WatchHill_WL.csv

4.2 Downloading and storing logger data

Data should be downloaded from the water level loggers, stored on HOBO® shuttles or field computers and copied to the NCBN file server upon returning to the office. Data download from the HOBO® data logger requires a HOBO® shuttle, coupler and USB cable that provides a connection to a computer (see *Appendix B. HOBO® Quickstart* Guide). The raw data files for each field site and retrieval date should be copied to the appropriate project folder on the NCBN file server upon returning to the office.

4.3 Initial Logger Configuration and Data Processing with HOBOware

Data created by the HOBO® data loggers are in a proprietary format with a **.hobo* file extension. The ultimate goal is to transfer these data to the Aquarius data management software, but Aquarius does not recognize the HOBO® proprietary software format. Therefore, data acquired from a data logger must first be opened in HOBOware, Onset's proprietary software. After any processing and data correction, the data should be exported as a csv text file, a format recognized by Aquarius. HOBOware must be installed for users intending to work with raw data acquired from the HOBO® data loggers. In order to process the absolute pressure reading to adjust for atmospheric pressure, Onset's *Barometric Compensation Assistant* software add-on must be installed, which requires a fully licensed version of HOBOware Pro.

4.3.1 Configure the HOBO® data logger (Adapted from HOBOware User's Guide)

To configure a HOBO® data logger for deployment, perform the following basic steps (see *Appendix B. HOBO® Quickstart* Guide for more detailed instructions):

1. **Connect the logger to the computer** for the initial setup, and open HOBOware Pro. Select the units in which the data are to be collected (US or SI (international)) from the main menu bar.

2. **Establish export settings.** In the main HOBOware Pro window, click *File/Preferences* to open the *Preferences* window. Under the *General* section, click the gray triangle next to *Export Settings* to expand this section.

   - Leave the box next to *Separate date and time into two columns* unchecked.

   - Select *Time format: 24-hr*.

The export settings window should look like Figure 4:

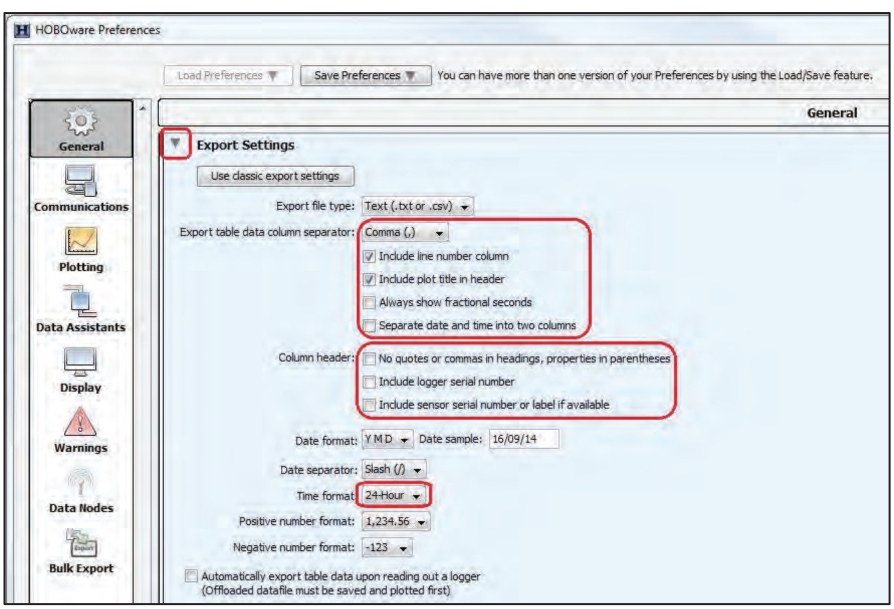


Figure 4. HOBOware Pro Export Settings.

3. **Click OK** to close the *Preferences* window.

4. **Launch the logger.** In the *Launch Logger* window, select or verify the appropriate parameters for the logger deployment, including:

   - Battery State
   - Logging Interval
   - Logging Start Time

After the parameters are set, launch (start) the logger by clicking the Delayed Start button.

5. **Check the status of the logger**. You have the option of checking the current status of the logger and any current readings while it is still connected to the computer. This can be helpful to verify that the launch configuration is as expected and to check the battery status (also available in *Launch Logger* window).

4.3.2 Open data file with HOBOware Pro

Launch the HOBOware Pro software and open the desired **.hobo* data file by clicking *File/Open Datafile(s).* Even if you only intend to export data to another format, you must plot the data first. After opening a data file, HOBOware will prompt the user to setup plot parameters for the logger data (Figure 5). The view will vary depending on the data parameters that were collected. Make sure that the units are correct, and that *Offset from GMT* time zone is correct. You may also click the *None* option under *Select Internal Logger Events to Plot.*

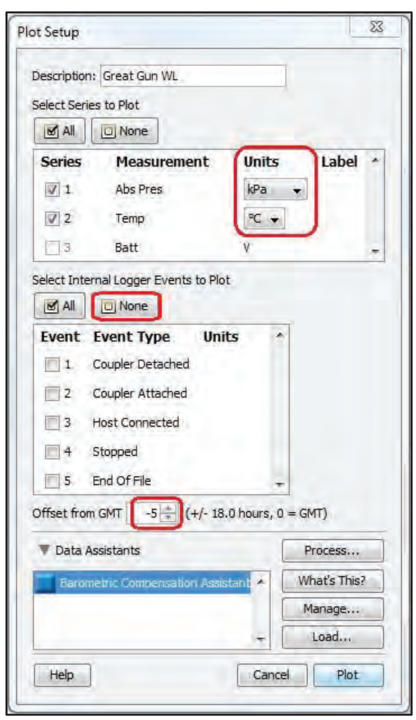


Figure 5. HOBOware Pro plot setup.

4.3.2.1 Time zone considerations

It is important that the atmospheric logger and water level logger are both set to the same time zone, so that the corresponding water and atmospheric readings have matching time stamps and can be processed correctly with the *Barometric Compensation Assistant.* GMT -5 corresponds to Eastern Standard Time (EST), and GMT -4 corresponds to Eastern Daylight Time (EDT). HOBOware allows you to manually manipulate the time zone at this step. If the data were collected in GMT -4, change the setting in the *Plot Setup* window to GMT -5 (EST). This will change the time values. It is important to process all the files with the same time zone because data from different deployments at the same site will later be appended into a single data set in Aquarius, and the time zone should be consistent within this Aquarius dataset.

4.3.3 Perform barometric compensation *(Taken largely from Onset's Barometric Compensation Assistant User's Guide)*

If the *Barometric Compensation Assistant* does not appear in the *Data Assistants* section at the bottom of the *Plot Setup* Form, click *Manage*, check the box next to *Barometric Compensation Assistant* and click *OK* (Figure 6).

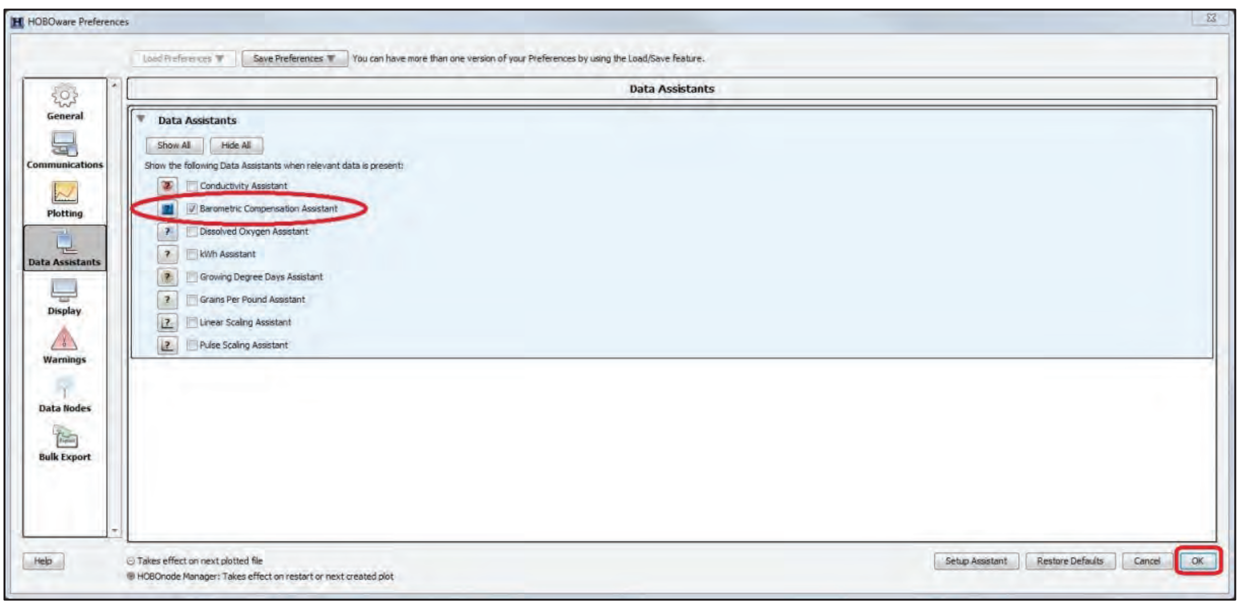


Figure 6. HOBOware Pro Data Assistants page.

Back in the *Data Assistant* section at the bottom of the *Plot Setup* window (Figure 5), click "*Process…*" which will open the *Barometric Compensation* dialogue box (Figure 7).

Choose the appropriate fluid density (Salt Water, Brackish Water, etc.) or enter a specific constant value. If you are unsure which fluid density to choose, you can use a refractometer to measure water salinity (or a hydrometer to measure the specific gravity). Online conversion tables and calculators (e.g. http://www.csgnetwork.com/h2odenscalc.html) can be used to convert salinity readings (or specific gravity) to density values.

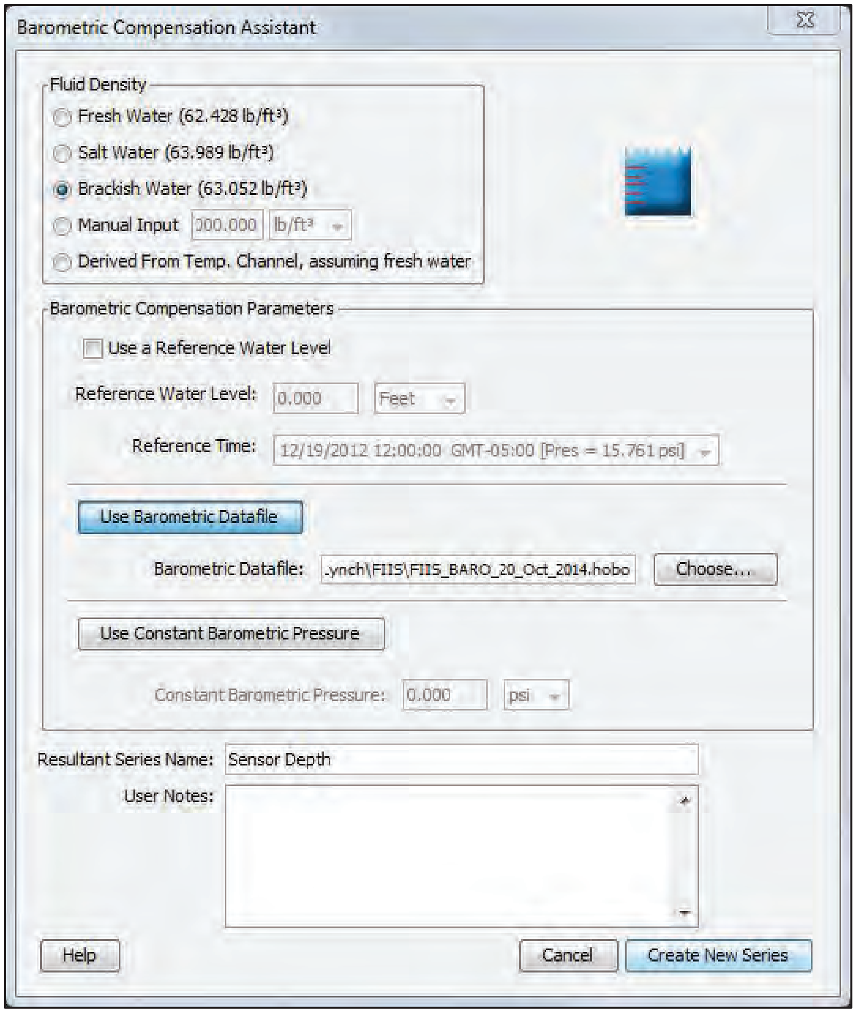


Figure 7. HOBOware Pro Barometric Compensation dialogue box.

To enter a reference water level, check the *Use a Reference Water Level* box, enter the water level, and indicate whether it is in feet or meters. The reference water level is the measured distance between the current water level and a local reference point such as a well cap, staff gauge, or other vertically stable reference point (Figure 3).

- Enter the reference water level as a *positive number* if it is measured upward from a reference point below the water surface.

- Enter the reference water level as a *negative number* if it is measured downward from a reference point above the water surface, such as a well cap.

Then, from the *Reference Time* drop-down menu, select the logged time and value that is closest to the time when you measured the water level. When selecting a logged value and time to link to the reference level, make sure the logger readings have stabilized. When a logger is first deployed in water, it takes about ten minutes for its temperature to reach equilibrium. You will get the best accuracy if you link your reference reading to a stabilized logger reading.

When using a reference water level, the resulting data series will contain water level values relative to this reference level. If you do not use a reference water level, the resulting data series will contain values for absolute sensor depth.

Click *Use Barometric Datafile* and navigate to the appropriate atmospheric logger file. The default *Resultant Series Name* is *Sensor Depth*. You have the option of changing this output name and adding descriptive notes in the *User Notes* box. Click *Create New Series*. This will take you back to the *Plot Setup* window where you will see the added series, named *Sensor Depth*. Click *Plot* when finished. The resulting screen will display the data in tabular and graphical views (Figure 8).

Figure 8. HOBOware Pro data plot.

Double-check that the units are correct. Various projects will use different units for the same parameter based on the needs of that project. Make sure that the required units are documented and that you check the units imported from the logger before exporting them.

4.3.4 Export data

Prior to exporting data, make sure that the HOBOware *General Preferences* are configured as shown in Section 4.3.1 (see Figure 4).

There are several options for export settings, and they can affect subsequent processing, especially as related to Aquarius import configuration files and Hot Folders (see Section 4.4.4). The red boxes in Figure 4 highlight the key areas on which to focus, and illustrate the recommended format, including:

- Header information
- Export Date and Time as separate columns
- Format date as Year/Month/Day
- Format time as 24Hour

Next, format the *Display Settings*. From the list on the left sidebar select *Display*, click on the gray arrow next to *Date/Time* (Figure 9) to expand that section. Once display preferences are established, click *OK* to close the *Preferences* window.

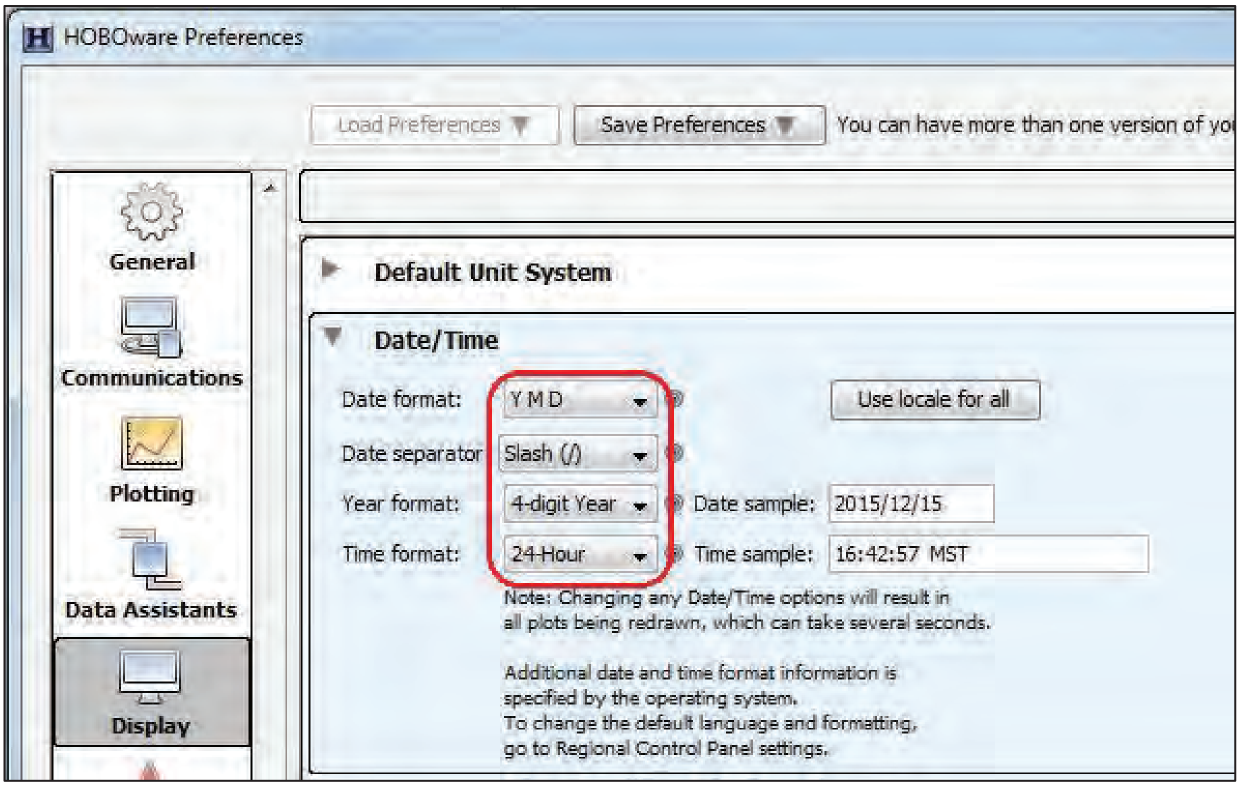


Figure 9. HOBOware Pro Date/Time Display Preferences.

Then select *File/Export Table Data* from the main menu bar and the *Export* window will open (Figure 10).

Click *Export*, navigate to the destination folder and name the file, using the naming convention described in Section 4.1. After these default settings have been established, they should be maintained by the software. Adjustments may be necessary following software updates.

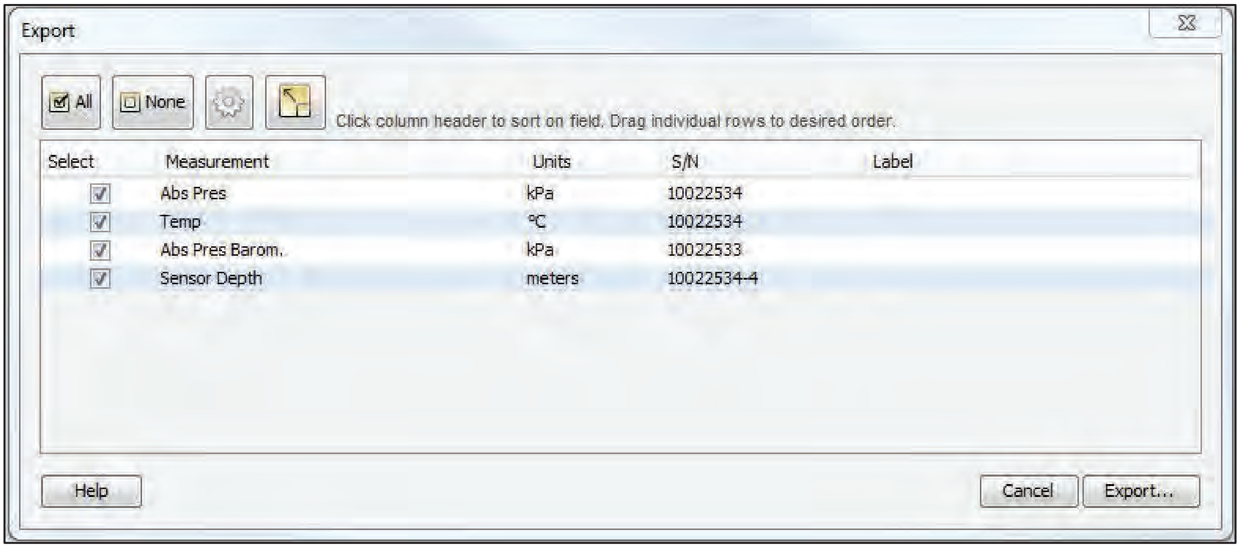


Figure 10. HOBOware Pro Export window.

4.4 Using Aquarius software to process and archive water level data

Much of the material in this section on Aquarius is either taken directly, or modified slightly, from a document created by Dean Tucker called *Introduction_Aquarius_3_Springboard.pdf*. Dean's document was written for Version 3.0, Release 5 of Aquarius Springboard. Note that significant changes to Aquarius are expected with the next release; NPS implementation of the new release is anticipated to occur during the first half of 2017.

Aquarius is a software package produced by Aquatic Informatics and designed specifically for managing and analyzing continuously acquired water monitoring data. Water level data collected with HOBO® loggers is commonly imported into Aquarius for analysis and archiving. Aquarius is expensive to purchase, costly to maintain and requires significant computer resources to run. Therefore, the software is managed by the NPS at the national level in Ft. Collins, CO and access is provided by the Natural Resource Stewardship and Science program.

4.4.1 Setting up Aquarius

To use Aquarius software, you need to request access by contacting Dean Tucker (dean_tucker@nps.gov), Natural Resource Specialist with the NPS Water Resources Division in Ft. Collins, CO. He will establish access for users who request it and forward some basic instructions. One of the things you will receive is the Aquarius Assistant shortcut that allows access to the Aquarius software. Dean has also created a number of helpful videos and documents for new Aquarius users that can be found at the following URL: http://nrdata.nps.gov/Programs/Water/Aquarius/AquariusVideos.htm. Users are strongly advised to watch these videos and browse the resource available before using Aquarius.

After receiving the Aquarius Assistant remote desktop connection shortcut file (AQAssistant.rdp) from Dean and saving it to your local computer, double-click the shortcut (Figure 11).

Figure 11. Desktop shortcut to access Aquarius.

You will probably get a warning saying that the publisher of the RemoteApp can't be identified (Figure 12). Click *Connect* in this warning window and you will be prompted to enter your NPS Smart Card PIN to access the Aquarius GETT1 server (Figure 13).

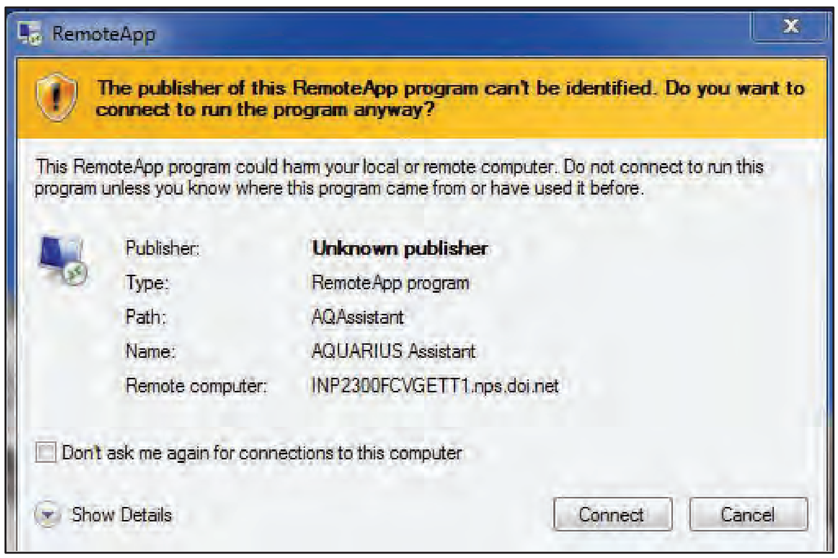


Figure 12. RemoteApp warning window.

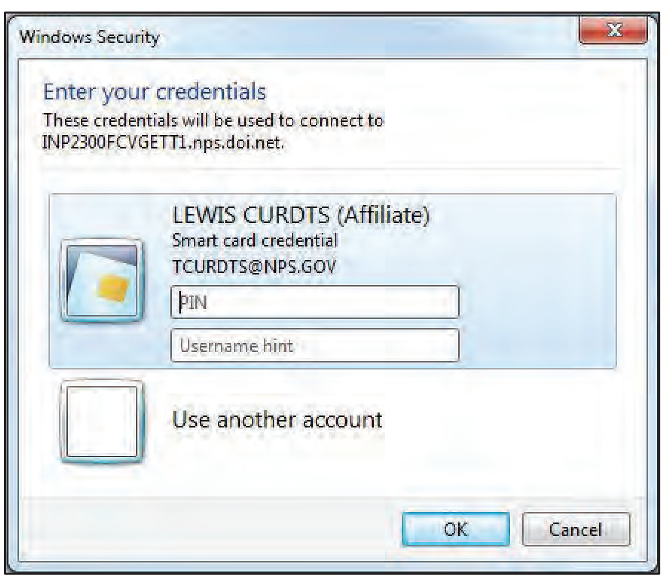


Figure 13. Smart card PIN prompt.

Upon entering the correct password you will gain access to the server running Aquarius (Figure 14).

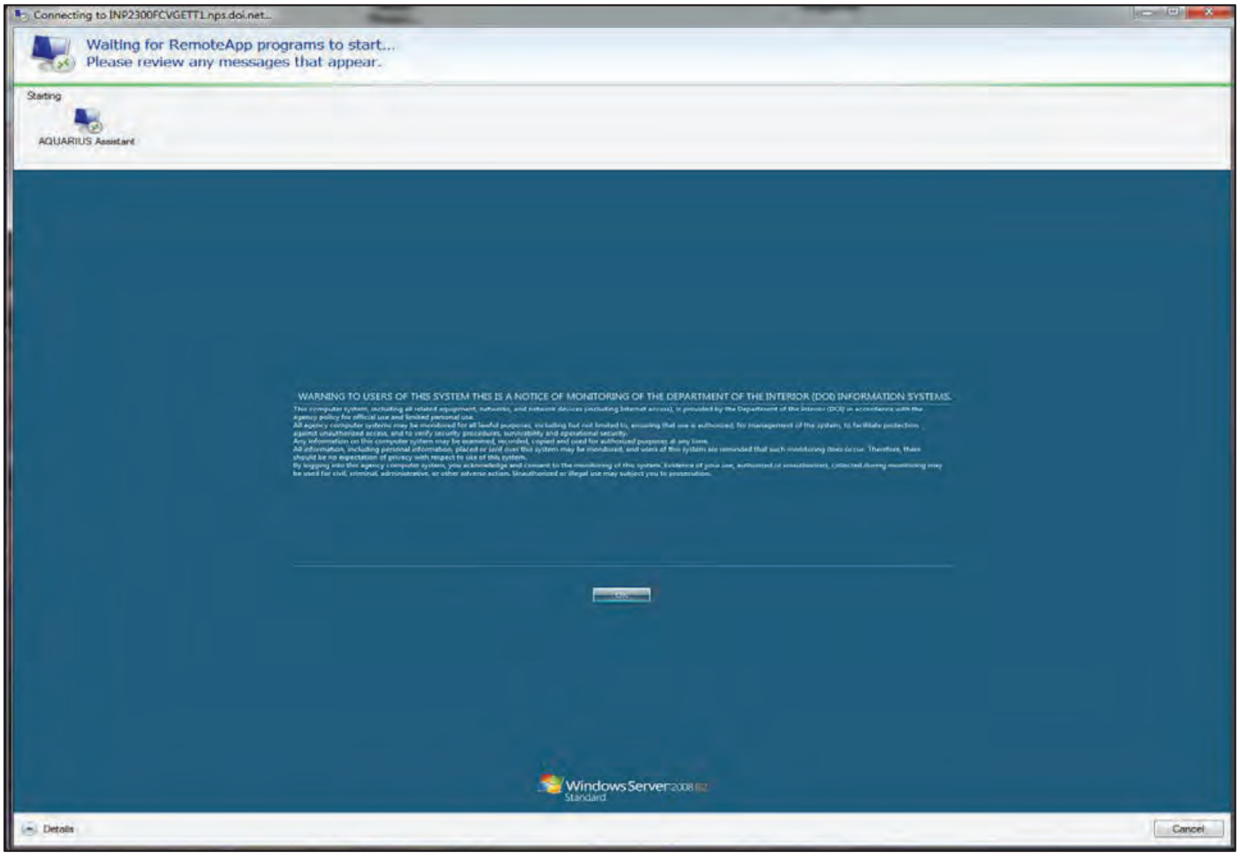


Figure 2. Initial access screen to Aquarius computer.

Once you click *OK*, that screen will close and return you to your desktop. A new Aquarius icon should now be visible in the system tray at the bottom right hand side of your screen (Figure 15).

Figure 3. System tray showing the Aquarius icon.

Right-click on the Aquarius icon in the system tray, and then select *Launch Springboard* from the resulting pop-up menu. The screen you see should look like Figure 16. The *Server* box should indicate "*localhost*."

Figure 4. Aquarius server selection window.

Click *OK*. You will then be prompted to log into Aquarius Springboard (Figure 17). Type your NPS Active Directory user name and password and click *Login*.

Figure 5. Aquarius login window.

It takes a few moments, but when the next screen appears and fully refreshes, you will be presented with the main screen for the Springboard application. A list of organizations will appear along the left sidebar, consisting of parks and program offices (e.g. I&M Networks) (Figure 18).

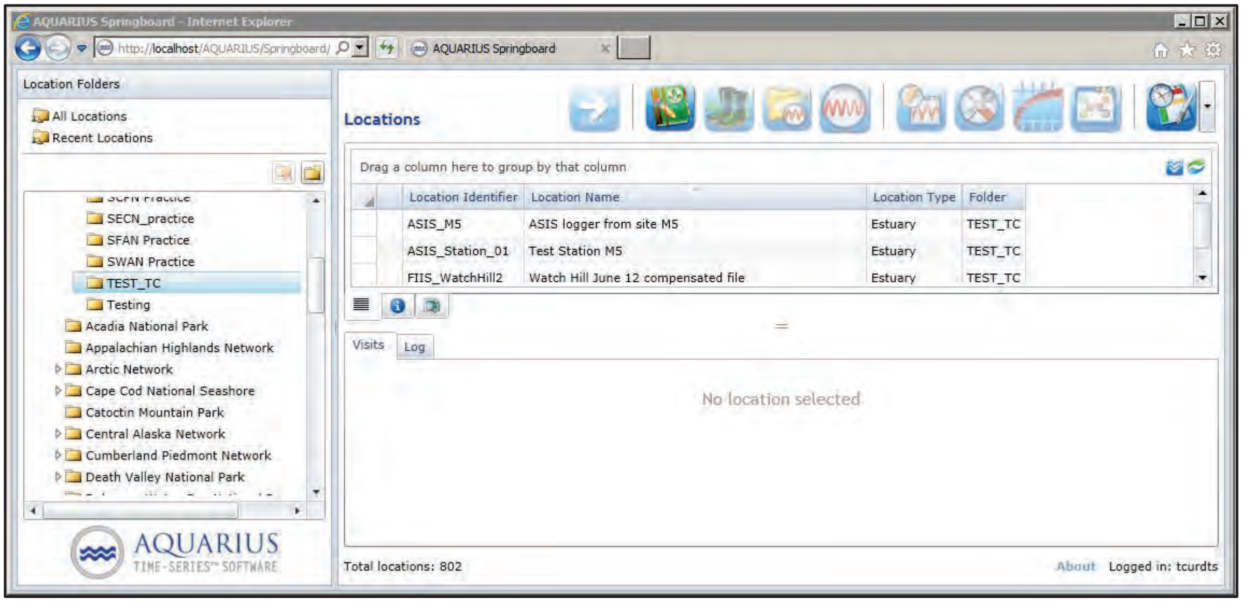


Figure 6. Main Aquarius Springboard window.

Selecting an organization's folder will display the associated locations to the right in the main panel of the form. NCBN users can establish locations directly in the Northeast Coastal and Barrier Network organization folder or create subfolders for specific projects. Each of these projects can have specific locations associated with them. Note that Aquarius only permits one tier of subfolders within the organization folder. For example, we have created a subfolder in the *Northeast and Coastal Barrier Network* organization folder called *SET_Water_Level_Data*, but Aquarius will not permit subfolders within the *SET_Water_Level_Data* folder, as illustrated below:

Northeast and Coastal Barrier Network/SET_Water_Level_Data/No additional subfolders allowed

4.4.2 Creating Aquarius "locations"

Prior to importing any data to Aquarius, users must create a "Location." An Aquarius Location can be thought of as a folder, or container, for site-specific data. In our case, a typical Aquarius Location would be established to ingest data from a particular HOBO® logger site at a particular park. To create a new location, either right-click the project folder and select *New Location*, or click on the *Location Manager* icon found in the top menu bar (outlined in red in Figure 19). If the project folder already contains locations, make sure none are selected before you click the *Location Manager* icon. If an existing location is selected and you open the *Location Manager*, the information for the selected location will be presented, not the blank form to create a new location.

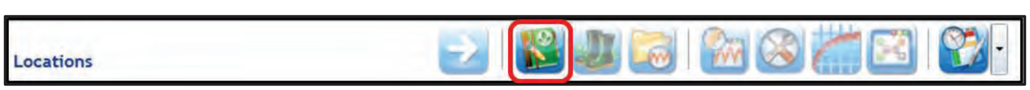


Figure 19. Aquarius Springboard menu bar.

The *Location Manager* enables users to control information about the monitoring site as well as manage data associated with the site (Figure 20). Establishing the site requires users to enter a Location *Identifier* and *Name*. These fields are highlighted in red on the form, indicating that they are required. The *Identifier* will later be used by Aquarius to form part of the *Data Set ID*. The format of the Location *Identifier* should begin with the location's four-character park code, followed by an underscore, site code, underscore and data type (e.g. "FIIS_WH_WaterLevel"). Users also have to choose the type of monitoring site from a large selection list (e.g. estuary, ocean, river, perennial streams, etc.), depending on the specific project. For coastal salt marshes, choose *Wetland Estuarine-Emergent*. Defining the site type determines what additional fields appear on the form.

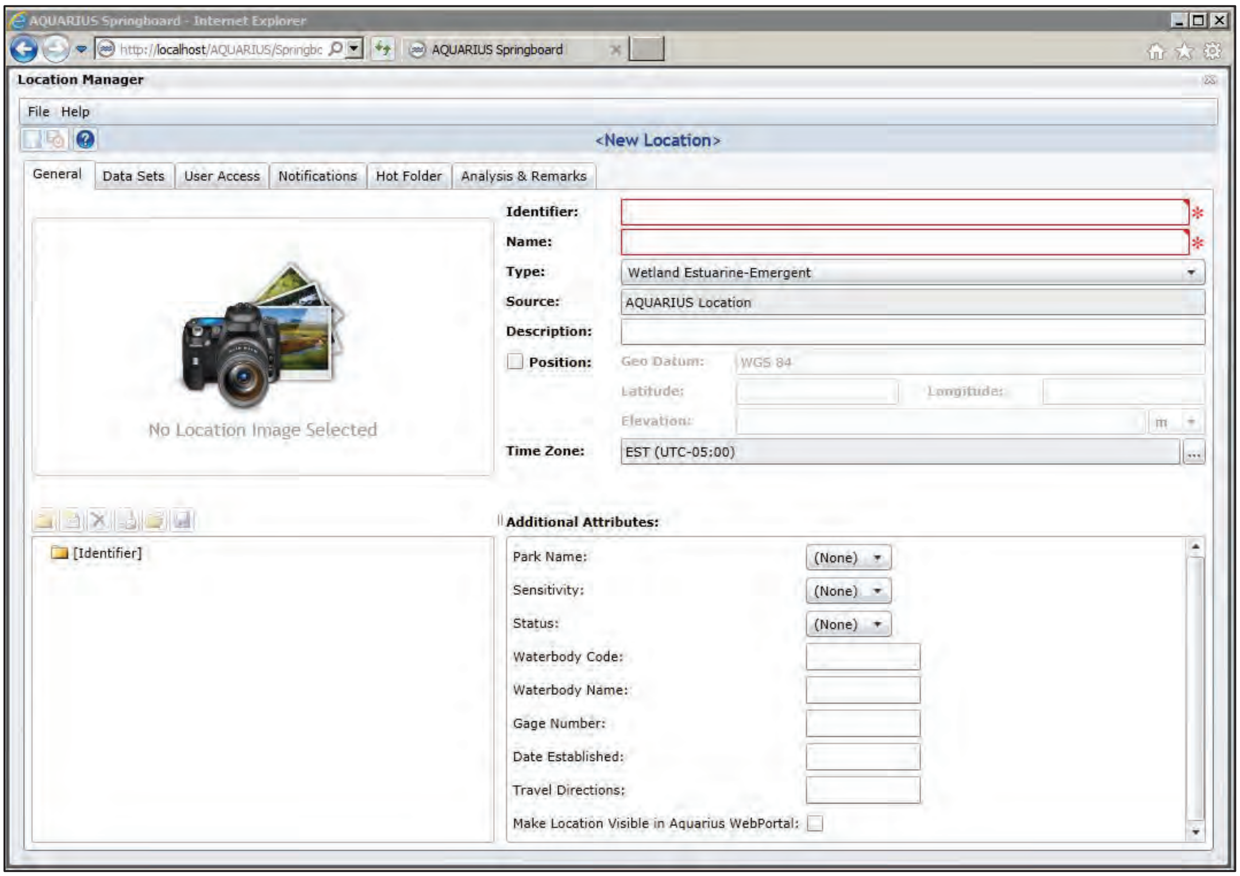


Figure 7. Incomplete Aquarius Springboard Location Manager window.

Users should complete as many of the remaining fields as possible, including *Description Latitude, Longitude* and *Time Zone*. NPS-specific fields are available under the *Additional Attribute* section of the form. To the left of the *Additional Attribute* section, there is also the option to upload a photo of the monitoring site. The photo will appear in the box in the upper left area of the form. While not mandatory, users should enter as much of this information as possible. The completed form should resemble Figure 21.

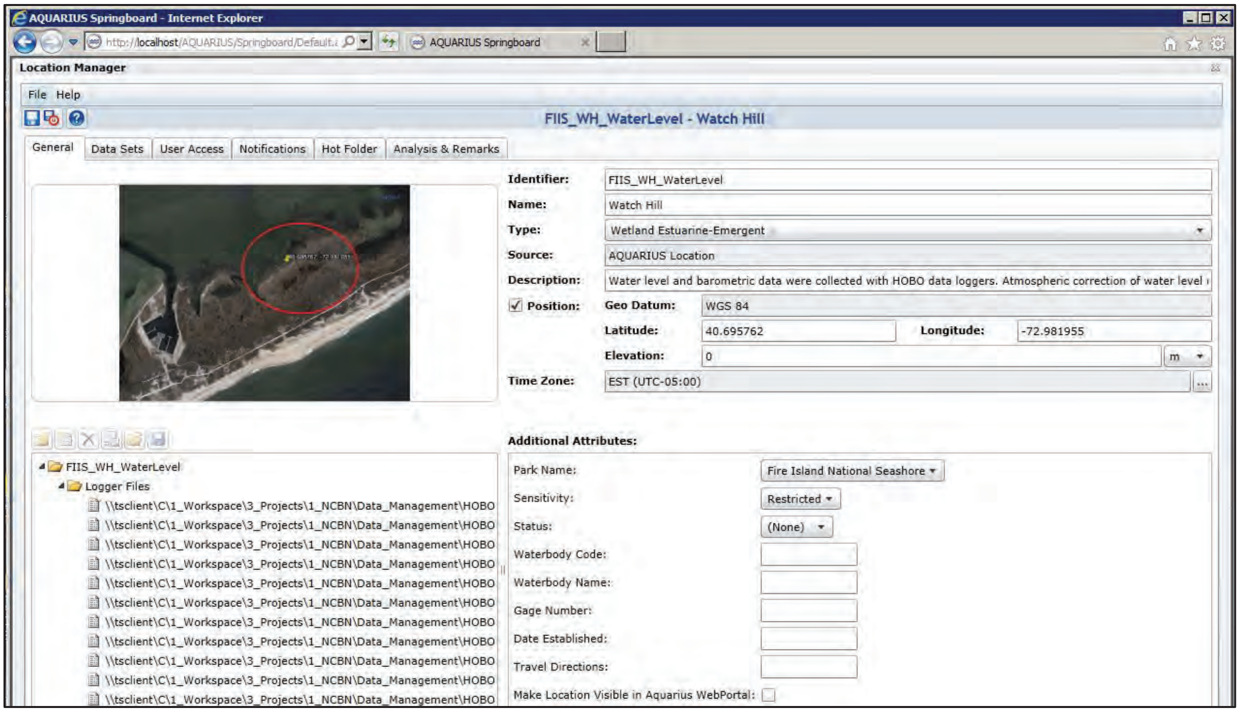


Figure 8. Completed Aquarius Springboard Location Manager window.

4.4.3 Appending data

In Aquarius terminology, the term "append data" can be thought of as "import data" into an Aquarius Location. In our case, we will be "appending" HOBO® csv data files into Aquarius Locations. To begin, select a monitoring location from the list of locations, and a number of the icons on the top of the form will become active. To append data, click on the folder icon, outlined in red below (Figure 22), or right-click a location and select "Append Logger File" from the drop-down menu.

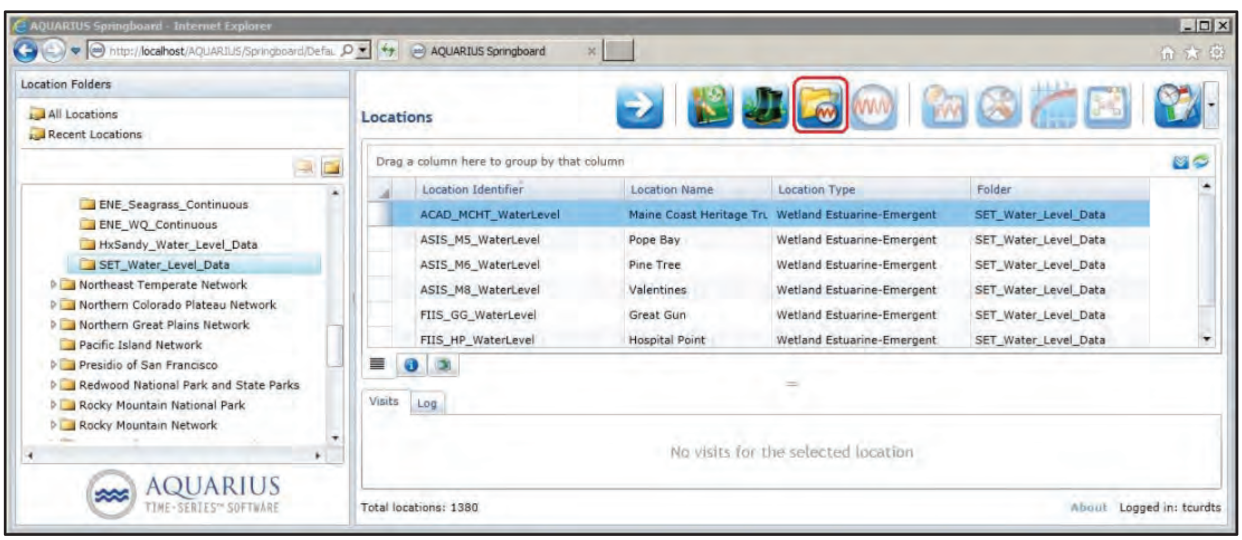


Figure 9. Aquarius Springboard location list.

This will open the *Append Logger File Wizard*. If you don't see the window, check behind other windows since it doesn't always open on top. Select the logger file that you want to import (.csv file that was exported from HOBOware Pro) by clicking on the ... button on the right side of the *Logger File* box (Figure 23, Step 1A) and navigating to the file location.

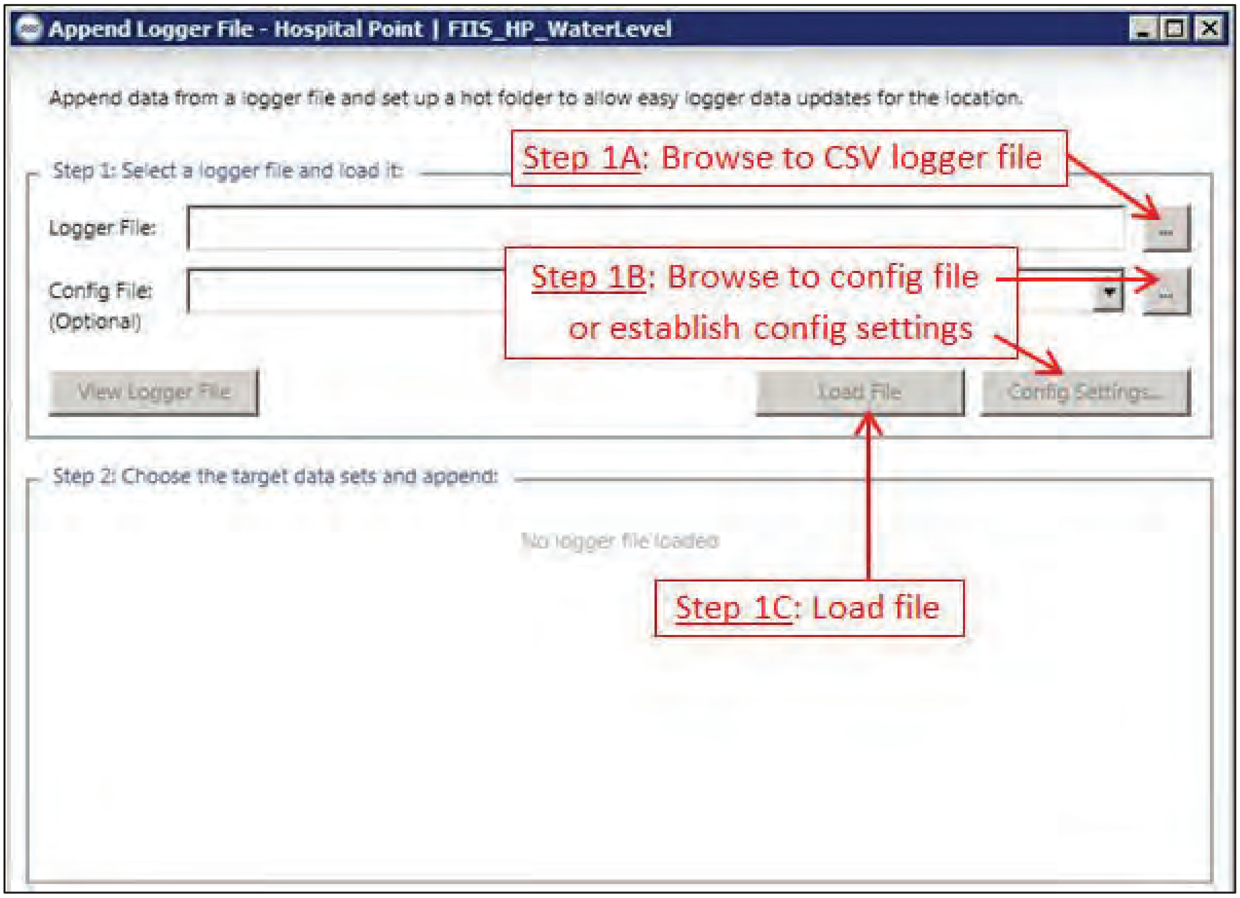


Figure 10. Aquarius Springboard Append Logger File Wizard.

Once a .csv file is selected you will need to either select an existing configuration file or configure the data upload settings. If you select an existing configuration file, it will appear in the *Config File: (Optional)* box. Click *Load File* to continue to Step 2.

If you don't already have a configuration file, you will have to manually configure the data upload settings. The following steps will walk you through the configuration wizard:

Step 1: Define the configuration settings

If this is the first time you are appending data, then you will need to establish the configuration settings. Click the Config Settings button (Figure 23), which will open the "Step 1 of 4" window of the Import From File Wizard (Figure 24). First, you must indicate the data type. The default setting is Time Series with a data type of Text File. These settings will work for almost all of the data we will be using, so there is no need to change these. Click the Next button.

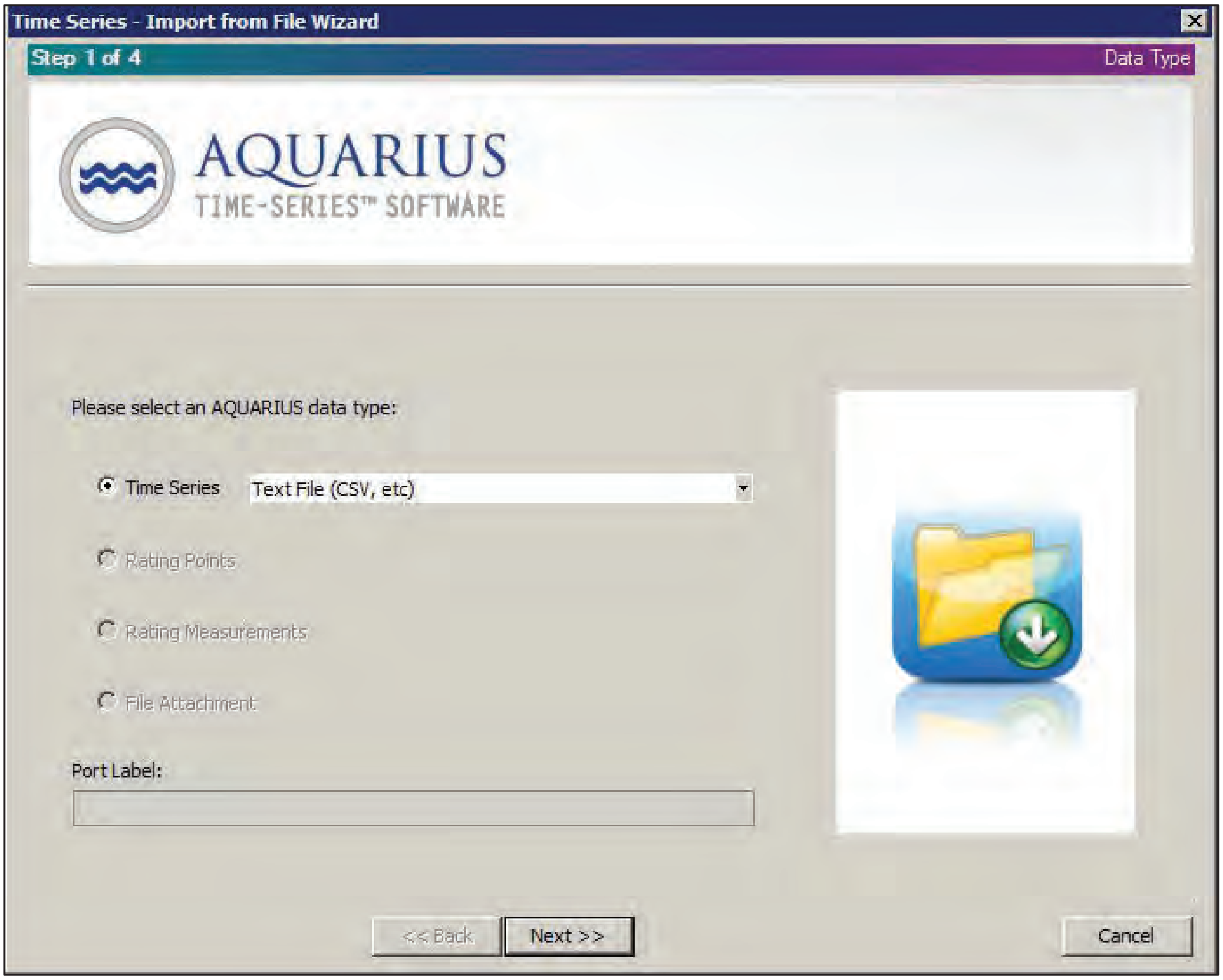


Figure 11. Aquarius Springboard Append Data: select file type.

Step 2: Define the configuration settings for the data table

Determine where the data values begin in the file and how many header rows you want to include by adjusting the values in the two fields circled in red in Figure 25. If your HOBO® export settings are the same as those shown in Figure 4, you should start import at row 3 and have 2 headers (Figure 25). Changing these values will adjust how the data are viewed in the window and which data will be imported.

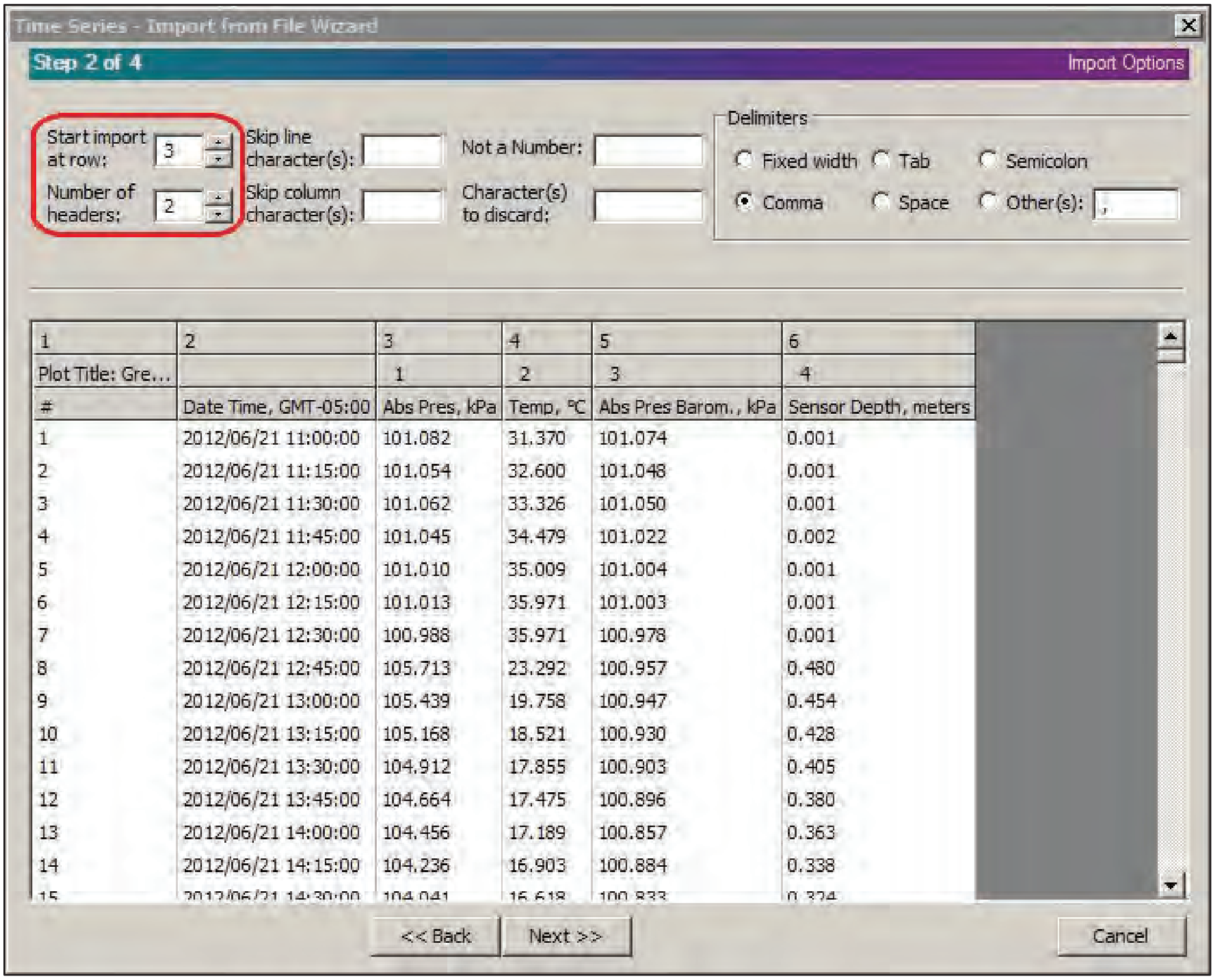


Figure 12. Aquarius Springboard Append Data: define first data row.

Step 3: Define the configuration for each data field

For a HOBO® file that has been atmospherically compensated, as described in Section 4.3.3, there should be five relevant parameter fields to configure and append (import):

1. Date/Time
2. Abs Pres (absolute pressure)
3. Temp (water temperature)
4. Abs Pres Barom (barometric pressure)
5. Sensor Depth (calculated during atmospheric correction)
   This assumes the HOBO® file was exported with the same settings shown in Figure 4.

Highlight the field you want to configure by clicking on the header at the top of a column. Using the radio buttons, users can choose to define the selected column as a Date/Time field, as Raw Data, or Skip importing that data field (Figure 26). The first column (#) can be skipped.

For the second column, click the browse icon (...) next to the *Date/Time Format* box and select the *yyyy-mm-dd HH:MM:SS* format from the resulting drop-down menu (Figure 26). If the date/time field in your data set is formatted differently, and there is not an exact match between your data format and the options in the drop-down menu, you can create a custom format to match your data by typing the desired format in the *Date/Time Format* box. Finally, verify that your time zone is correct. For NCBN, use UTC-5:00 (Eastern Standard time zone).

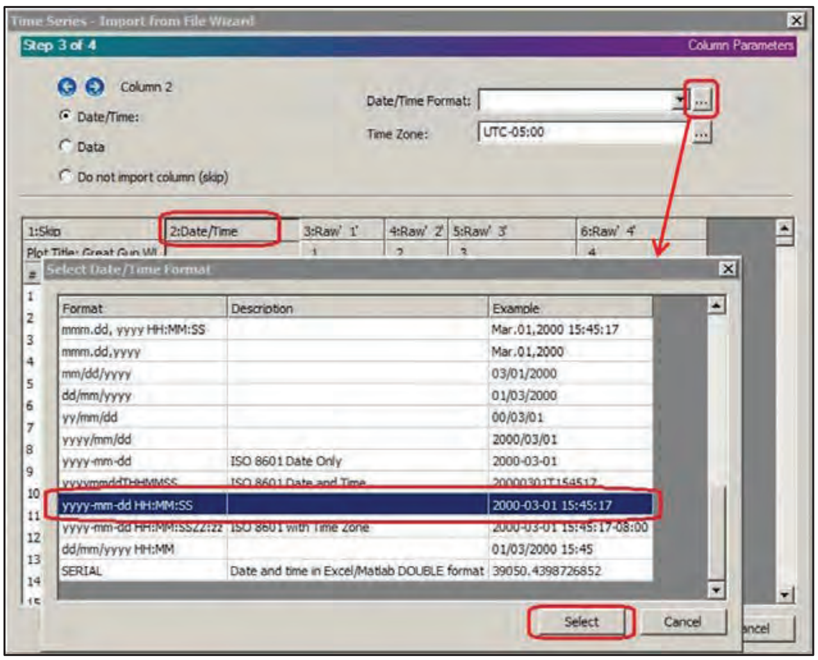


Figure 13. Aquarius Springboard Append Data: select the Date/Time format.

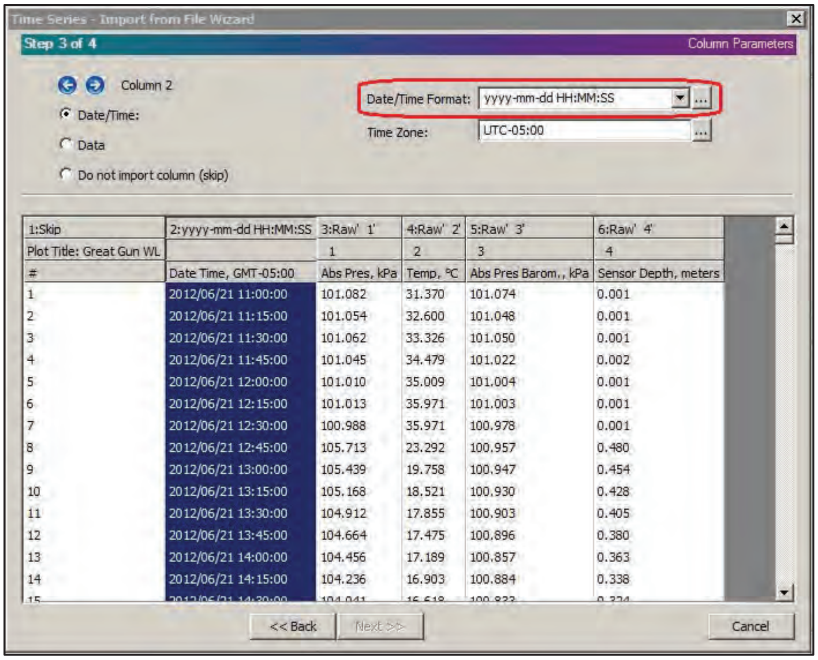


Figure 14. Aquarius Springboard Append Data: Date/Time format selection results.

When formatting non-date fields for all data parameters, make sure that the radio button on the left, next to *Data*, is selected and that the type of data is *Raw*. These should be the default settings when selecting a new field (Figure 28).

The first data field should be Absolute Pressure. Select a parameter for the data field by either clicking the black triangle ( ) on the right side of the *Parameter* box and selecting a pre-existing entry from the resulting drop-down list, or by clicking the button to the right of the black triangle, and selecting the correct parameter. After the parameter is selected, make sure that the *Units* and *Gap Tolerance* fields are filled in correctly.

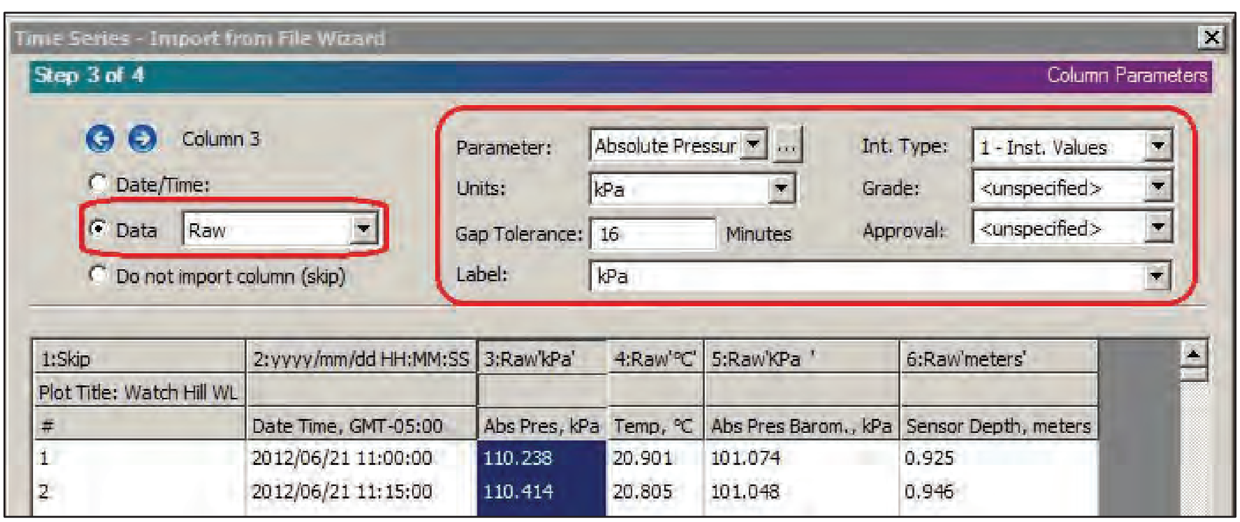


Figure 15. Aquarius Springboard Append Data: absolute pressure format.

The *Gap Tolerance* should be set one minute larger than the data collection interval. For example, for a data set with a 15-minute collection interval, enter 16; for a 6-minute interval, enter 7, etc. The *Gap Tolerance* defines how much time can elapse between consecutive measurements before Aquarius will identify a "gap" in the time series. You could define the gap tolerance to the exact data collection interval, but if your clock is off by even a second, the software will insert a gap marker. It is better to set the gap tolerance one minute higher so these isolated occurrences will not be considered a 'gap' in the data. For additional information on the complexities of *Gap Tolerance*, refer to Dean Tucker's Aquarius Frequently Asked Questions.

The *Label* field allows the user to enter an additional descriptor for that data field. Note that the values for the *Parameter* and *Label* fields, plus the *Location Name*, will be concatenated to form the *Data Set ID*. For this reason, it is a good idea to use the *Label* field for a specific modifier and not use a term that will be redundant with the *Parameter* field. Units of measure are suggested for the *Label* value. For example, for the *Absolute Pressure* parameter, insert *kPa* in the *Label* field.

The *Absolute Pressure* column should be formatted as shown in Figure 28. Continue to define columns 4 through 6 (*Temperature*, *Absolute Barometric Pressure*, and *Sensor Depth*) as shown for the *Absolute Pressure* column. Suggested settings for these columns are shown below in Table 2.

Table 2. Parameters for Aquarius configuration file.

Column	Parameter	Units	Gap Tolerance	Label	Int. Type
3	Abs Pressure	kPa	16 *[or logging interval + 1]*	kPa	1 - Inst. Values
4	Water Temp	°C	16 *[or logging interval + 1]*	°C	1 - Inst. Values
5	Atmos Pres	kPa	16 *[or logging interval + 1]*	kPa	1 - Inst. Values
6	Depth	m	16 *[or logging interval + 1]*	meters	1 - Inst. Values

Once all the columns are defined, click the *Next* button at the bottom of the "*Step 3 of 4*" window. This brings up the "*Step 4 of 4*" window (Figure 29). During the configuration process, users should have established a gap tolerance, and should select the *Apply Gap Processing Tolerance* radio button. Users are also given the option to save the configuration settings as a configuration file. The configuration file can be used in the future to avoid having to go through the configuration setup process again. This will save time when appending (importing) data files that have the exact same configuration, whether you append the data using Aquarius's *Append to Logger* tool or Hot Folders (Section 4.4.4). The default name for the configuration file is the name of the input csv file with a .*cfg* extension. Configuration files are parameter and format specific, so it is a good idea to include parameters (such as data type and collection interval) in the configuration file name. In the examples below, *WL* stands for water level and the logging interval is indicated by *06min* or *15min*. Click *Finish*.

Config_HOBO_WL_06min.cfg
Config_HOBO_WL_15min.cfg

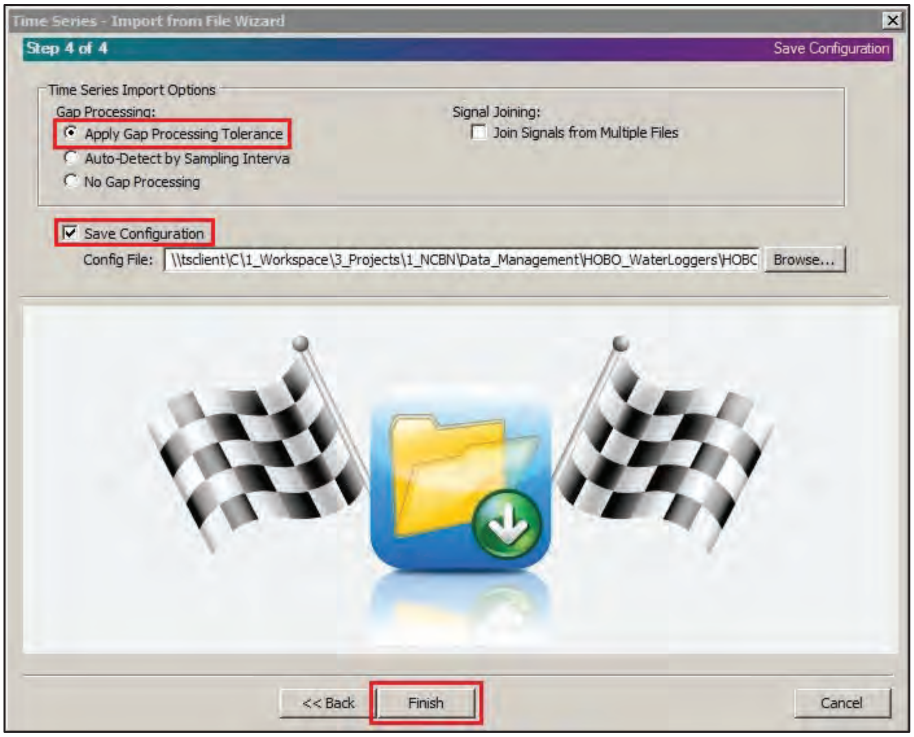


Figure 29. Aquarius Springboard: complete the Append Data Wizard.

Step 4: Complete the append process

After completing the wizard, the data parameters selected for appending appear on the Append Logger File form (Figure 30)[3]. Users have the option to append (Create New Time Series or Append to an Existing Time Series) or ignore data sets (Do Not Append), by selecting the appropriate option from the drop down menu in the Append To column. If this is the first time to append data for this particular location, choose "Create New Time Series". Subsequent append operations for this monitoring location would use "Append Logger File." Click the Append button to complete the append process.

[3] If you selected an existing configuration file instead of using the *Import from File Wizard*, you will have to click the *Load File* button before the data parameters appear on the *Append Logger File* form.

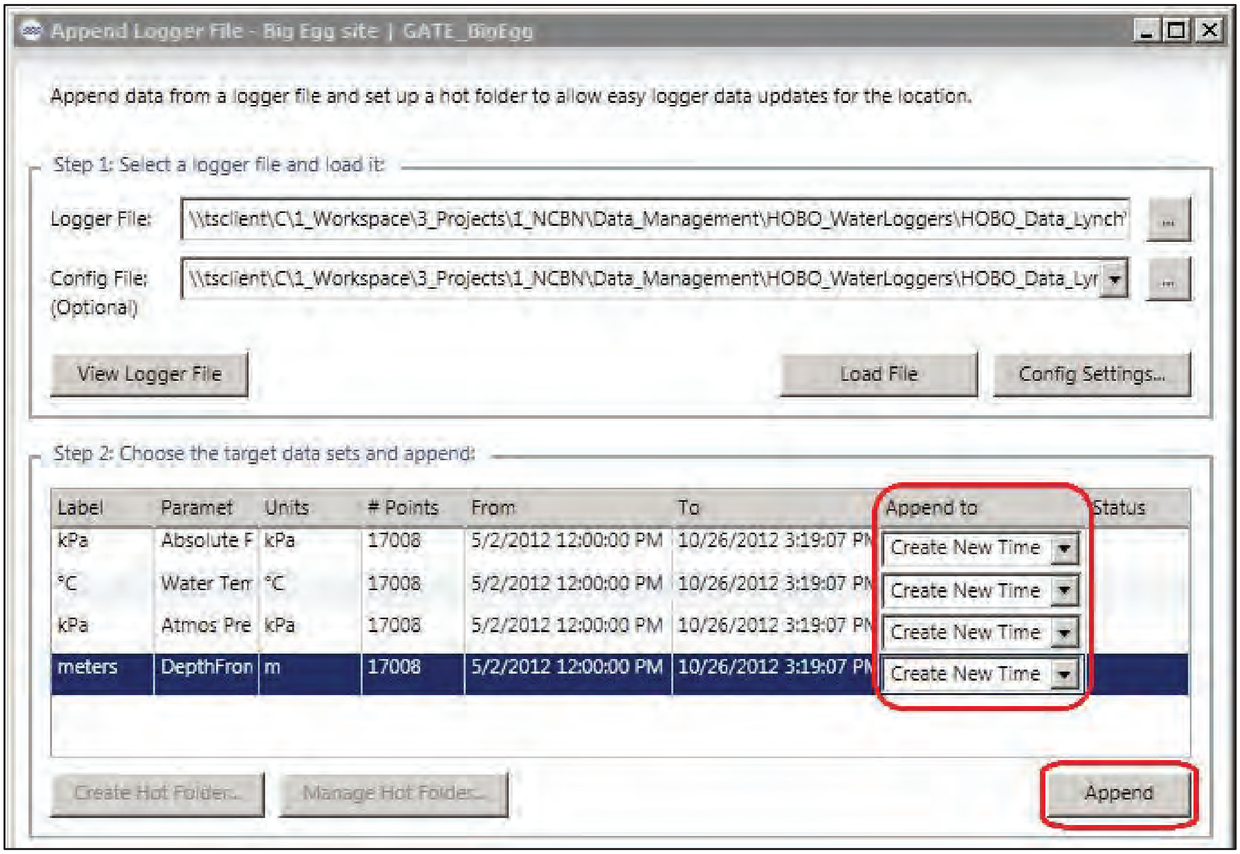


Figure 16. Aquarius Append Logger File window.

Once the append process is complete, a confirmation message will appear (Figure 31) and the *Append History* at the bottom of the form will be updated to reflect the append action that just took place. If users realize a mistake occurred, they can choose to "undo" the append action for a specific data set. Closing the *Append* form will return users to the main Springboard form.

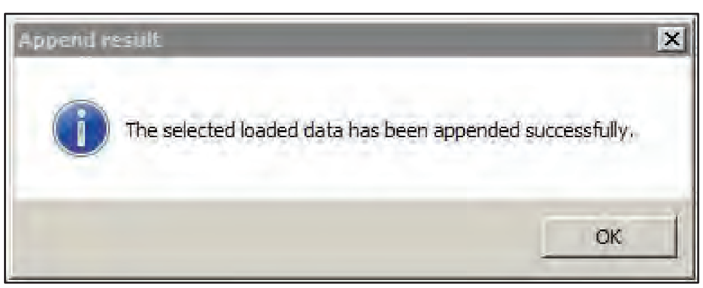


Figure 17. Append confirmation message.

For plotting and analytical purposes, appended data sets can be accessed by selecting a location and then clicking the big blue right-pointing "Go to Data Sets" arrow (Figure 32). General information about data sets can be accessed via the *Location Manager*.

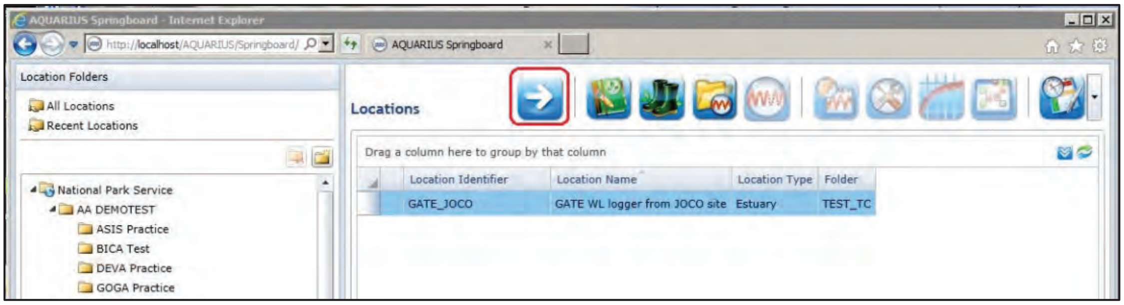


Figure 18. Go to Data Sets button.

4.4.4 Hot Folders

Another means of appending data to existing data sets in Aquarius is to use Hot Folders. Hot Folders are site-specific but once they are established, users can drag and drop data into the hot folder like a user would copy data from one folder to another. Once Hot Folders are established, users can append data to Aquarius data sets without ever starting Aquarius. For detailed written and video instructions on setting up Hot Folders, see Dean Tucker's file at http://nrdata.nps.gov/programs/water/aquarius/Docs/Hot_Folders.pdf.

After the Hot Folder is created, the user will need to map the Hot Folder location as a network drive using the following address: \\INP2300FCVGETT1\AQUARIUSHotFolders

Once the Hot Folder has been mapped, select and open the site-specific Hot Folder (which includes an Aquarius icon).

After dragging the .csv file from the network drive to the Hot Folder, Aquarius will process it and the file will automatically be moved from the root of the Hot Folder to either the "Succeeded" sub-folder (indicating a successful append) or the "Failed" sub-folder (indicating a problem) (Figure 33). Once the file has been processed, Aquarius produces a log file that documents what occurred during the appending process. If the Hot Folder transfer failed, review the log file to try and determine the reason for the failure.

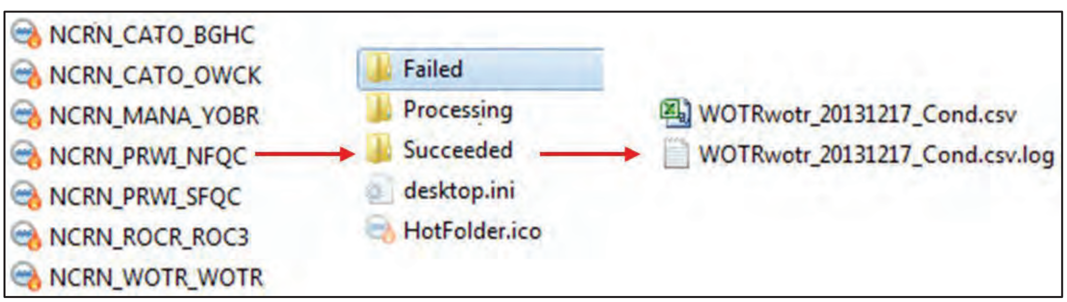


Figure 19. Hot Folder processing results.

Note that appending data via Hot Folders only appends the data. Details about field visits are not created. Users will need to log into Aquarius in order to document their field visits.

4.4.5 Data correction

Examine your data for any obvious errors or anomalies such as data gaps, spikes or flat-lines. In some cases, the cause of a data anomaly may be readily apparent, but in many cases substantial professional experience and judgement are necessary to correctly interpret and/or appropriately correct any perceived data anomalies. Erroneous data can have many causes, including equipment damage or failure, low battery voltage, biofouling, or exceedance of sensor thresholds. Data can be examined with a variety of tools in either graphic or tabular format, but the actual data-editing should be done using the Aquarius *Data Correction Toolbox*. The toolbox offers a variety of tools for correcting data, deleting data regions from analysis, setting data approval levels, undoing corrections, etc. (Figure 34). Aquarius always preserves the original data, while allowing you to make corrections (e.g., mark and delete data tails from analysis), and it documents all of the corrective actions that have been applied to the data.

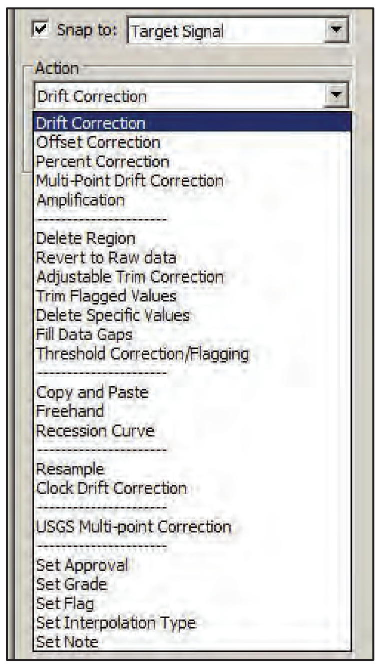


Figure 20. Aquarius Correction Control tools.

<u>4.4.5.1 Trim pre- and post-deployment tails</u>

The most obvious data anomalies that can and should be removed are the beginning and end “tails” of data that are collected when the logger is out of the water, before and after a deployment period (Figure 35). It is good practice to begin data logging before the logger is deployed in the field location. It is also helpful to let the logger continue to log data for a short time after it has been retrieved, post-deployment. These data tails that indicate periods of non-submersion are to be expected and it would be unusual to see similar discrete anomalies at the beginning and end of a data series that were caused by anything other than exposure to the air. These tails should be trimmed from the data before analysis.

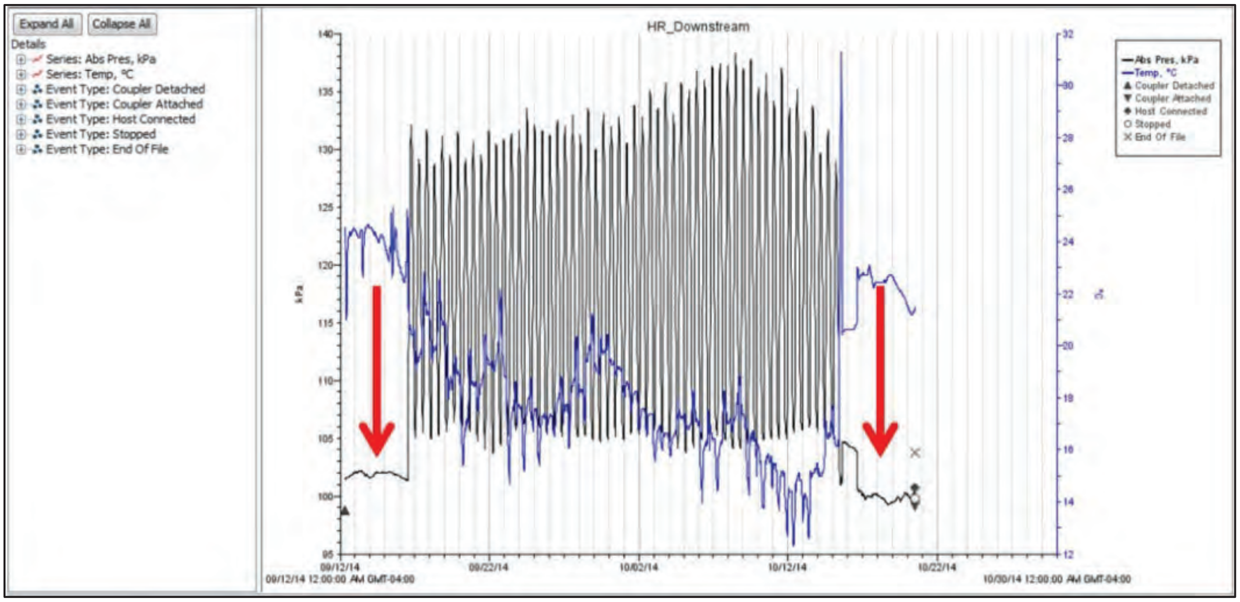


Figure 21. HOBOware Pro plot showing pre- and post-submersion data tails.

To open the Aquarius *Data Correction Toolbox,* click on a data set to select it, and then either right-click it and select *Data Correction*, or left-click on the *Data Correction* icon ( ).

The *Data Correction* tool (Figure 36) is a busy series of window panes that you can customize by turning on and off, moving, and/or resizing. To summarize, you use the graph pane (#1) and/or *Time Series Grid* pane (#2) on the right (default settings) to select the data to work with, or to view the results of previous corrections. Corrections are applied using the *Correction Control* pane (#3) on the left. You can see the changes in summary/list form at the bottom via the *Change List* pane (#4) and its various tabs. If the screen does not appear as depicted below, choose *View* / *Go to default layout* from the main menu and then click the first tab (*Ch…*) in pane #4 so it shows the *Change List*, rather than the *Overview*.

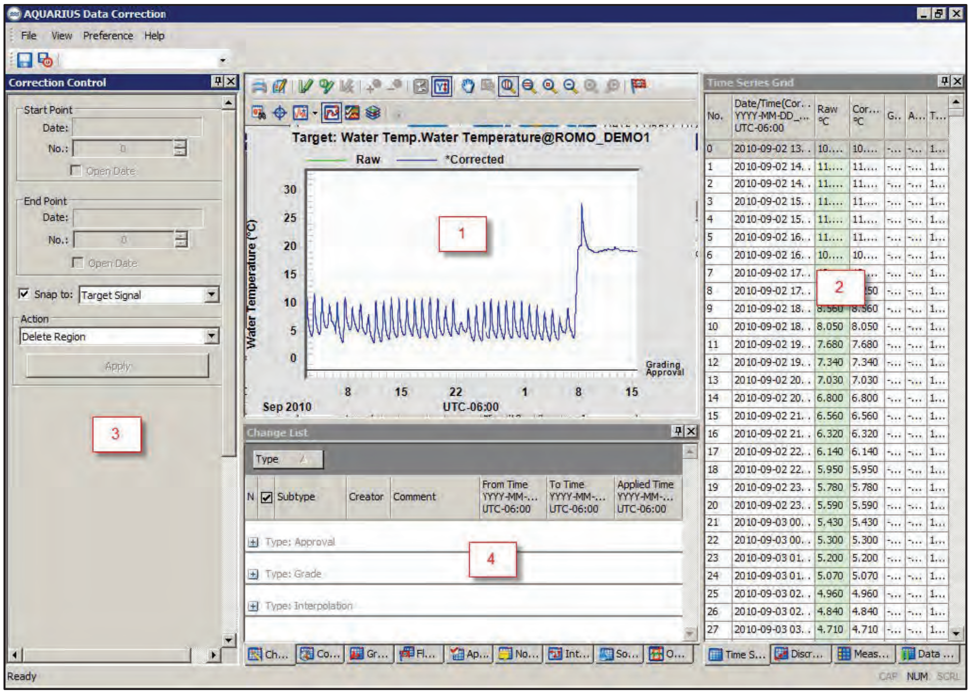


Figure 22. Components of the Aquarius Data Correction tool.

To trim a data tail, first select the appropriate block of data using the *Mark Region* tool (Figure 37). You can select records either from the graph or the *Time Series Grid* by clicking the first record, then shift-clicking the last record. The selected data records are highlighted in dark blue in the *Time Series Grid* and in cyan in the graph (Figure 37).

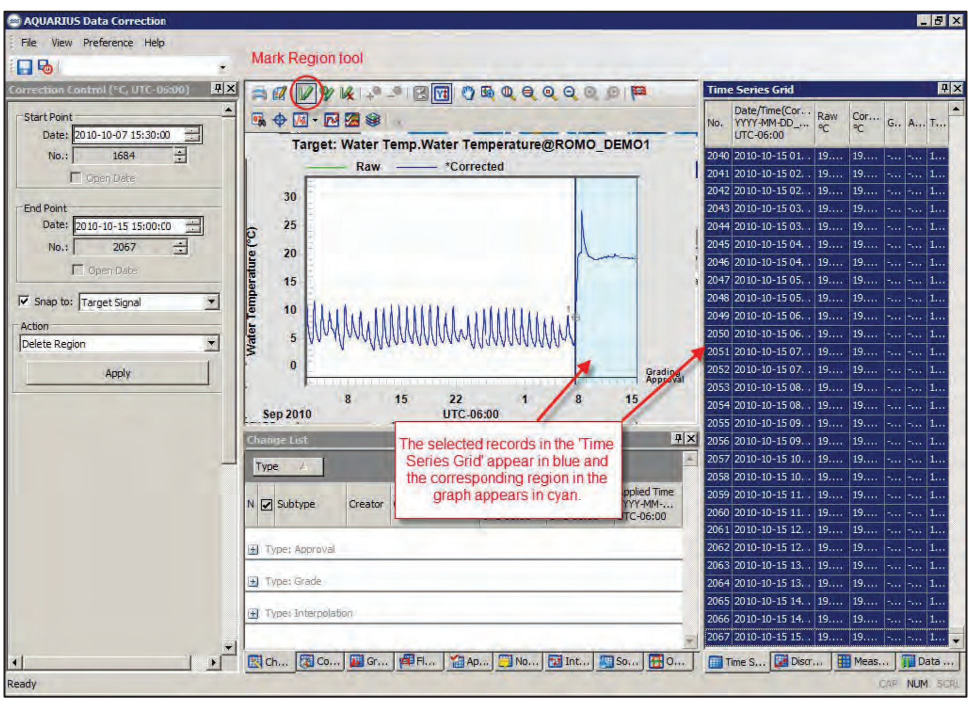


Figure 23. Records selected with the Mark Region tool.

Once you have the desired area selected/highlighted, use the *Action* combo box in the *Correction Control* pane to select 'Delete Region' and then click the *Apply* button to actually apply the action (Figure 38).

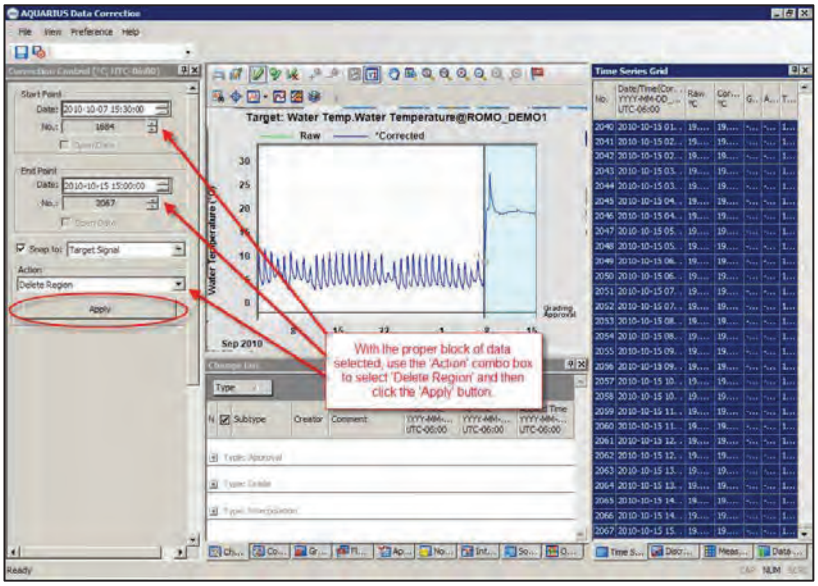


Figure 38. Applying the Delete Region correction.

Aquarius will display an 'Apply Correction' form (Figure 39) and allow you to attach a new comment (or retrieve a saved one) to the correction. Enter 'Sensor out of water' in the *Comment* area. Click *OK* to finalize the *Delete Region* correction.

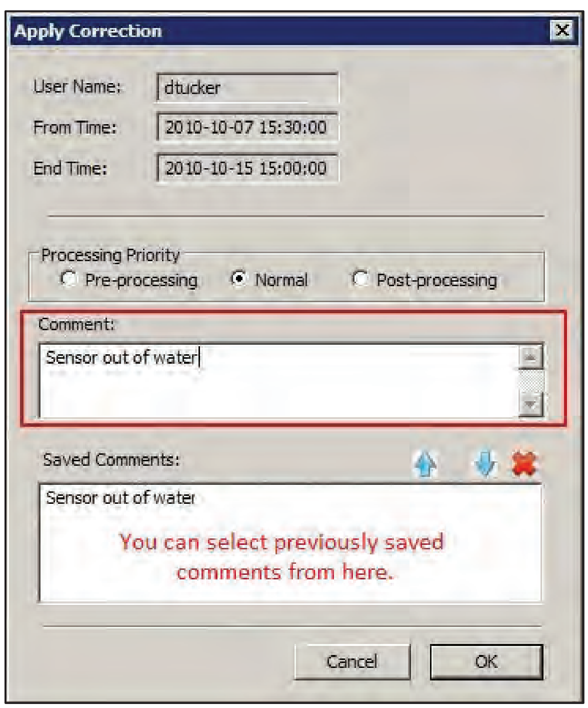


Figure 39. Aquarius Apply Correction window.

The *Data Correction* toolbox 'deletes' the data. Notice in the graph in Figure 40, the portion of the time series that was 'deleted' appears as a green line since it is still part of the 'Raw' (original) data. Aquarius doesn't actually delete or change the original data. The corrected time series is the blue line. In the *Time Series Grid*, notice that the raw/original data values are still all there and are in green-shaded cells. The adjoining corrected column now shows the word 'Empty' next to raw data that has been 'deleted'. Note the information about the *Delete Region* operation that appears in the *Change List* window at the bottom of the form. You can use the check box to toggle the deleted region on or off to restore it to the corrected signal if desired. Aquarius only maintains the raw data stream. It generates the corrected data stream on the fly by applying the user specified corrections.

There is currently not a way to apply corrections to multiple data sets (time series) simultaneously. You will have to repeat the above tail-trimming correction process for each individual data set (e.g. absolute pressure, water temperature, atmospheric pressure and water depth). The beginning and end of data tails are not always obvious and well-defined. To insure that the exact same records are trimmed from each data set, examine each data set and determine the record numbers (first column in *Time Series Grid*) that define the tails. Use the same record numbers to define the regions to be deleted for each data set. It is possible that a future version of Aquarius will permit simultaneous corrections to multiple data sets.

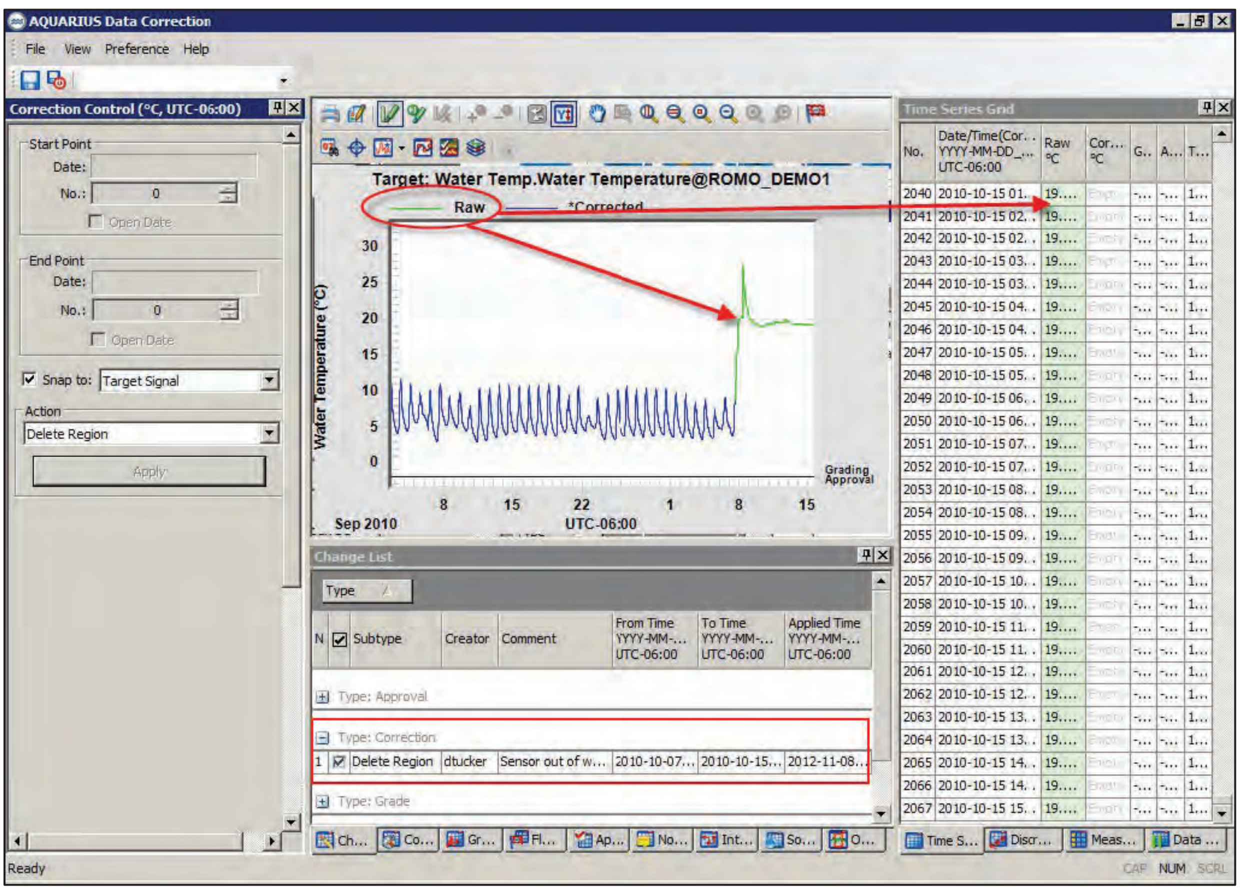


Figure 24. Aquarius corrected data.

4.4.5.2 Other types of anomalies

Similar data anomalies can also occur mid-deployment if the logger is exposed to the air (e.g. during low tides) (Figure 41). Not all anomalies will require correction. Additional reference water level measurements made during the deployment can help determine whether data anomalies indicate actual rapid changes in water temperature or pressure, if they are due to the logger being exposed and recording air temperature and pressure, or if they indicate a logger malfunction.

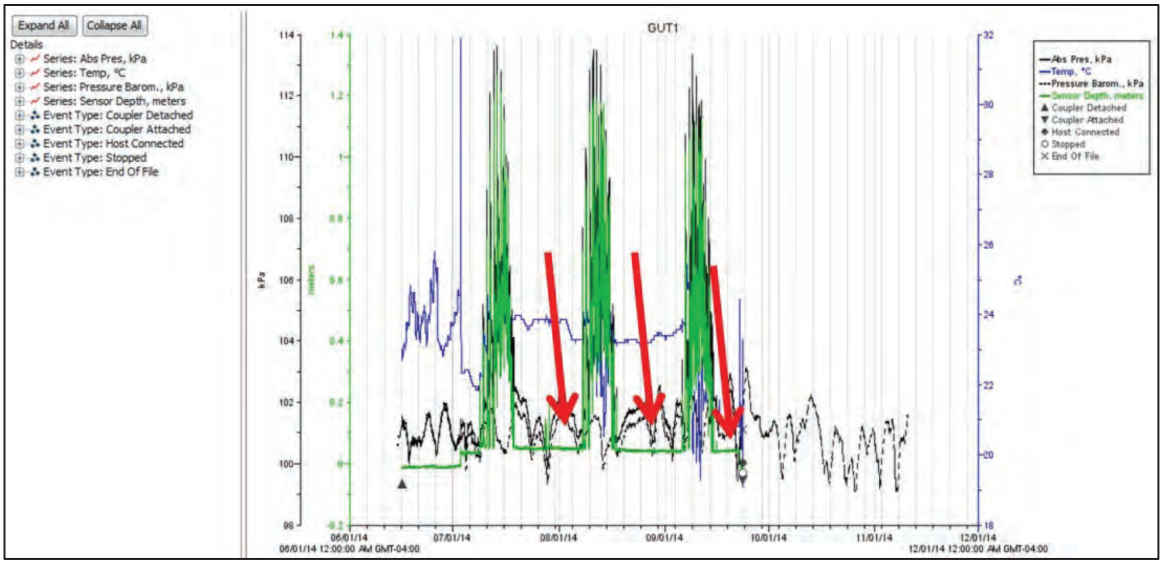


Figure 25. HOBOware Pro plot showing data anomalies (see red arrows) due to tidally induced atmospheric exposure.

Figure 42 shows an example of data from an instrument that malfunctioned. This illustrates the importance of a bucket test (Figure 2) to insure that the logger is functioning properly before deployment.

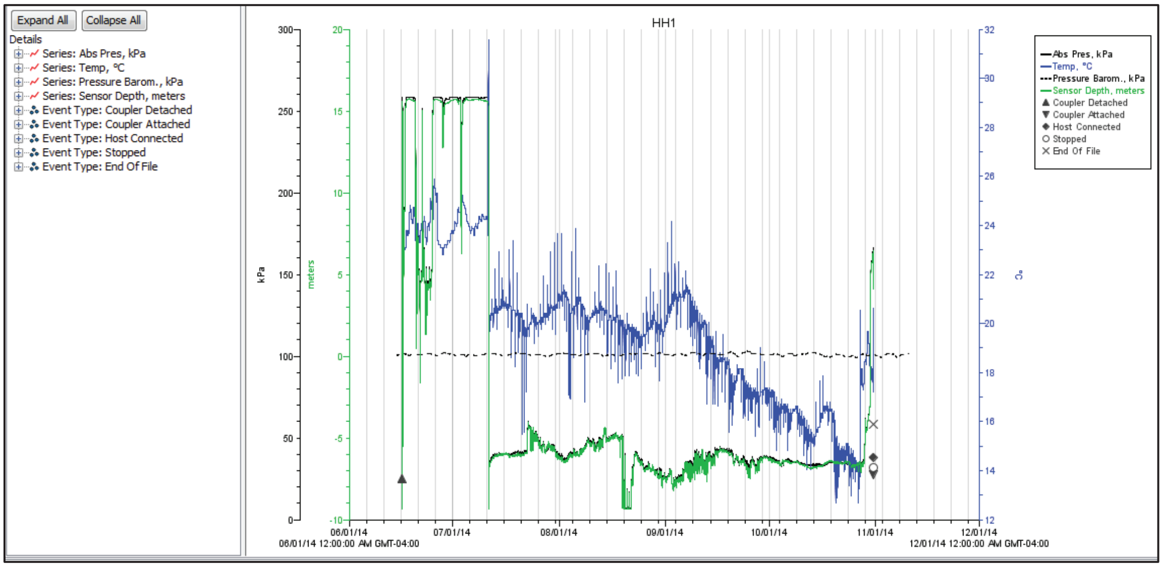


Figure 26. HOBOware Pro plot showing data anomalies due to instrument malfunction.

4.4.5.3 Sensor drift

All pressure sensors are subject to drift over time. Drift is a gradual change of the signal response to an identical stress over time, and is quantifiable through manual reference measurements at the beginning and end of deployments. For example, assume that the water level remains constant at 1.0 feet, and that the data logger records the water level once a day for 10 days, and that the recorded water level after 10 days is 1.1 feet. The drift is 0.1 feet. Compensation for drift is accomplished by prorating the differential between the recorded water level and the measured water over the monitoring period. In this case, the water level would be adjusted by 0.01 feet per day to have a total correction of 0.1 feet after 10 days.

If the reference level is at the beginning of the time series, then the maximum drift correction occurs at the end of the data file. The time ratio should start at 0 and increase to 1. The time ratio is calculated as:

$$ratio = \frac{current\ time - start\ time}{end\ time - start\ time}$$

where *current time* is the only variable. *Start time* and *end time* are constant values.

If the reference level is at the end of the time series, then the maximum drift correction occurs at the beginning of the data file. The time ratio should start at 1 and decrease to 0. The time ratio is calculated as:

$$ratio = \frac{end\ time - current\ time}{end\ time - start\ time}$$

where *current time* is the only variable. *Start time* and *end time* are constant values.

In both cases, the drift correction is the time ratio (a number between 0 and 1) multiplied by the total observed drift (the difference between the measured and recorded water level).

An example of drift correction is illustrated in Figure 43 and Figure 44. In these figures, the blue line indicates the recorded water levels and the red dots indicate the manual reference measurements. The beginning water level measurement on May 20 was used as the reference level for the dataset in Figure 43, and anchors the data at the start of the file to that measurement. The calculated water level measurement is off by nearly 0.2 feet by the end of the dataset.

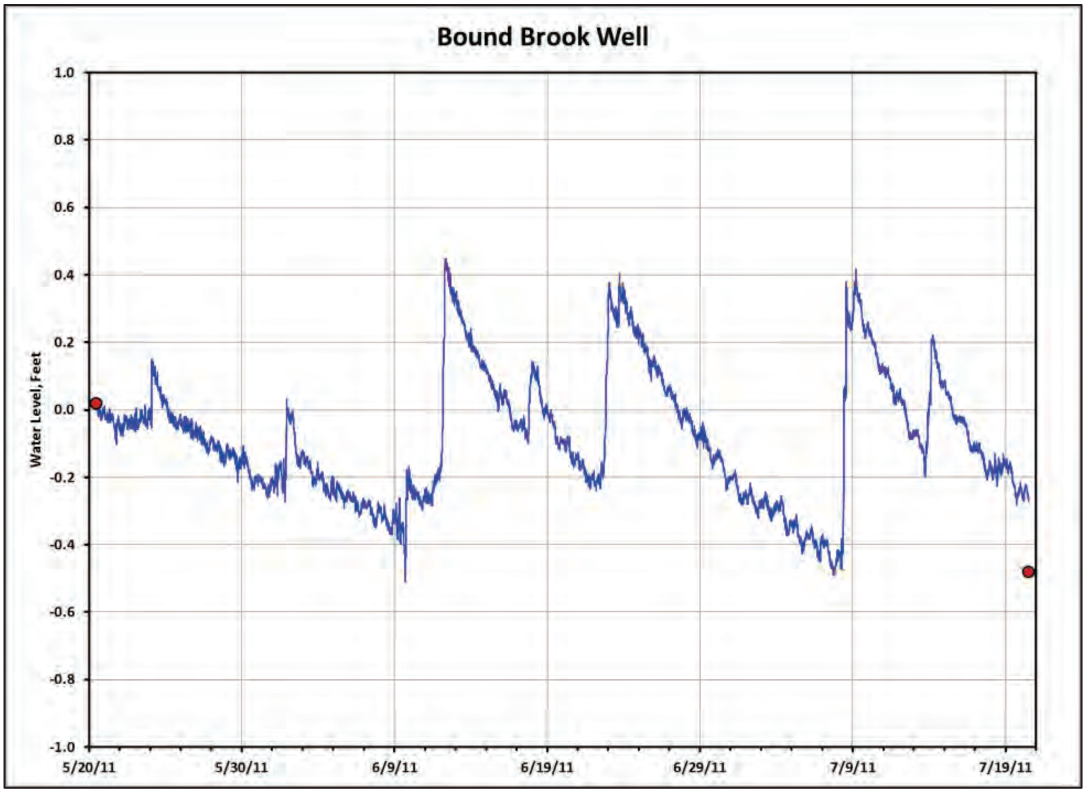


Figure 27. Graph of water level data before correcting for drift.

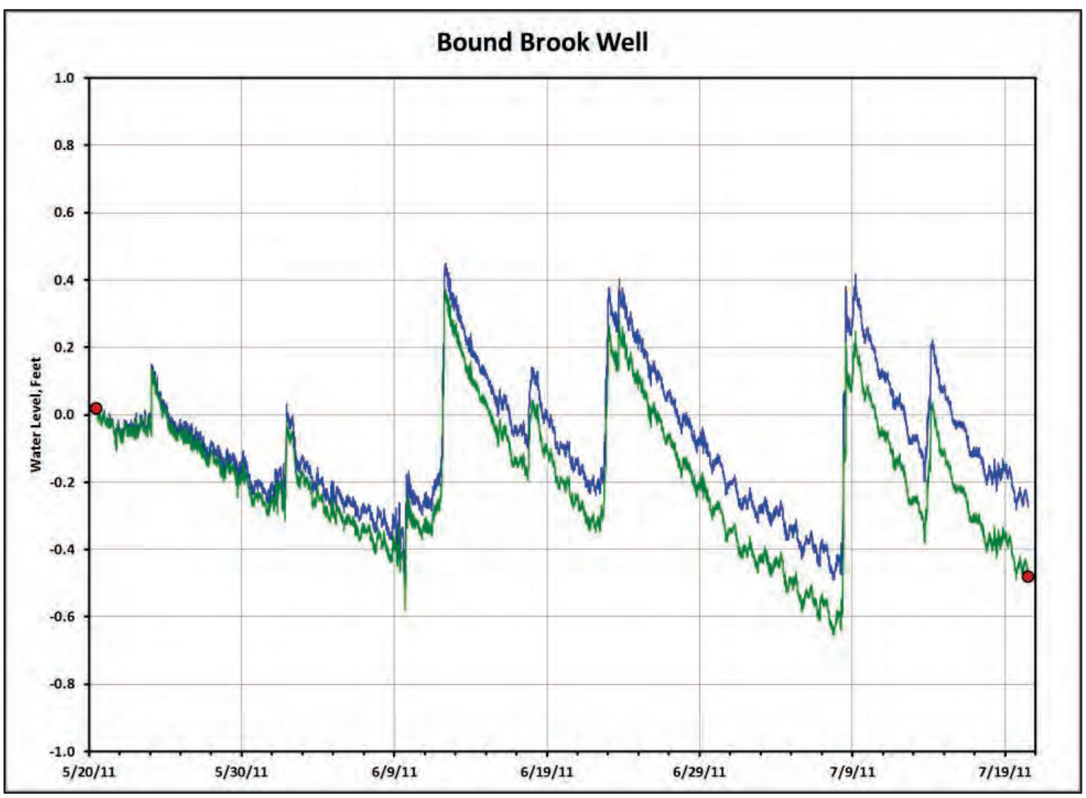


Figure 28. Graph of water level data after correcting for drift.

In Figure 44, the blue line indicates the recorded water levels, the green line indicates the corrected water levels, and the red dots indicate the manual reference measurements. The initial reference level measurement acts as a hinge or pivot point. The measurement error and drift are prorated over the monitoring period, forcing the final recorded data to match the water level measurement on July 20.

The Aquarius *Correction Control* pane contains two drift correction tools: the simple *Drift Correction* tool and the *Multi-Point Drift Correction* tool (Figure 34). You should have at least two reference measurements, one at the beginning and one at the end of a deployment period. Ideally, additional reference measurements will be obtained during the deployment period. If you have two or more reference measurements, choose the *Multi-Point Drift Correction* tool. A short video about using the *Multi-Point Drift Correction* tool, provided by Evan Baddock, can be seen at http://bit.ly/1Jejnix.

Select the block of data to which you wish to apply the drift correction, using the *Mark Region* tool ( Figure 37). The *Multi-Point Drift Correction* tool includes a *Pivot Points* table. The pivot point table is initially populated with the *Time/Date* values for the first and last records of the selected data block. If you have additional reference points, add them to this table using the *Add Pivot Point* button ( Figure 45). After selecting this icon, click in the graph at the approximate date/time that the field reference measurement was made. A crosshairs icon will appear on the graph and a new record will be added to the pivot points table. Edit the *Date/Time* value of the newly added point to match the exact time the reference measurement was made. The *Difference* values must be populated manually, and are determined by comparing the reference measurements to the logger readings with the corresponding time stamps. Note that after the *Difference* values are populated, dotted lines appear on the graph giving a preview of the pending data correction. After all pivot points are added to the table and populated with difference values, check to see that the *Snap to: Target Signal* box is checked and that *Adjustment* method is set to *Linear* and the *Adjust Step* is 0, as indicated in the red box in the left of Figure 45. Click the *Apply* button.

The Aquarius *Apply Correction* form (Figure 39) will appear and allow you to add a new comment (or retrieve a saved one) to the correction. The *Comment* box will contain the values from your pivot point table. Type "Adjusted to reference measurements" in the *Comment* box. Click *OK* to finalize the *Multi-Point Drift Correction*. The data values in the graph and *Time Series Grid* will be corrected for the selected data block. The raw (original) values appear as a green line in the graph and in the green highlighted *Raw* column in the *Time Series Grid* (Figure 46). Corrected values appear as a black line in the graph, and in the *Corrected* column in the *Time Series Grid*.

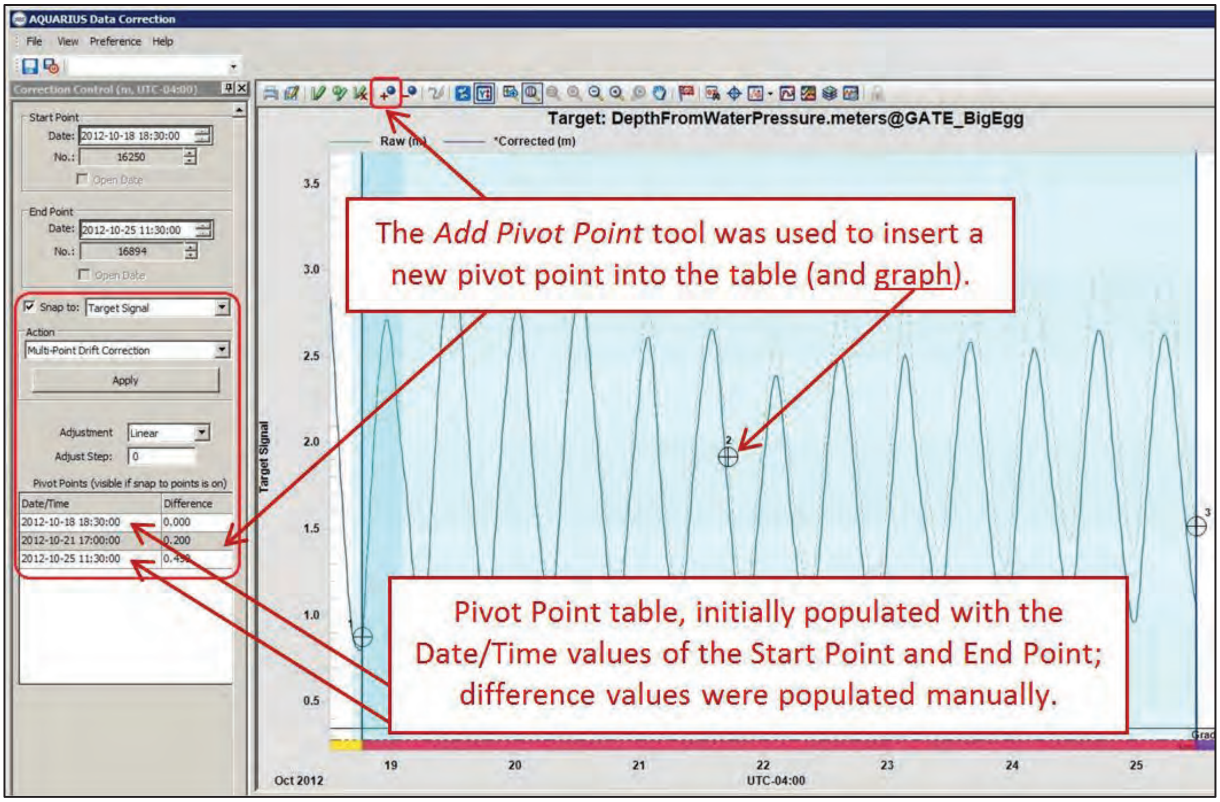


Figure 29. Aquarius multi-point drift correction tool.

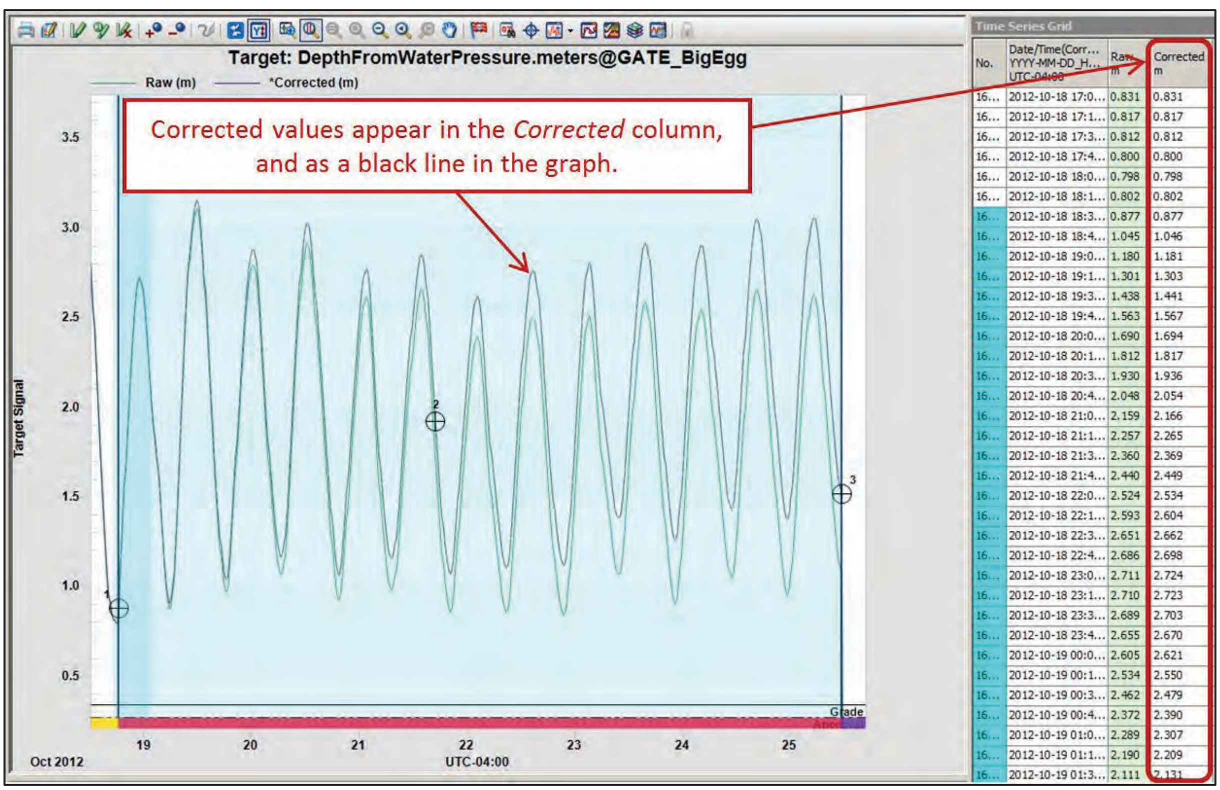


Figure 30. Aquarius drift correction control results.

4.4.6 Calculating marsh flooding events and tidal statistics

Two derivative products that we want to calculate from the atmospherically compensated water level data are 1) marsh flooding events (frequency and depth) and 2) tidal statistics (e.g. mean high water (MHW) and mean low water (MLW)). For years, this information has been calculated using a Microsoft Excel spreadsheet. New custom reporting tools, recently developed by Aquatic Informatics and Dean Tucker, allow us to calculate the tidal averages and flood events within Aquarius.

4.4.6.1 Calculate marsh flood events, depths and durations

If the elevation difference between the sensor and the marsh surface is known, depth and duration of local marsh flooding events can be determined. To determine the sensor-to-marsh distance, two measurements are needed:

1. The distance between the sensor connection point (CP) and the sensor
2. The distance between the CP and the marsh surface

Sensor to Marsh Distance = CP to Sensor – CP to Marsh

By subtracting the *Sensor to Marsh Distance* from the atmospherically compensated water level measurements, we can derive the water level relative to the marsh surface for every reading collected by the data logger. Negative values indicate water levels below the marsh surface and positive values indicate water levels above the marsh surface, or flooding events (see Figure 47).

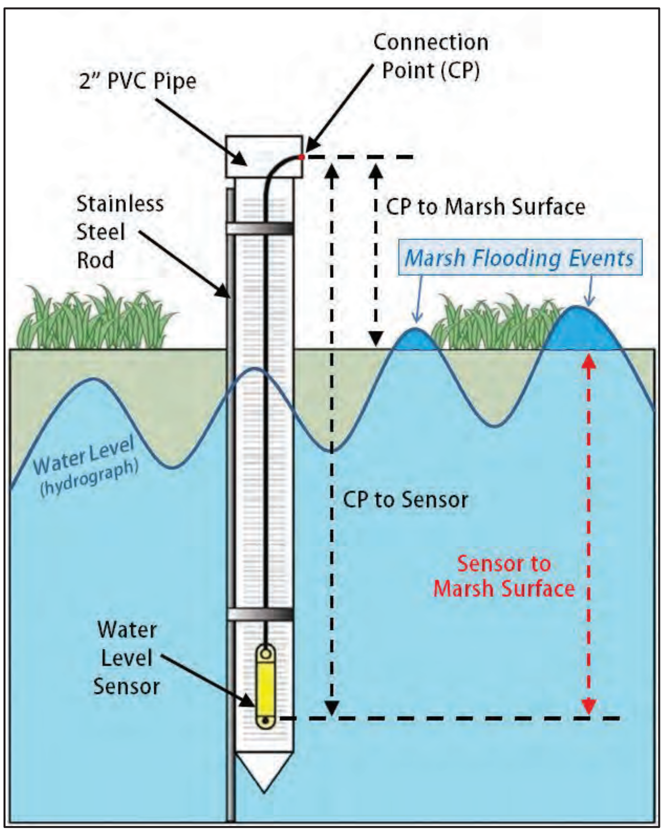


Figure 31. Well diagram showing sensor to marsh distance and flooding events.

We can calculate these “water level relative to marsh surface” values in Aquarius by creating a “calculated derived” time series data set. To do this, select the *Location*, then right-click it and select the *Location Manager* icon ( ). The *Location Manager* is also available from the icon toolbar at the top of the Aquarius window (Figure 48).

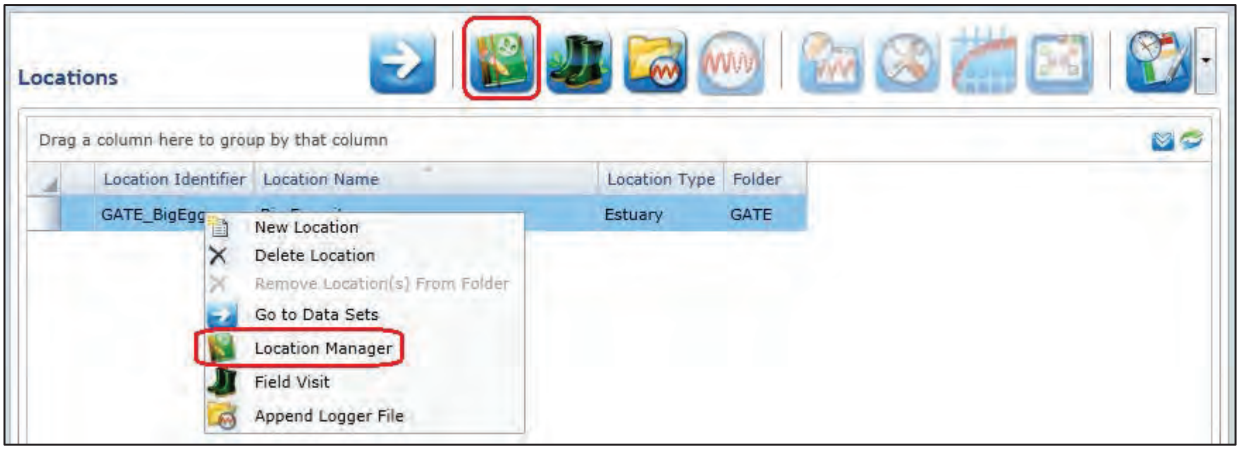


Figure 48. Two options for opening the Aquarius Location Manager.

In *Location Manager*, click the *Data Sets* tab (Figure 49). Next, click the *New* drop-down menu and select the *Time Series - Calculated Derived* option.

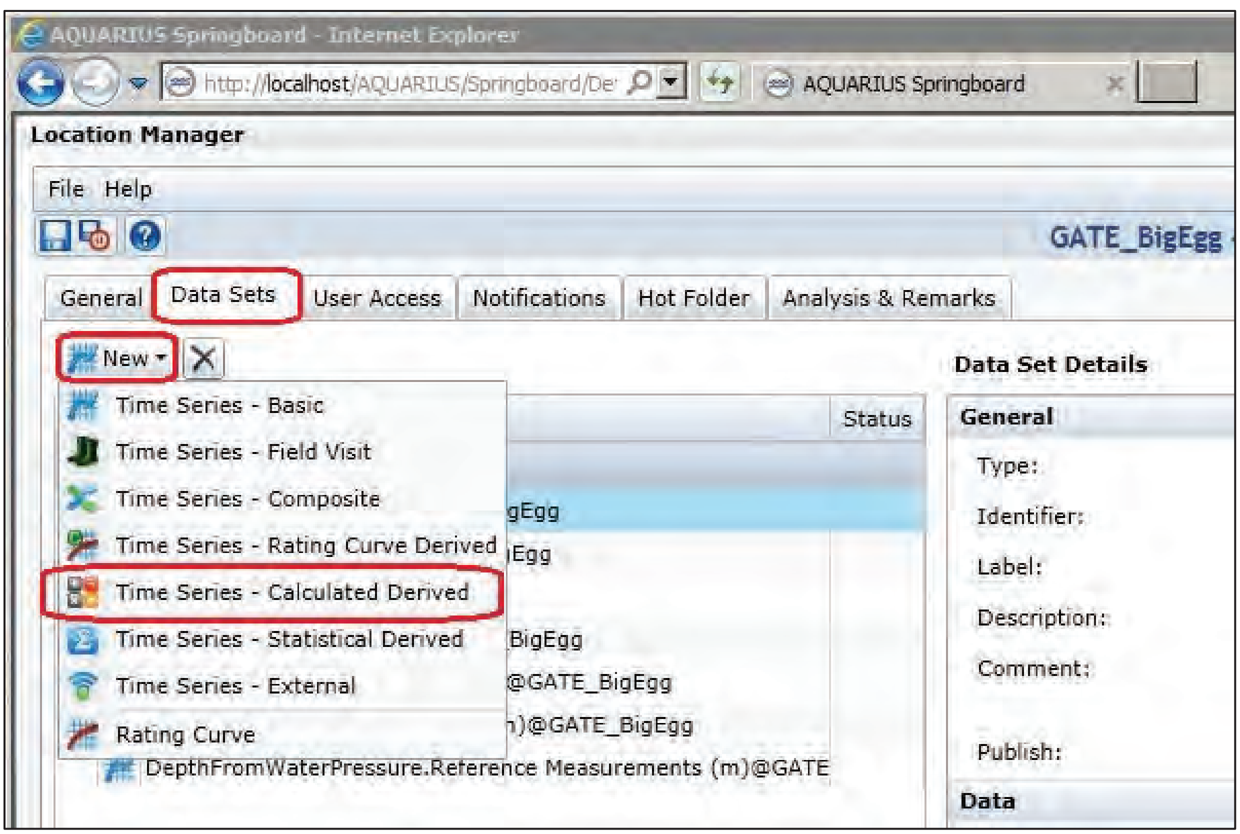


Figure 49. Create new “calculated derived” data set.

The *Data Set Details* window will open and have several boxes highlighted in red to indicate that they are required fields (Figure 50). In the *Calculation* section, click the black triangle at the right of the *Input Time Series* box and select the *Depth.meters@...* data set from the resulting drop-down menu (Figure 50).

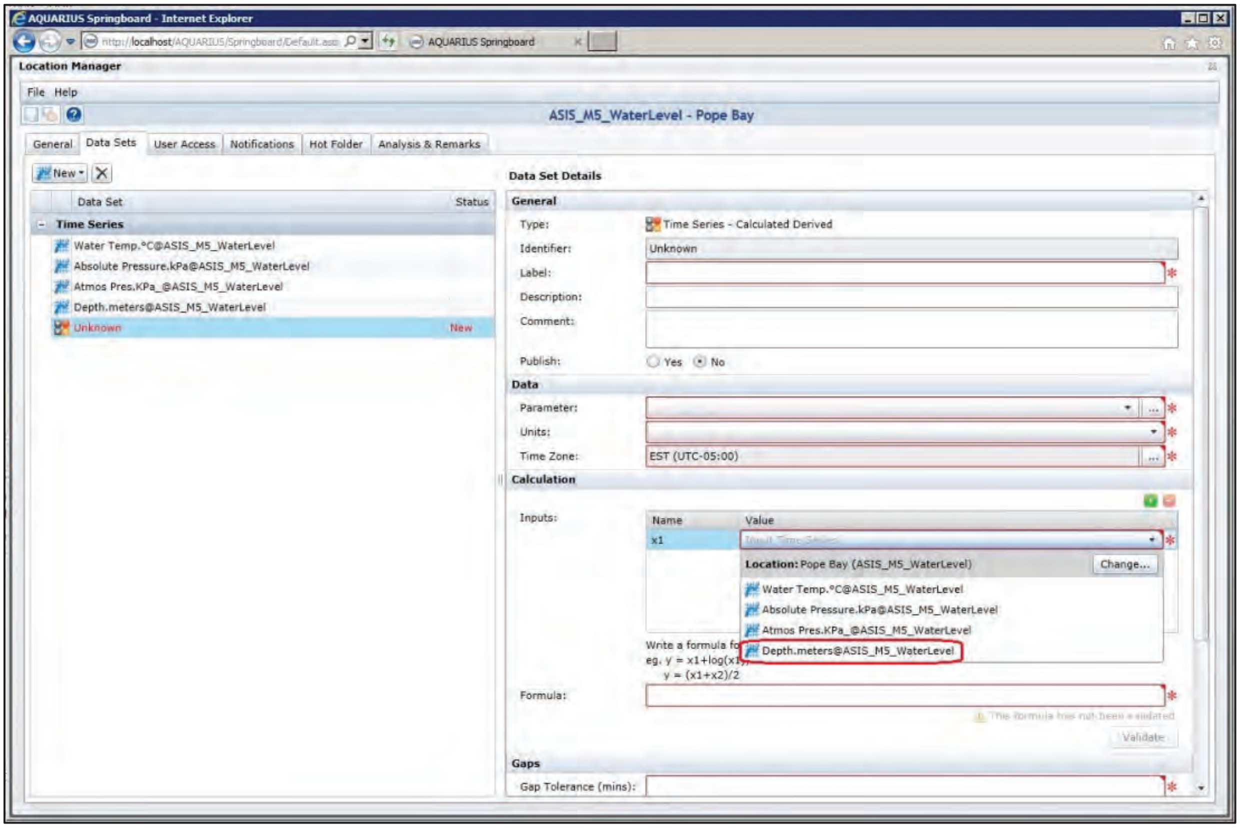


Figure 32. Select the input data set in Data Set Details window.

At the bottom of the *Calculation* section, in the *Formula* box, type:

y = x1 – [*sensor-to-marsh distance*]

The *sensor-to-marsh distance* is determined as described above. The value for *x1* will come from the *Input Time Series* (*DepthFromWaterPressure…*) that you selected in the previous step (this is the atmospherically compensated water level data set). After entering the formula, you will see a warning and a button to validate the formula. Click the *Validate* button (Figure 51).

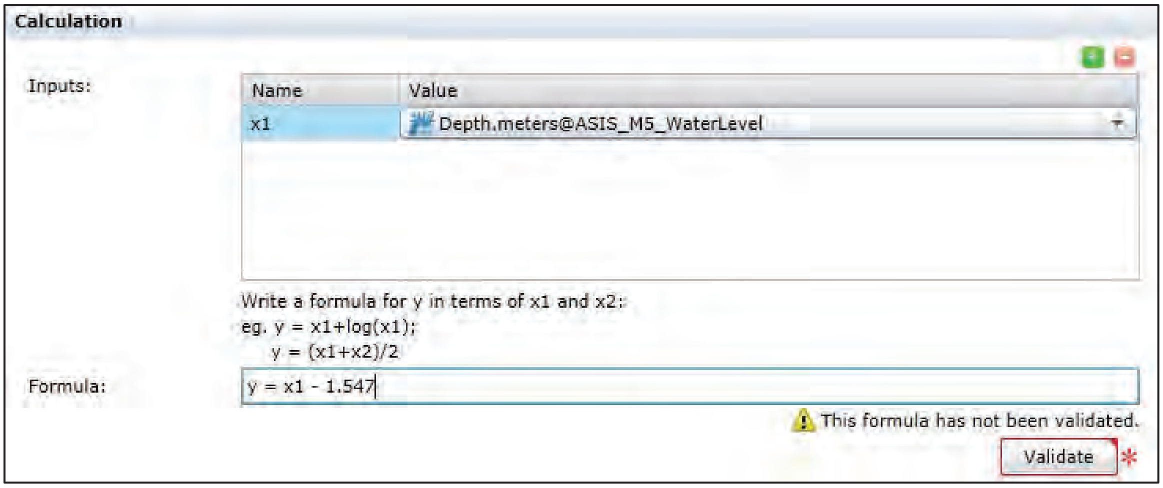


Figure 33. Validate the formula.

In the *Data* section, to the right of the *Parameter* box, click the navigation button (*) and type “water level” in the search box. Select *Water Level*, and click *OK* (Figure 52). This will take you back to the *Data Set Details* window; make sure the *Units* and *Time Zone* fields are correct in the *Data* section.

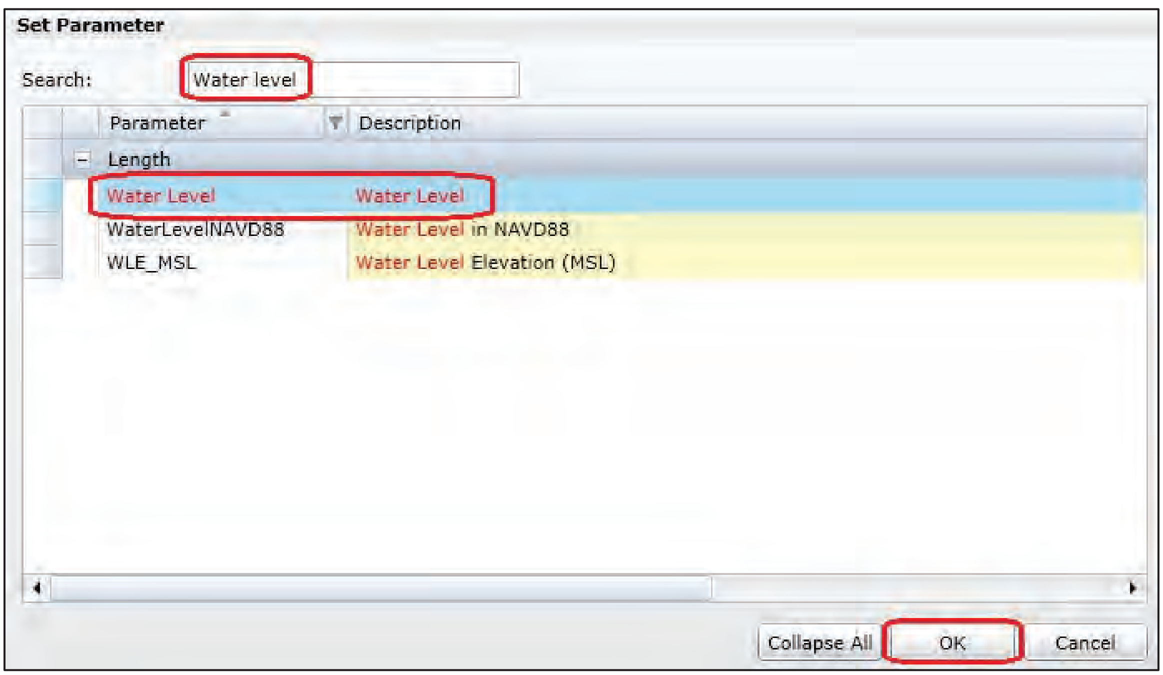


Figure 34. Choose Water Level to set the parameter.

Next, in the *General* section at the top of the *Data Set Details* window, type “AboveMarsh” in the *Label* box. Notice that as you type in the Label field, the Identifier field above reflects the changes. This will result in an Identifier (Time Series ID) of *WaterLevel.**AboveMarsh**@[LocationName]*. Add optional text in the *Description* and *Comment* fields.

Finally, in the *Gaps* section at the bottom of the *Data Set Details* window, enter a value one minute higher than the data collection interval, as explained in Section 4.4.3 (Gap *Tolerance*).

The completed form should resemble Figure 53. After clicking *Save* or *Save & Exit* (), the *Statistics* section at the bottom of the *Data Set Details* window will be populated automatically.

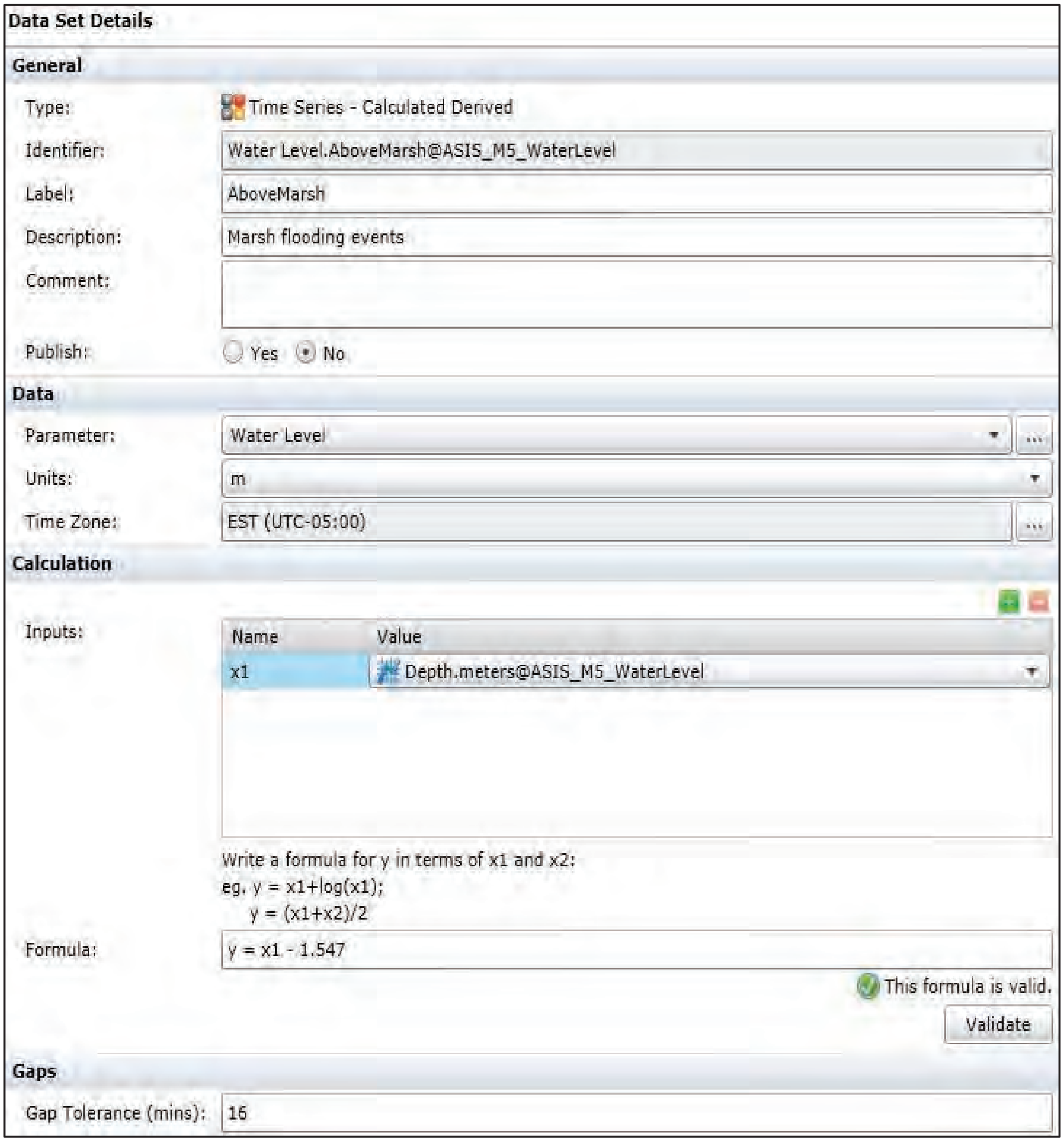


Figure 35. Completed form for creating a "calculated derived" data set that will be used to determine marsh flooding events.

The newly created "calculated derived" data set now appears as an entry in the *Time Series* list (*Location Manager/Data Sets* tab) with a multi-colored mathematical operations icon (, see Figure 54). Statistics such as number of flood events, longest flood event and flood depth can now be computed from the positive values (flooding events) in the calculated derived data set. This is accomplished through the use of custom code (written by Aquatic Informatics and Dean Tucker) using the Aquarius Reporting Tool (see Section 4.4.7).

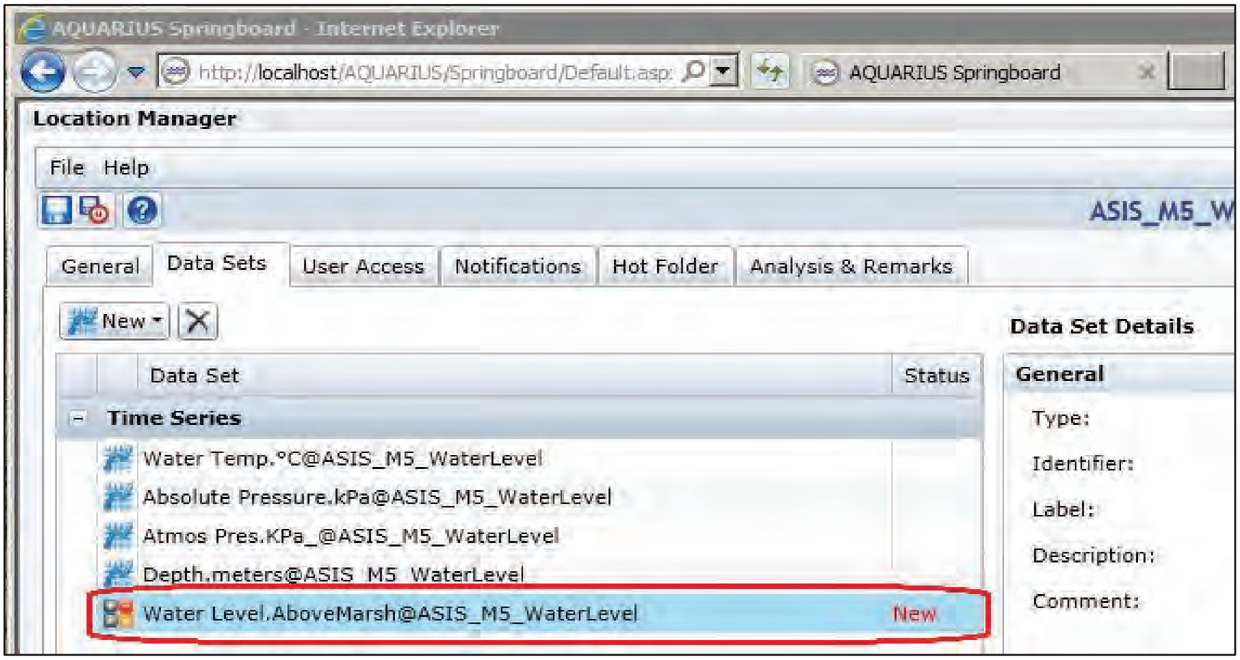


Figure 36. Newly created "calculated derived" time series data set

It is important to note that the method for calculating marsh flooding events described above uses a local field measurement for the marsh surface height, relative to the water level sensor. Two limitations of this method are that 1) it characterizes the entire marsh surface elevation using a single measurement at only one specific point on the marsh (well location), and 2) the water levels and flooding events cannot be related to other nearby marshes without additional work.

A variation on this method employs the use of GPS data collection (or geodetic leveling) to obtain NAVD88 (North American Vertical Datum of 1988) values for the sensor elevation and the marsh surface elevation. This allows you to address the two limitations described in the previous paragraph. First, by collecting marsh surface NAVD88 elevations at multiple locations around the sensor, you gain the ability to average multiple elevation values, or perhaps select a single representative marsh elevation value from a location slightly removed from the well, in order to better characterize the marsh surface elevation. Local surface disturbance and compaction from well installation and site visits can change the marsh surface elevation at the actual well site. Second, collecting NAVD88 values for sensor elevation and for marsh surface elevations allows you to record these values from multiple sites on the same vertical datum. This allows a comparison of water levels and marsh elevations from multiple sites on a common vertical datum.

4.4.6.2 Calculate tidal statistics

To calculate tidal statistics, create another "calculated derived" time series data set in Aquarius (like in the previous section), and run a custom report. The report will calculate the mean high water (MHW) and mean low water (MLW) for the logger deployment period. The MHW and MLW values will be reported in NAVD88 values so they can be compared to other monitoring sites. Therefore, we need to determine the NAVD88 elevation of the sensor.

The NAVD88 elevation of the sensor is calculated by first using a GPS receiver (or geodetic leveling) to determine the NAVD88 elevation of the sensor's connection point (CP). The CP-to-sensor distance is then subtracted from the CP's NAVD88 elevation. This gives us the NAVD88 elevation of the sensor.

NAVD88 Sensor Elevation = NAVD88 CP Elevation – CP to Sensor Distance

Repeat the steps in the previous section to create a new "calculated derived" time series data set for the sensor's NAVD88 elevation. As in the previous section, select the *Depth.meters@...* data set as the input, represented by x1 in the equation below:

y = x1 + [*NAVD88 Sensor Elevation*]

After entering the formula in the formula box of the *Calculation* section, click the *Validate* button.

In the *Data* section, to the right of the *Parameter* box, click the navigation button (...*) and type "water level" in the search box. Select *WaterLevelNAVD88*, and click *OK* (Figure 55). This will take you back to the *Data Set Details* window; make sure the *Units* and *Time Zone* fields are correct.

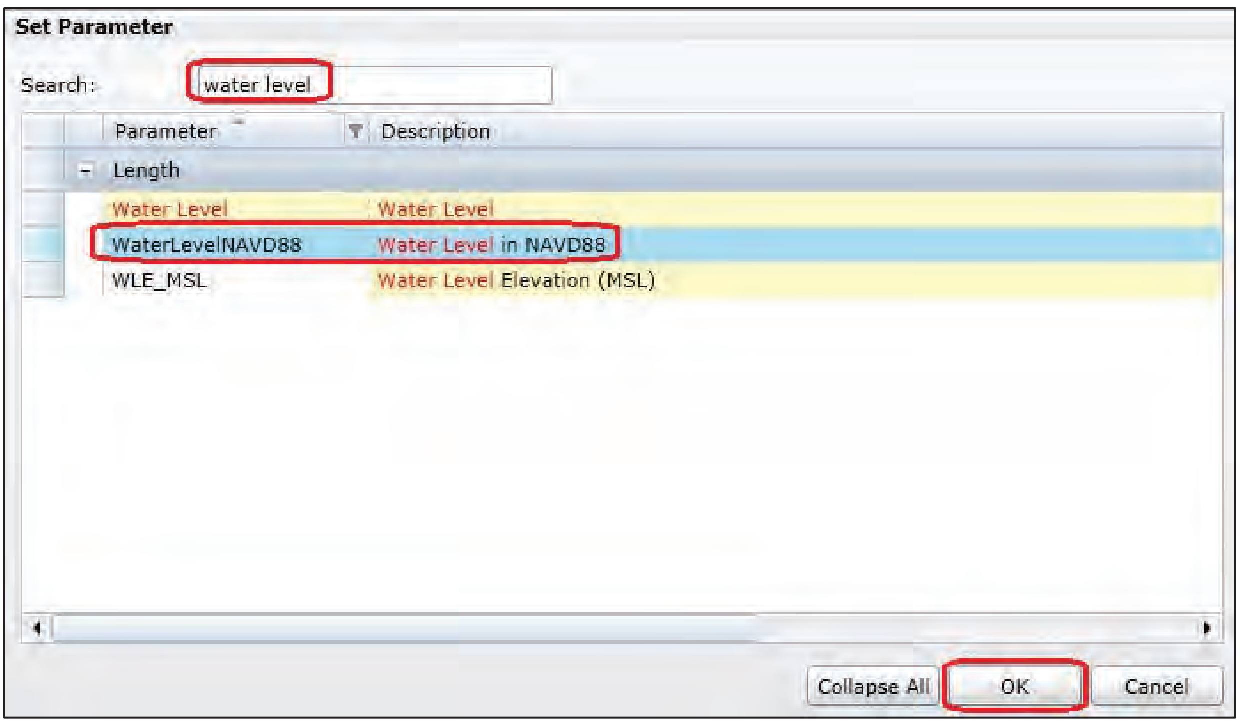


Figure 37. Choose WaterLevelNAVD88 to set the parameter for calculating tidal statistics.

Note in the *General* section of the *Data Set Details* window, that the *Identifier* is "WaterLevelNAVD88." Aquarius requires a label field to further describe the data set. Since NAVD88 is already included in the *Identifier*, type the name of the current geoidal model in the *Label* box (e.g. "12B"). This will result in an Identifier (Time Series ID) of *WaterLevelNAVD88.12B @[LocationName]*.

Finally, complete the *Gaps* section of the *Data Set Details* window, as described Section 4.4.3 (Gap *Tolerance*). The completed *Data Set Details* window should look like Figure 56. After you *Save* or *Save & Exit* (), the *Statistics* section at the bottom of the *Data Set Details* window will be populated automatically.

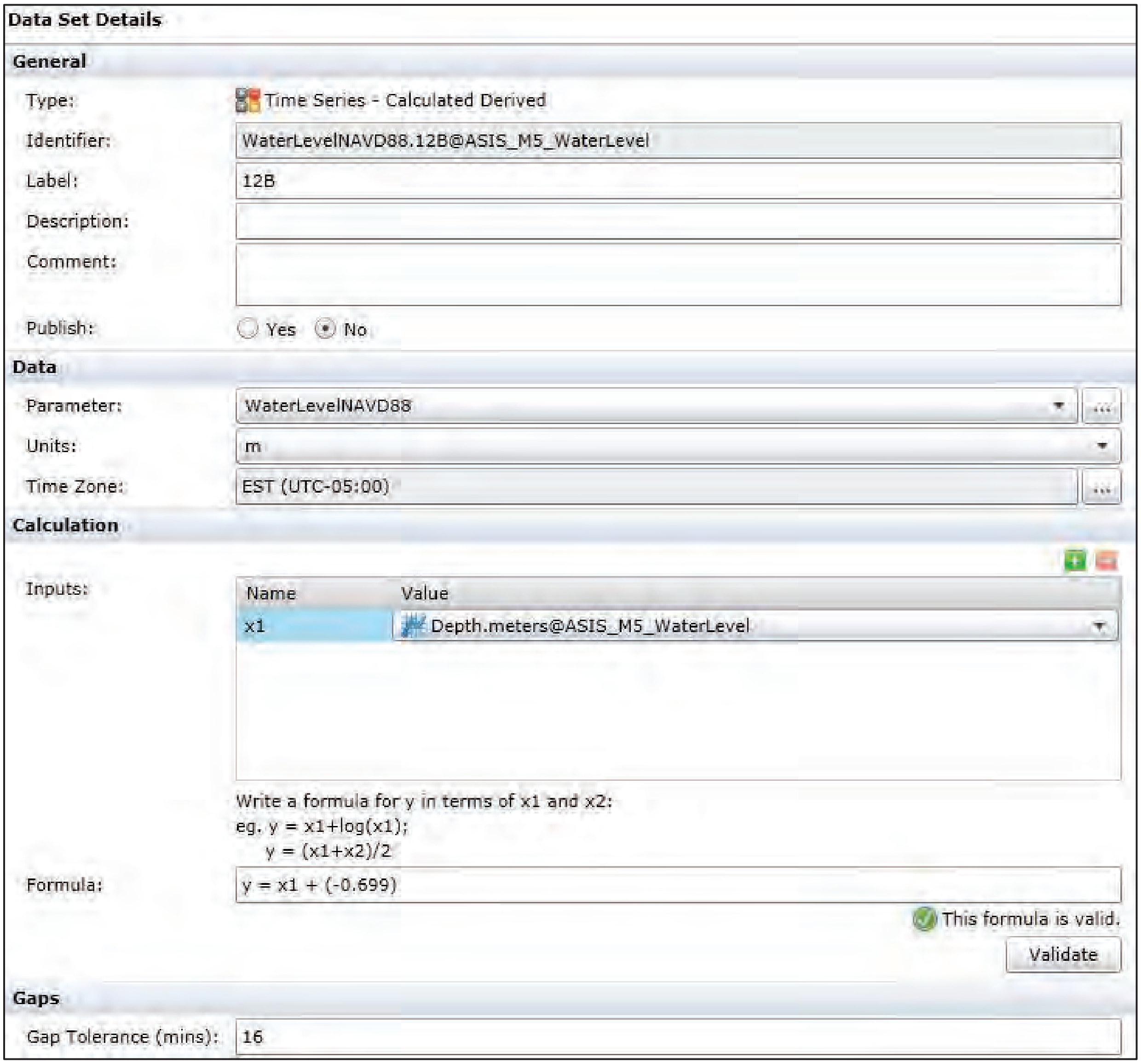


Figure 38. Completed form for creating a "calculated derived" data set that will be used to compute tidal statistics.

The newly created "calculated derived" data set now appears as an entry in the *Time Series* list (*Location Manager/Data Sets* tab) with a multi-colored mathematical operations icon (), like the *WaterLevel.Above Marsh* calculated derived dataset in Figure 54. Tidal statistics such as MHW and MLW can now be computed from the NAVD88 water level values in this calculated derived data set. This is accomplished through the use of custom code (written by Aquatic Informatics and Dean Tucker) using the Aquarius Reporting Tool (see Section 4.4.7).

4.4.7 Generating Custom Reports

Now that we have created the "calculated derived" data set for the water level relative to the marsh surface (Section 4.4.6.1), we can generate a report on marsh flooding events. Similarly, our second newly created "calculated derived" data set for NAVD88 water level values (Section 4.4.6.2) allows us to compute the NAVD88 MHW and MLW values for the logger deployment period.

<u>4.4.7.1 Generate Report on Marsh Flooding Statistics</u>

To generate a report with marsh flooding statistics, select the *Location*, right-click it and select the *Go to Data Sets* icon ( ). Select the calculated data set that was created in Section 4.4.6.1 (*WaterLevel.AboveMarsh)@[Location]).* Right-click this data set and select the *Report Tool* icon ( ) to open the *Reporting Toolbox* window. The *Go to Data Sets* and *Report Tool* icons are also available from the icon tool bar at the top of the window.

The *Reporting Toolbox* window should open, but it might be obscured behind existing windows. In the *Reporting Toolbox* window, click the drop-down arrow in the *Choose Template / Report* box and select *NPS_NCBN_Tidal_Flood_Stats* (Figure 57).

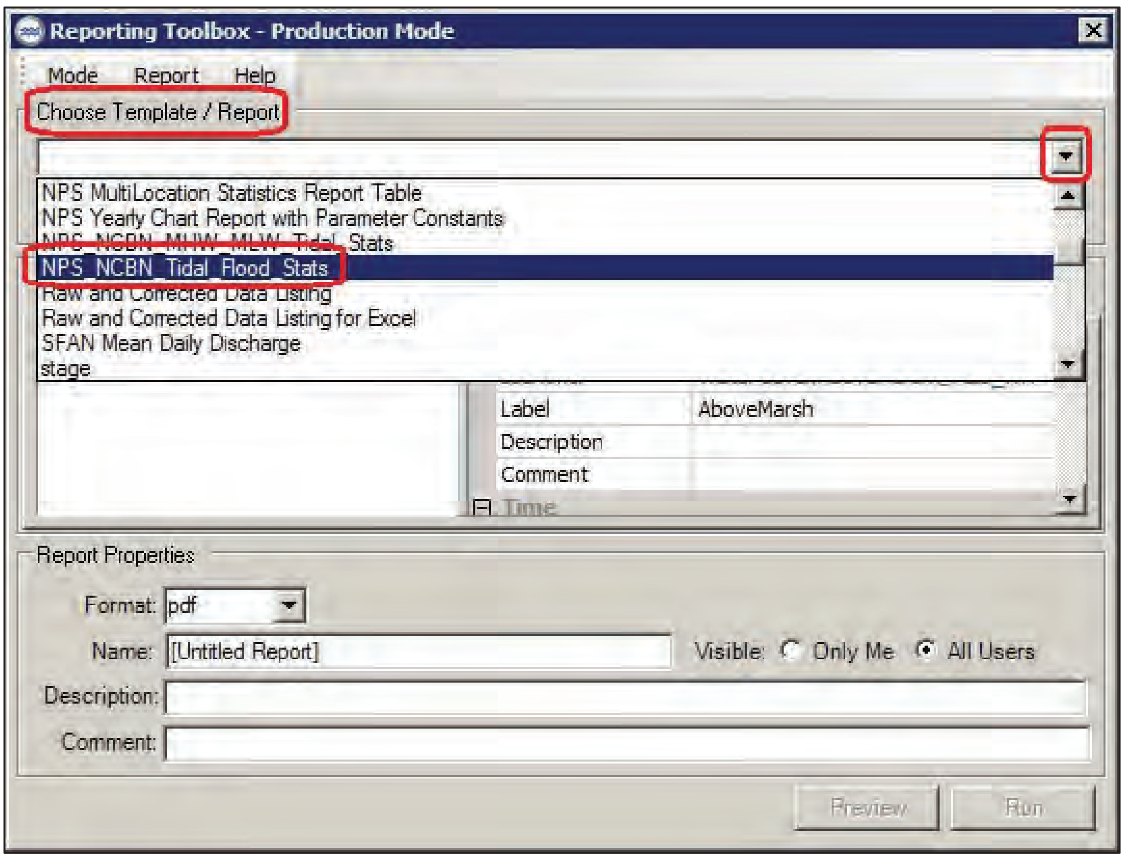


Figure 39. Select the Flood Sats Report in the Reporting Toolbox.

After the report is chosen, a new *Time Series* tab will appear in the *Reporting Toolbox* (Figure 58). Make sure the *Entire Range* radio button is selected, and add a *Name*, *Description* or *Comment* if desired.

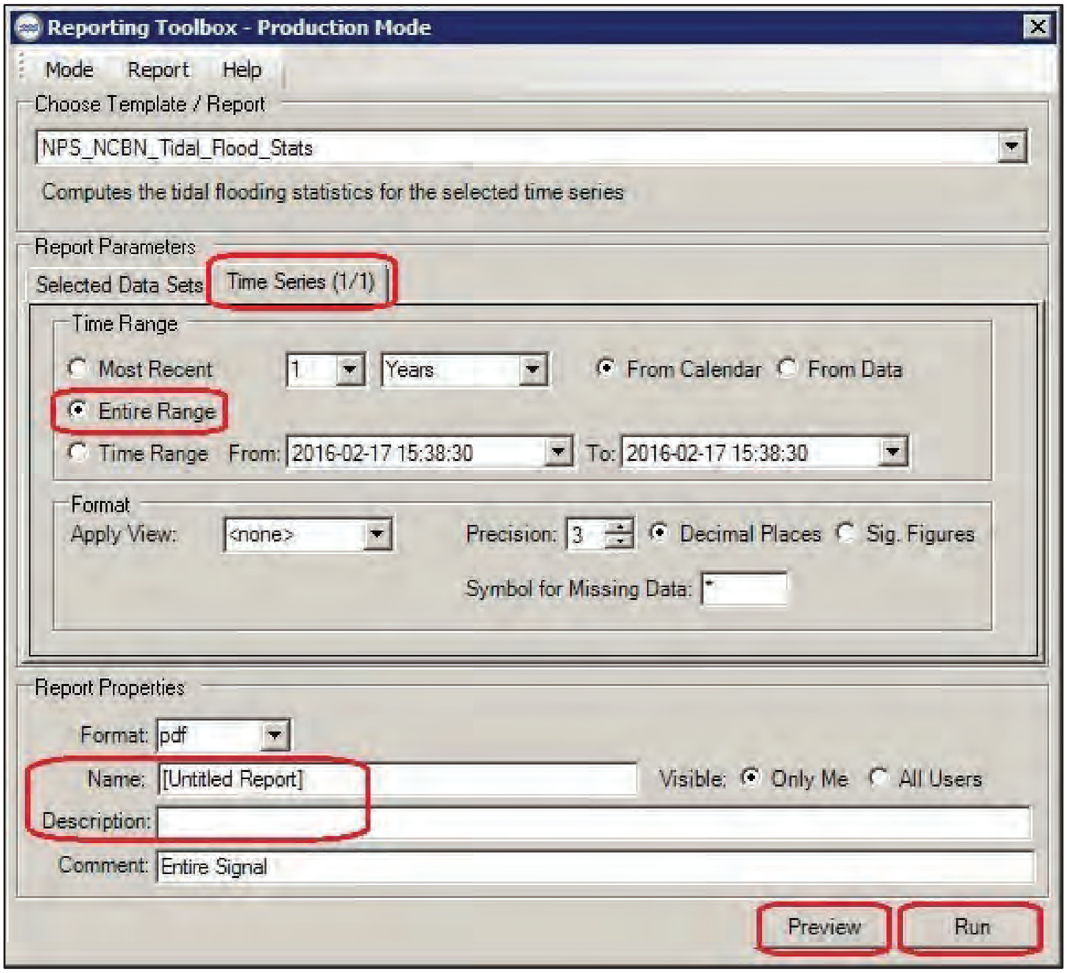


Figure 58. Set report parameters in Reporting Toolbox.

The values you put in the *Name* and *Description* fields will show up as the sub-title of the report. If you don't want to set the report *Name*, consider removing the default text of "[Untitled Report]" since that is the default sub-title that will appear on the report (Figure 60). You can preview or generate the report by clicking *Preview* or *Run*, respectively.

Finally, you can choose from numerous output formats, including PDF, several image formats, Excel spreadsheet and text file (Figure 59).

Figure 59. Report format options.

To generate the report click *Run*. The first page of the report will contain a graph of the water level data, with Date/Time on the x axis and Water Level on the y axis (Figure 60). The zero value on the y axis represents the marsh surface and is displayed as a horizontal red line in the graph. Data above the red line indicate marsh flooding events and data below the red line indicate water levels below the marsh surface. The report will also contain statistics and tabular data (Figure 61).

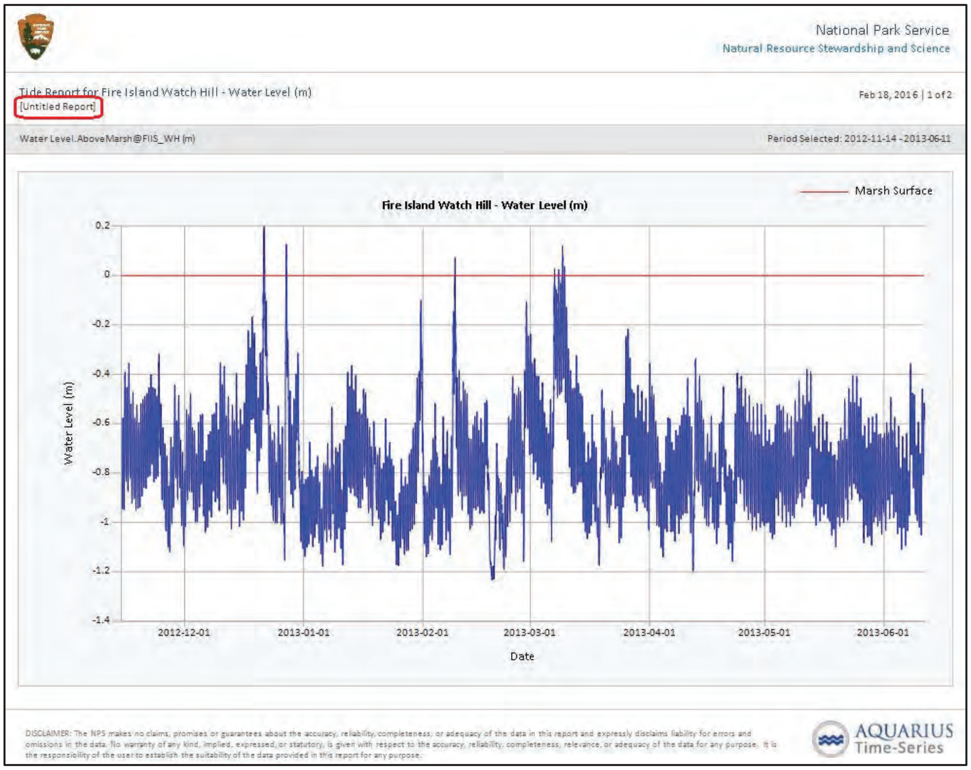


Figure 40. Title page and graph from the Aquarius NCBN Tidal Flood Stats Report.

Tide Report for Fire Island Watch Hill - Water Level (m)
[Untitled Report]

Water Level.AboveMarsh@FIIS_WH (m)

Start Time:	2012-11-14 13:00
End Time:	2013-06-11 13:45
Total Days:	209.03125
Total Minutes:	301005
Flood Minutes:	1050
# Flood Events:	10
% Flooded:	0.35
Longest Flood (hrs)	7.25
Flood Depth (cm):	3.981

Marsh Flooding Statistics

Start Time	End Time	TimeSpan (minutes)	TimeSpan (hours)	Avg. Depth (m)
2012-12-21 13:15	2012-12-21 20:15	435	7.25	0.102
2012-12-27 09:00	2012-12-27 11:30	165	2.75	0.074
2012-12-27 12:15	2012-12-27 12:15	15	0.25	0.026
2012-12-27 13:00	2012-12-27 13:15	30	0.5	0.023
2013-02-09 09:30	2013-02-09 09:45	30	0.5	0.041
2013-03-07 07:00	2013-03-07 07:15	30	0.5	0.015
2013-03-08 07:00	2013-03-08 07:00	15	0.25	0.010
2013-03-08 08:15	2013-03-08 08:45	45	0.75	0.016
2013-03-09 07:15	2013-03-09 09:45	165	2.75	0.069
2013-03-09 19:45	2013-03-09 21:30	120	2	0.024

Figure 41. Statistics and tabular data from the NCBN Marsh Flood Stats Report.

4.4.7.2 Generate Report for Mean High and Mean Low Water

Generating a report for Mean High Water (MHW) and Mean Low Water (MLW) is similar to generating the report in the previous section. Select the *Location*, right-click it and select the *Go to Data Sets* icon ( ). Select the calculated data set that was created in Section 4.4.6.2 (*WaterLevelNAVD88.12B@[Location]).*

Right-click this data set and select the *Report Tool* icon ( ) to open the *Reporting Toolbox* window.

The *Reporting Toolbox* window should open, but it might open behind existing windows. In the *Reporting Toolbox* window, click the drop-down arrow in the *Choose Template / Report* box and select *NPS_NCBN_MHW_MLW_Tidal_Stats* (Figure 62). Make sure the *Entire Range* radio button is selected, and add a *Name, Description* or *Comment* if desired. These will show up as the sub-title of the report (see Figure 60). If you don't want to set the report Name, consider removing the default text of "[Untitled Report]" since that is the default sub-title that will appear on the report. You can preview or generate the report by clicking *Preview* or *Run*, respectively.

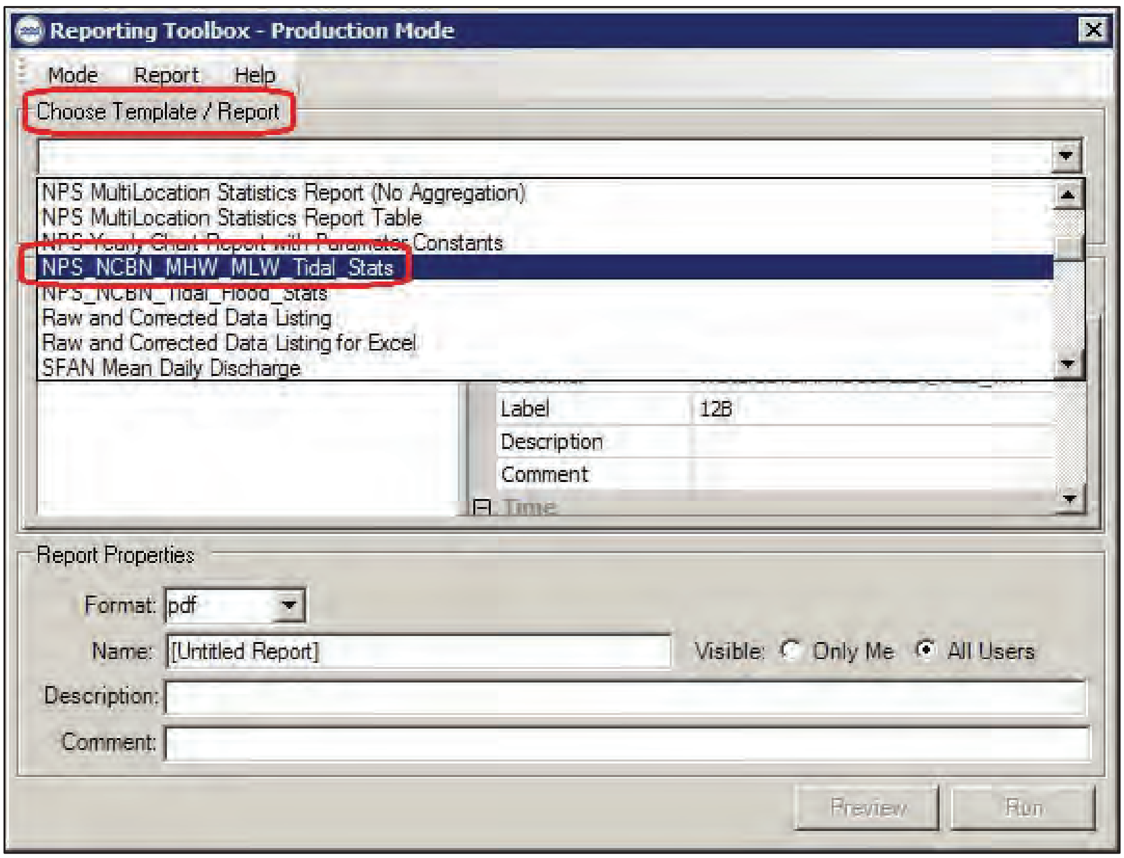


Figure 42. Select the Tidal Stats report in the Reporting Toolbox.

The first page of the report will contain a graph of the water level data, with Date/Time on the x axis and Water Level on the y axis (Figure 63). The top of the second page will contain several tidal statistics including MHW and MLW (Figure 64). The rest of the report shows all of the high waters levels, low water levels and their corresponding times for the data set.

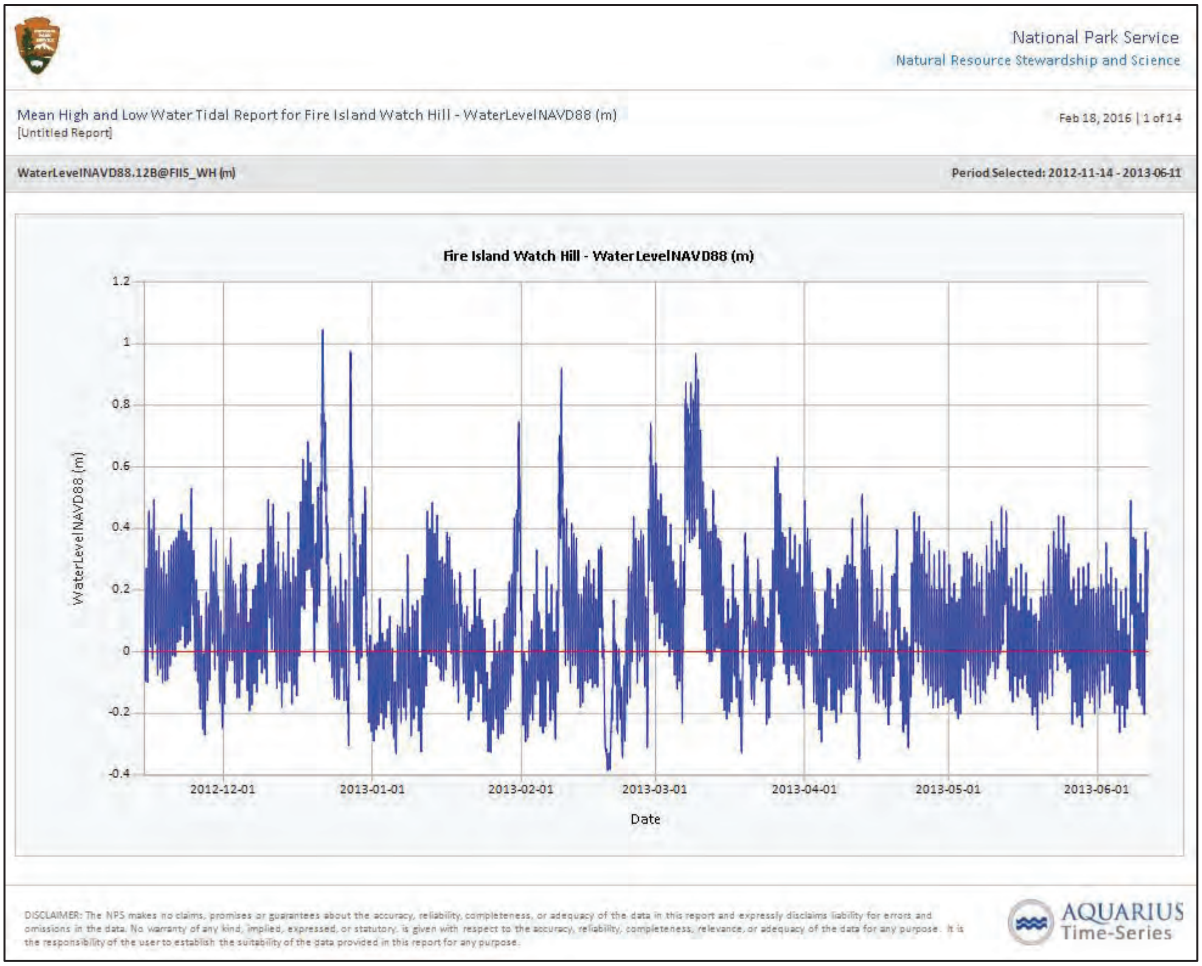


Figure 43. Title page and graph from the Aquarius NCBN Tidal Stats Report.

Mean High and Low Water Tidal Report for Fire Island Watch Hill - WaterLevelNAVD88 (m) Feb 17, 2016
[Untitled Report]

WaterLevelNAVD88.12B@FIIS_WH (m)

Average Water Level:	0.086
Mean High Water (MHW):	0.273
Mean Low Water (MLW):	-0.091
MTL:	0.091
Range:	0.364

Tidal Statistics Summary

High Level Time	High Level: (m)	Low Level Time	Low Level: (m)
2012-11-14 13:00	0.208	2012-11-14 17:30	-0.096
2012-11-14 23:00	0.271	2012-11-15 05:30	-0.099
2012-11-15 12:00	0.456	2012-11-15 18:30	0.016
2012-11-15 23:45	0.395	2012-11-16 06:30	-0.025
2012-11-16 12:15	0.493	2012-11-16 19:45	0.027
2012-11-17 00:30	0.327	2012-11-17 07:45	-0.074
2012-11-17 13:30	0.375	2012-11-17 20:45	-0.055
2012-11-18 01:30	0.270	2012-11-18 08:30	-0.099

Figure 44. Statistics and tabular data from the NCBN Tidal Stats Report**.**

Appendix A. Reference Resources

- HOBO-related Resources
  - HOBOware User's Guide: http://www.onsetcomp.com/support/manuals/12730-MAN-BHW-UG
  - HOBOware Pro Barometric Compensation Assistant User's Guide: http://www.onsetcomp.com/files/manual_pdfs/Barometric-Compensation-Assistant-Users-Guide-10572.pdf
  - HOBO® U20 Water Level Logger Manual: http://www.onsetcomp.com/files/manual_pdfs/12315-F-MAN-U20.pdf
  - Specifications for HOBO® U20 Water Level Loggers: http://www.onsetcomp.com/files/data-sheet/Onset%20HOBO%20U20%20Water%20Level%20Data%20Loggers.pdf
  - Specifications for HOBO® U20L Water Level Loggers: http://www.onsetcomp.com/files/data-sheet/Onset-HOBO-U20L-Water-Level-Data-Logger-Series.pdf
- Aquarius-related Resources
  - A variety of informative documents and videos created by Dean Tucker for NPS employees and affiliates that want to get started with Aquarius: http://nrdata.nps.gov/Programs/Water/Aquarius/AquariusVideos.htm
  - Aquarius FAQs: http://nrdata.nps.gov/programs/water/Aquarius/Docs/Aquarius_FAQS.pdf
- Miscellaneous
  - Northeast Coastal and Barrier Network Information Management Plan. https://irma.nps.gov/App/Reference/Profile/2195239/

    Includes:

    Standard Operating Procedure (SOP) – Electronic File Naming Guidelines and Standards

Appendix B. HOBO® Quickstart Guide

(Modified from Gwen Gerber's "Cheatsheet")

I. Launching a HOBO® water level logger:

1. Attach black plastic coupler to the waterproof shuttle (Figure B 1).

2. Remove the black plastic endcap from HOBO® water logger. Insert the logger into the coupler and attach the shuttle to a computer with the USB cable. Squeeze the black lever on the coupler to activate the shuttle. The green "OK" light on the shuttle should come on, indicating a proper connection.

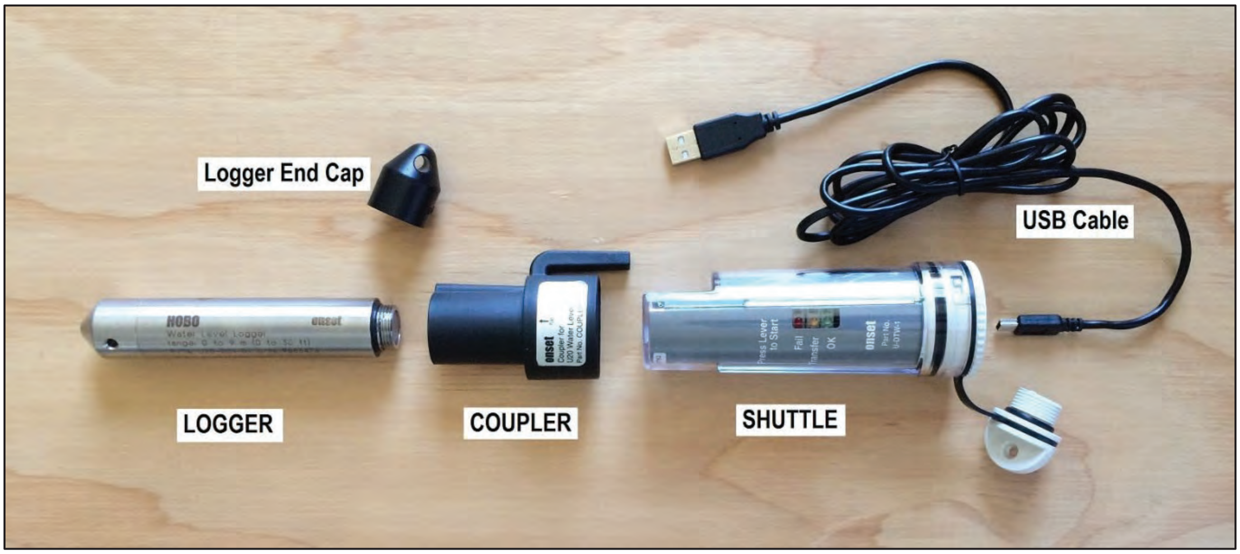


Figure B 1. HOBO data logger and auxiliary components.

3. Make sure appropriate units are selected (US or SI (=metric)) on the main menu bar (Figure B 2).

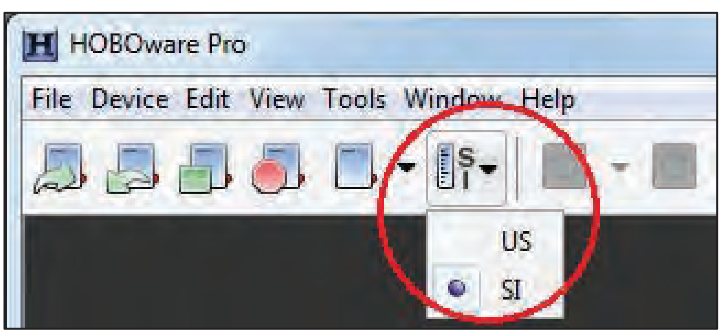


Figure B 2. Select appropriate units.

4. Under the “Device” menu, select “Launch” (Figure B 3).

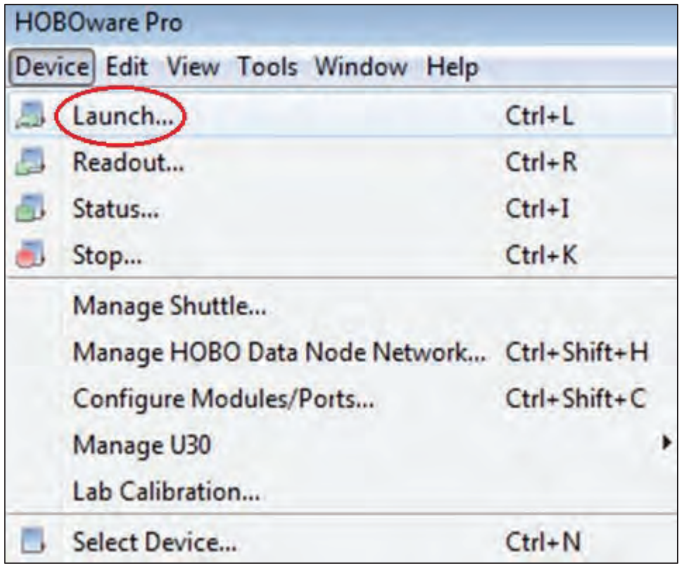


Figure B 3. Select Device/Launch.

5. Select device and hit “OK” (Figure B 4).

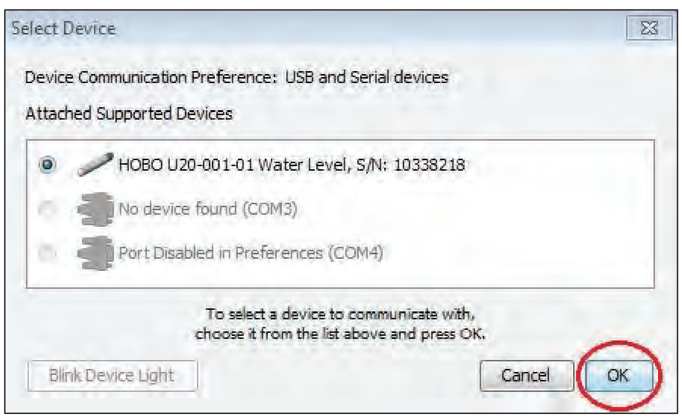


Figure B 4. Select and launch device.

6. The “Launch Logger” window will pop up (Figure B 5). Do the following:

    a. Note the logger being launched on your field form.

    b. Check battery state.

    c. Set Logging Interval to appropriate interval (6 minutes is NOAA standard for tide gauges; 15 minutes has been used with marsh monitoring) and notice under the “Logs until” column how long the logger will record with the specified interval. Note that with a 6-minute collection interval, the logger will be full in 90 days, and will stop collecting data until the data are downloaded from the logger. To set a logging interval of 6 minutes, you will have to select the Custom option from the bottom of the Logging Interval drop-down menu.

d. Start logging "At Interval" or "On Date/Time", and write logging start time down on field form. It is a common practice to start the loggers at a specified "future date" in the office prior to heading to the field.

e. Hit enter, or click "Delayed Start."

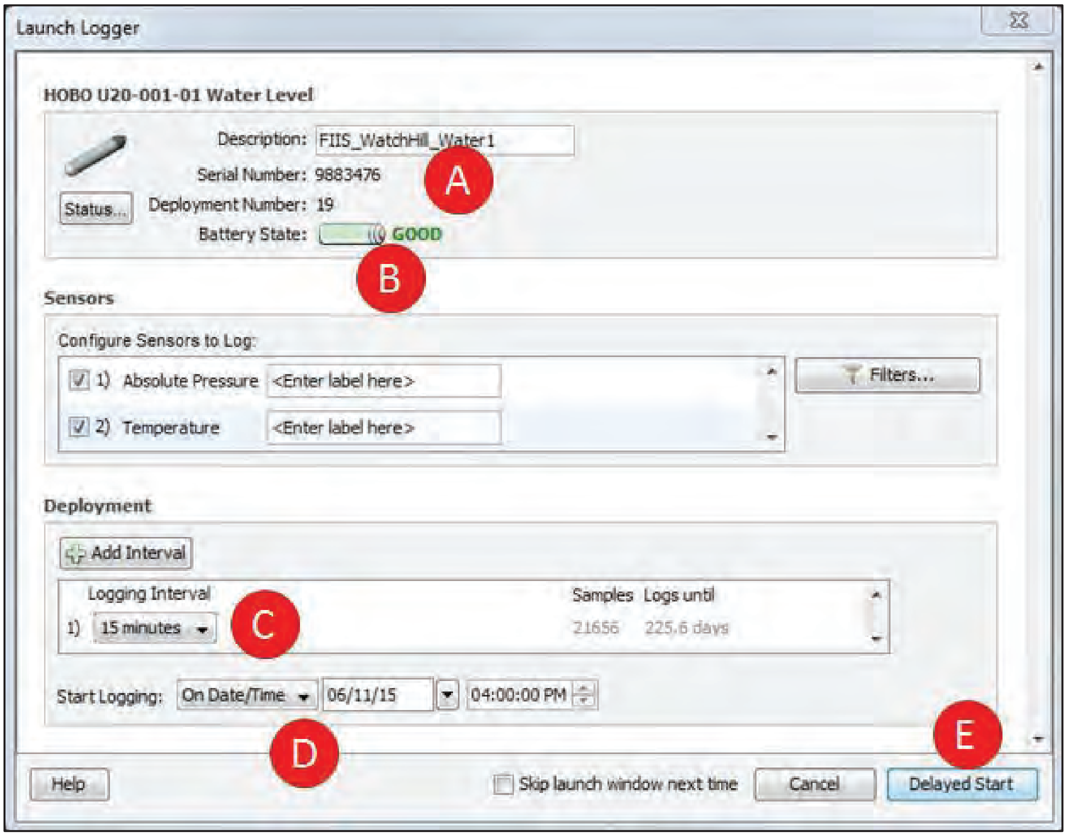


Figure B 5. Examine and fill out fields in Launch Logger window.

7. The Launching Logger status window will appear (Figure B 6).

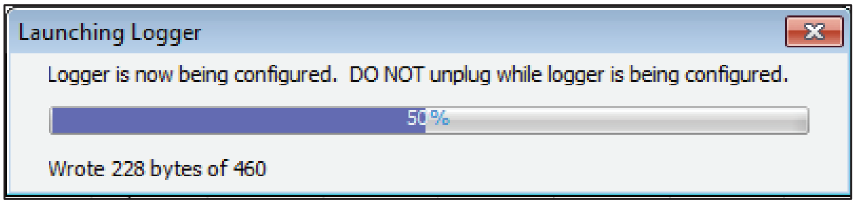


Figure B 6. Launching Logger status window.

Make sure "Launch successful" shows up in the lower left hand corner of the screen.

8. To confirm that the logger has been launched, you can go to the "Device" menu and select "Status." The status window will pop up and display information about the logger (Figure B 7).

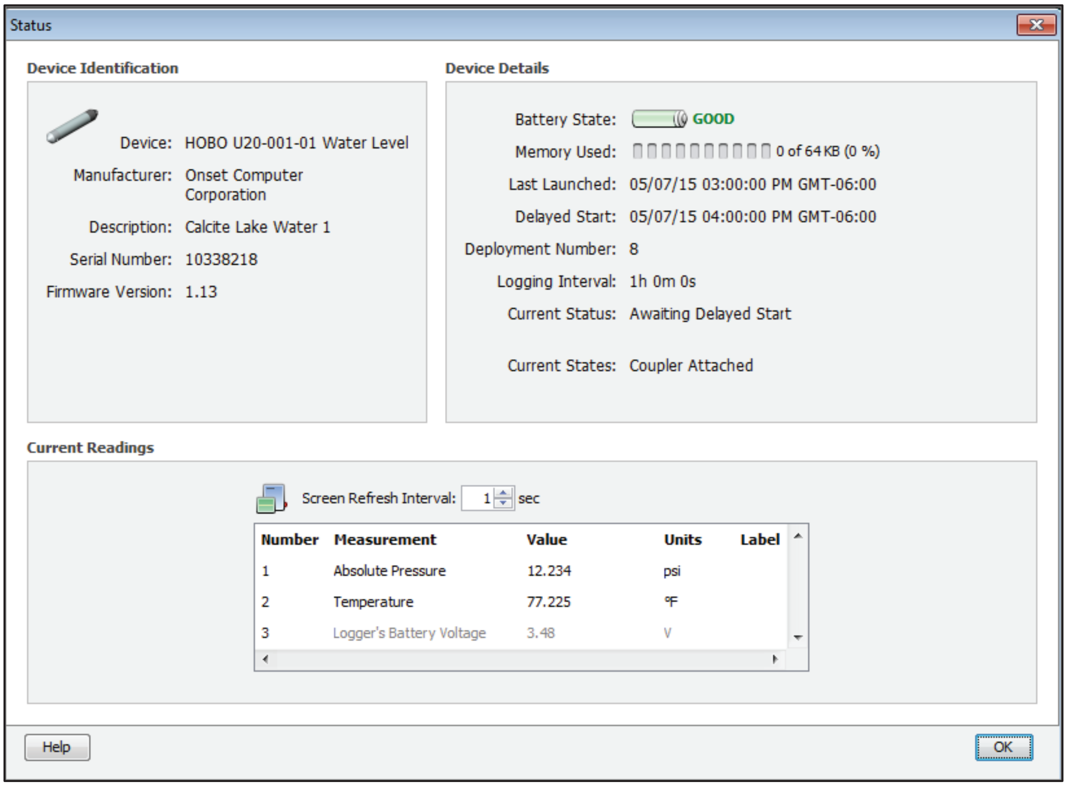


Figure B 7. Device status window.

9. Remove the logger from the coupler and replace the logger's end cap. The logger is ready to be deployed.

10. Repeat Steps 1 - 6 for both the Air and Water HOBO® Loggers prior to transporting to the site.

II. Downloading data from a HOBO® water level logger:

1. Attach black plastic coupler to the waterproof shuttle (Figure B 1).

2. Remove the black plastic endcap from HOBO® water logger. Insert the logger into the coupler and attach the logger/coupler/shuttle assembly to a computer with the USB cable. Squeeze the black lever on the coupler to activate the shuttle. The green "OK" light on the shuttle should come on, indicating a proper connection.

3. Open HOBOware Pro software

4. Under the "Device" menu, select "Readout" (Figure B 8).

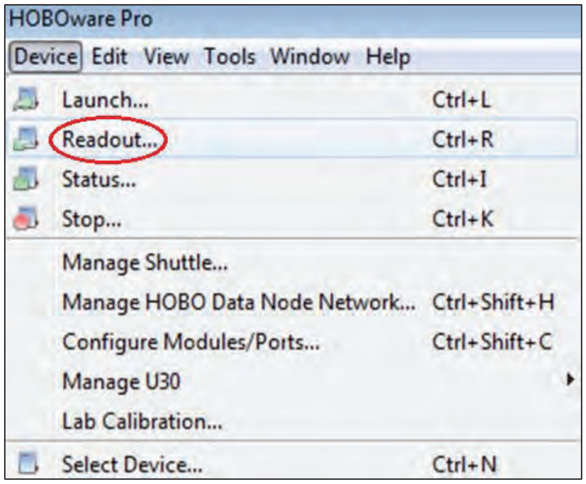


Figure B 8. Select Device/Readout.

5. Select device and hit “OK” (Figure B 4).

6. Stop the logger (Figure B 9).

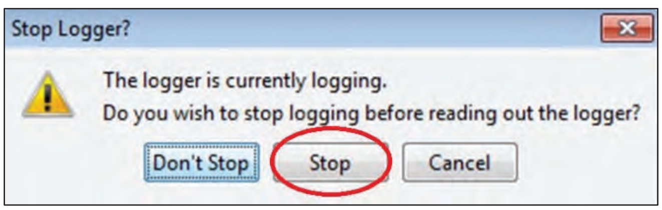


Figure B 9. Stop logger.

7. The Readout Logger status window will appear (Figure B 10).

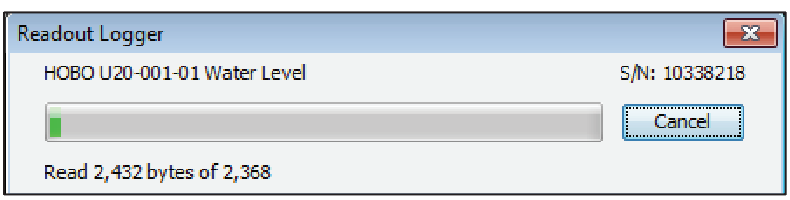


Figure B 10. Readout Logger status window.

8. Save the file with the deployment start date and today’s date in the filename format shown below, and write down file names on the appropriate field from. Once you enter “Save,” the raw files will be saved.

   FIIS_20130301_20130612_Lynch_WH_WL_RAW.hobo
   FIIS_20130301_20130612_Lynch_WH_BARO_RAW.hobo

9. The “Plot Setup” window will pop up (Figure B 11). Select “Cancel” to exit, or “Plot” to see your data. If you choose cancel, you should see Readout completed successfully. on the lower left side of the screen.

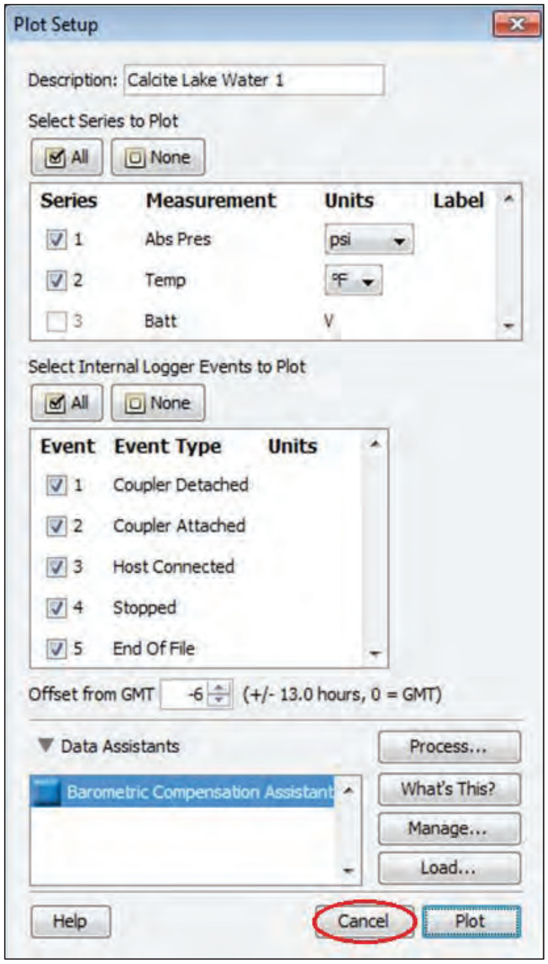


Figure B 11. Plot setup window.

10. Repeat Steps 1 - 6 for both the Air and Water HOBO® Loggers

11. Scan the field forms and save as PDF files with the appropriate filename format (below).

FIIS_20130301_20130612_Lynch_WH_FieldForm.pdf

Appendix C. Water Level Logger Installation Guide

These instructions assume you are installing the water level sensor in a wetland or an adjacent tidal creek.

Supplies needed:

1. Water level logger (deployed in the water) - Onset HOBO® water level loggers are non-vented and therefore record absolute pressure (sum of atmospheric and water pressure). These loggers also record water temperature.

2. Barometric logger (deployed in the air) – This is the same instrument as a water level logger, but deployed in air. It therefore does not record water pressure and only records atmospheric pressure. These loggers also record air temperature.

3. 2" PVC pipe (housing for the sensor) - 2" PVC pipe (regular schedule 40 PVC or well pipe), plus end caps and fittings. Well pipe has thin slits already cut into the pipe and are excellent for water level recorders since the slits reduce wave action and are small enough to reduce the amount of sediment that enters the pipe. Regular PVC pipe will also work very well.

4. Sensor cable (suspends sensor within the PVC housing) – It is important to use a material that won't stretch, kink or degrade over time. Heavy braided nylon line works very well.

5. 2" soil auger (used to drill a hole in the marsh or creek bottom).

6. Metal rods or wooden post (attachment structure for PVC pipe).

7. Stainless steel hose clamps (for attaching PVC pipe to metal rod or wooden post).

The water level sensor is suspended inside a PVC pipe in a wetland or tidal creek. The sensor hangs in the pipe just far enough from the well bottom (~6-12 inches) to avoid being fouled by any sediment that may accumulate inside. The barometric sensor is located on a post or tree far above the wetland surface. It is also kept inside a PVC pipe for protection. The barometric sensor should NOT go underwater at any time during the deployment. Since the loggers are sealed pressure transducers, the water level data will have to be corrected to remove changes in atmospheric pressure. This is accomplished post-deployment using the pressure data from the barometric logger and software from the manufacturer.

Installing the well housing:

1. Well Pipe: Cut a piece of 2" PVC pipe to length (~3-4') and install caps at each end with PVC cement (use well pipe if possible). Make sure the top of the pipe has a cap which can unscrew to allow for access.

2. Barometric Logger: Use a small piece of the same PVC pipe (~1 ft long) to make a protective housing for the barometric logger. If possible, deploy the barometric logger in a location

where temperature fluctuations are minimal. Consider mounting on the shaded north side of a tree, post, bird nesting box (see below), or other suitable structure.

3. Spray paint both pipes with camouflage colors to make them blend in with the surroundings.

4. Drill 2 small holes (~1/8" diameter) about 1/2" apart near the removable screw cap on the PVC housing. These holes are where the nylon line will attach to the PVC pipe. This is called the "Connection Point," or CP. The other end of this line attaches to the HOBO® data logger. The water level logger hangs vertically inside the PVC pipe, suspended by the nylon line from the CP. This allows one to easily remove the logger for servicing, and ensures that the logger returns to the same vertical position when re-deployed in the pipe.

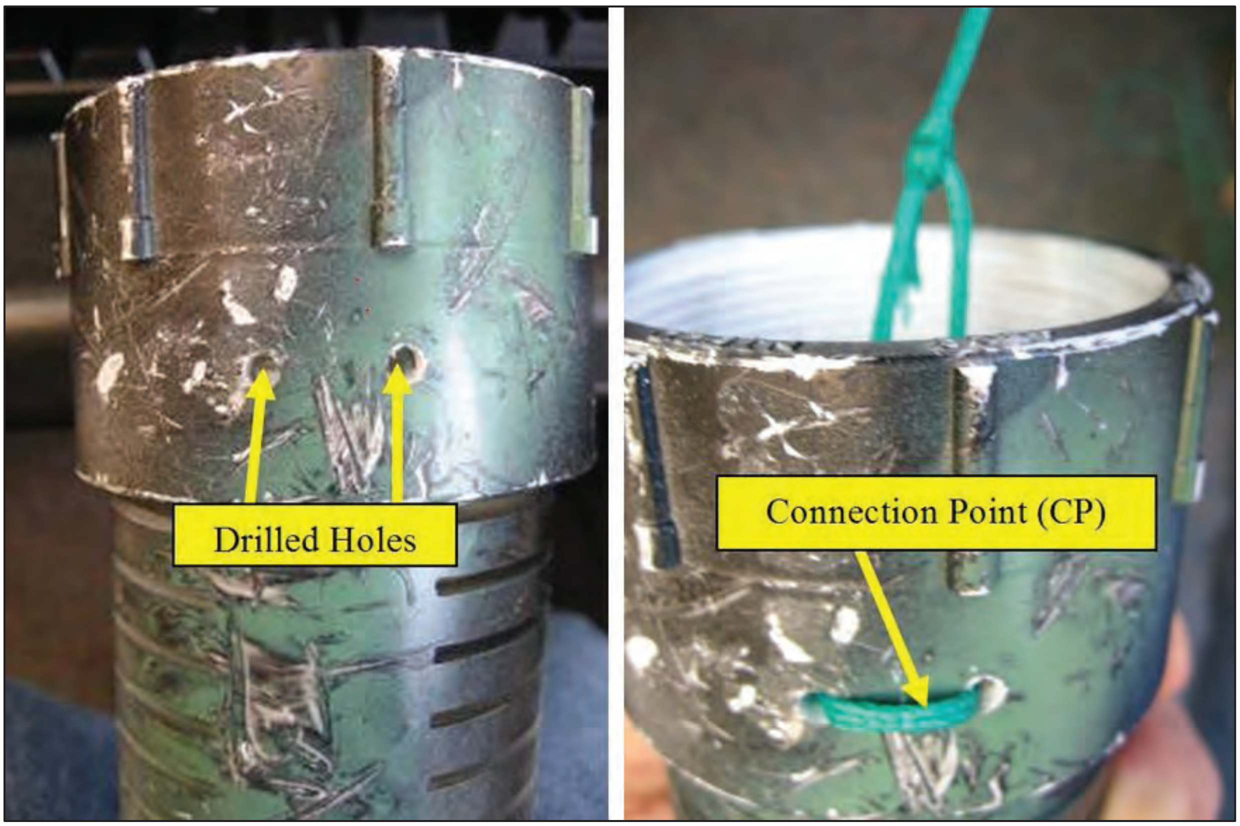


Figure C 1. Drilled holes and connection point (CP) in top of well casing.

Field installation:

1. In a Wetland: Drive a wooden post or stainless steel rod into the wetland where the sensor will be located. Auger a hole next to this post for the PVC housing. Push the PVC housing pipe into the hole you created. To minimize visibility, try to keep the top of the PVC pipe close to the wetland surface (~3-5" above the surface). You may need to use a small sledgehammer to knock it into the ground and secure it. To avoid damaging the well pipe, place a board on top of the pipe and hammer the board. Attach the top of the PVC housing to the post (or metal rod) using stainless steel hose clamps.

2. In a Tidal Creek: Find a location that is adjacent to the wetland to decrease the visibility of the housing. Try to get the sensor as low as possible in the creek. Note that the water level sensor may go dry during low tide. This is common for this type of installation. Install the wooden post or metal rods, as described in the previous step for a wetland installation. These are needed to stabilize the sensor housing. Auger a hole and drive the PVC pipe into the creek bottom (full length) or have it stick up from the bottom a few feet. Use stainless steel hose clamps to attach the PVC well to the post or rod.

3. Attach nylon line to the PVC housing (the connection point) using a bowline knot. Adjust the length of the line and attach the other end to the sensor using the same knot. Make sure the sensor does not rest on the bottom of the PVC pipe. It should hang straight down inside the housing about 6-12" from the bottom.

4. Record the following information on the datasheet (Appendix 4) when you first install the sensor:

    a. CP to Sensor: Measure the distance from the Connection Point (CP) to the sensor and record it on your data sheet in centimeters (see diagram below).

    b. CP to water level: the distance from the point of connection of the cable to the water surface in centimeters. If the tide is low, you may not be able to record this number when you install the logger. NOTE: If the water is above the CP, record a positive number. If the water is below the CP, record a negative number.

    c. CP to wetland surface: If installed in the wetland, record this distance in centimeters.

    d. Time and Date (including whether time recorded is Standard or Daylight time).

5. Barometric logger installation: Attach the sensor to the PVC housing with a nylon line. Find a suitable structure for the "baro" logger and install it. Place the opening at the bottom and the cap at the top to try to minimize water (from rain or snow) getting into the housing. The barometric logger can be located up to a few miles away from the water level logger.

6. Surveying: If possible, survey the elevation of the water level logger with a level, total station, or with survey-grade GPS equipment. Knowing the elevation of the sensor will allow you to convert water levels to NAVD88 elevations. Survey to the connection point (CP) if possible. Otherwise, survey the top of the PVC housing (the cap) and precisely measure and record the distance between the PVC cap and CP. Repeat surveys can check the vertical stability of the well.

Figure C 2. Water level sensor in a wetland (Rachel Carson National Wildlife Refuge, Maine).

Figure C 3. Barometric sensor attached to bird nesting box (Rachel Carson National Wildlife Refuge, Maine).

Figure C 4. Water level housing next to a wetland (Jamaica Bay, Gateway National Recreation Area).

Figure C 5. Water level sensor and PVC housing (Fire Island National Seashore).

Example 1 – WL logger installation in the marsh:

- Pros – Records actual water levels that the marsh vegetation is exposed to.
- Cons – Records only the higher tides; does not record the low water events.

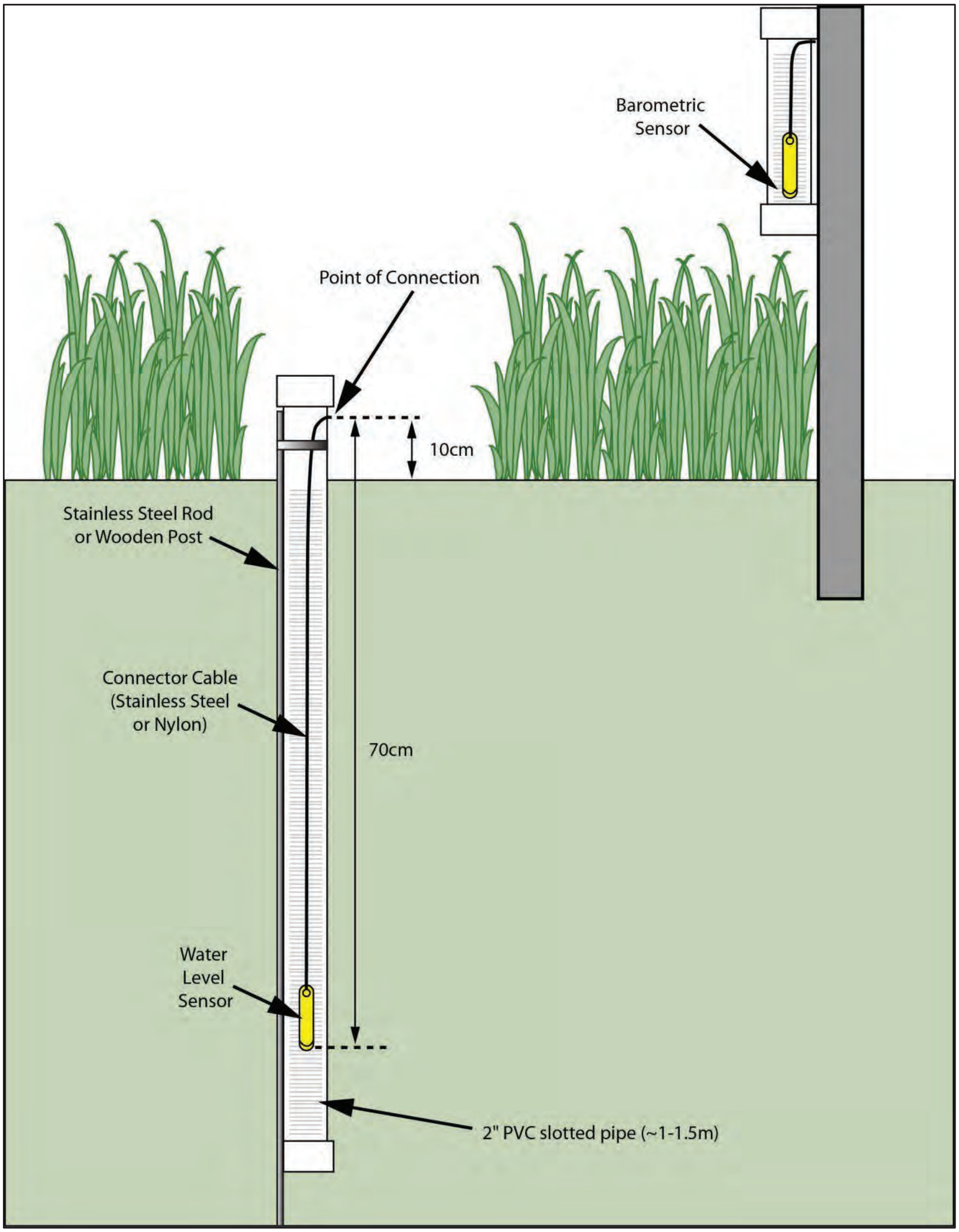


Figure C 6. WL logger installation in the marsh.

Example 2 – Water level logger installation in a tidal creek or on the edge of a wetland (some of the PVC housing is exposed).

Note: sensor should hang above the mud surface since the pipe fills with sediment.

- Pros: easy to access the housing
- Cons: Pipe is prone to filling in with sediment, and is more visible.

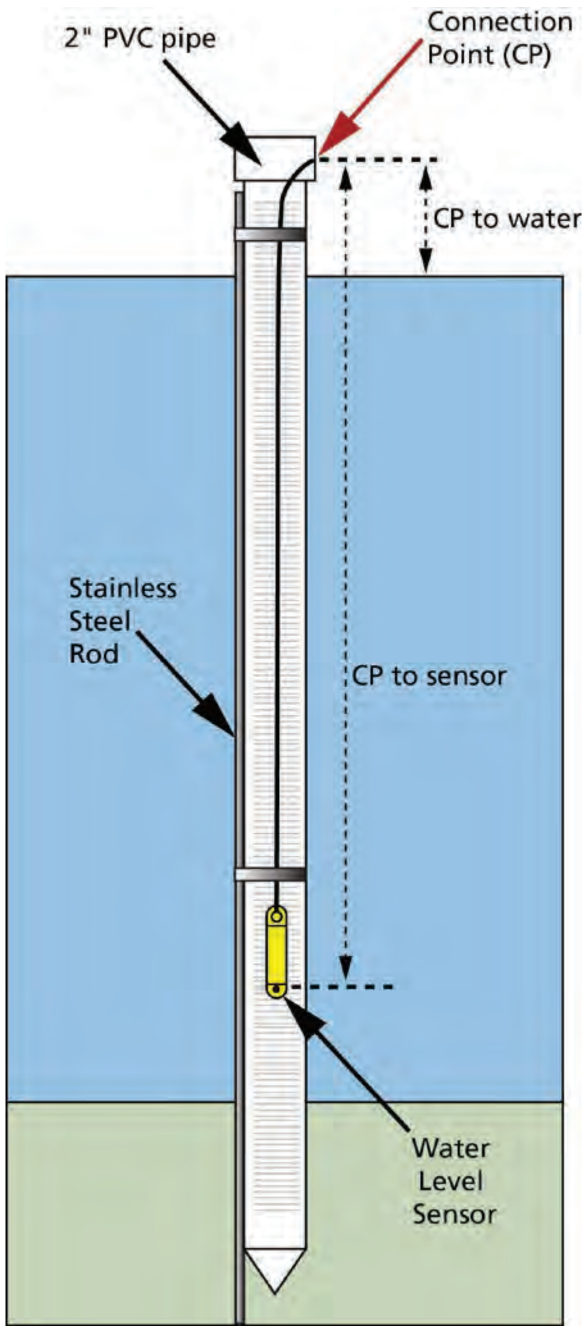


Figure C 7. Water level logger installation in a tidal creek or on the edge of a wetland (some of the PVC housing is exposed).

Example 3 – Water level logger installation in the bottom of tidal creek.

- Pros: Sensor is very low so you are more likely to record the high and low tide events.
- Since most of the slots are in the mud, the pipe does not fill quickly with sediment.
- Cons: Pipe can only be checked and serviced at low tides. More difficult to access. Pipe will eventually fill with sediment.

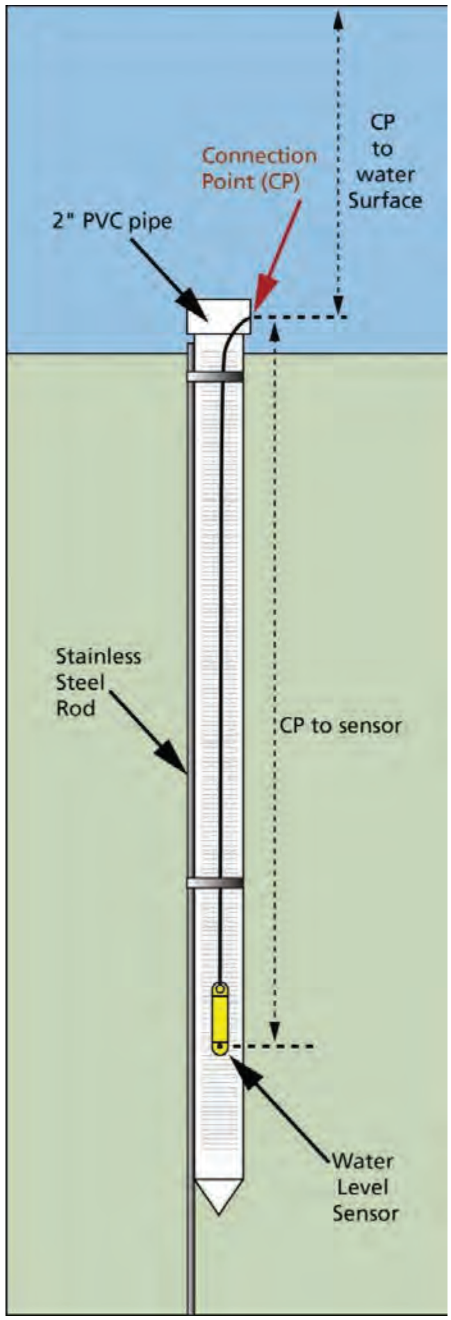


Figure C 8. Water level logger installation in the bottom of tidal creek.

Questions about logger installation:

Jim Lynch
National Park Service, Northeast Coastal & Barrier Network
4598 MacArthur Blvd, NW
Washington, DC 20007
410-924-5412
james_lynch@nps.gov

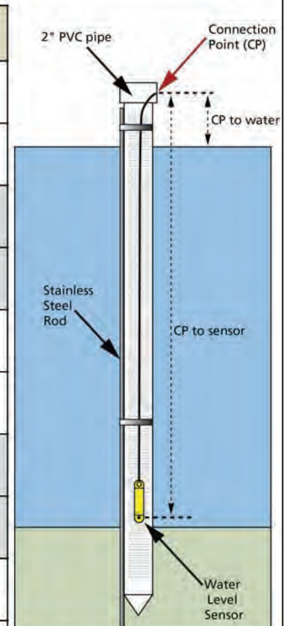
Appendix D. Water Level Logger Field Data Sheet

(Print on "rite in the rain" paper.)

Water Level sensor/Barometric sensor
Log Sheet

Park	Site

Date	Action		Sensor info	CP to Sensor	CP to water*	Time
1)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:			Personnel:			
2)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:			Personnel:			
3)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:			Personnel:			
4)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:			Personnel:			
5)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:			Personnel:			



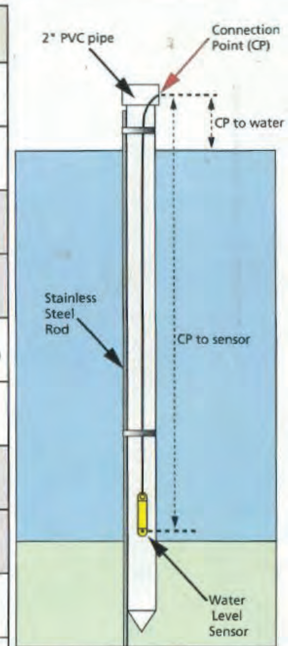
* CP = negative if water is below CP
CP = positive if water is above CP

Figure D 1. Example of a Blank form (v5).

Water Level sensor/Barometric sensor Log Sheet

Park	Site
ASIS	Developed Area

Date	Action		Sensor info	CP to Sensor	CP to water	Time
1) 9/24/14	☒ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger	10527256	56cm	- 15cm	11:15
Notes: CP to top of PVC collar = 3cm Support rod is 12ft deep N = 38.20118 W = 75.16198						
2) 12/2/14	☐ Deploy Logger ☒ Dump Data	☐ WL check ☐ Remove Logger	PLASTIC 10527256	56	-18cm	1245pm
Notes: TOP COLLAR TO CP = 3cm JIM LYNCH TOP CAP TO CP = 5cm						
3) 4/24/15	☒ Deploy Logger ☒ Dump Data	☐ WL check ☐ Remove Logger	105 27256		-14cm	1245pm
Notes: 3cm from CP to top of PVC collar Dumped & redeployed logger — Jim Lynch						
4)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:						
5)	☐ Deploy Logger ☐ Dump Data	☐ WL check ☐ Remove Logger				
Notes:						



Don't forget to record the names of the personnel.

Figure D 2. Example of a completed form (v4).

The Department of the Interior protects and manages the nation’s natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 962/135920, January 2017

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

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Appendix F – Field Instructions

Pore water salinity

Reference: Bottitta, G. and K.Whiting-Grant. 2004, based on Neckles and Dionne 2000 (App. B).

Equipment: Syringe with tubing; refractometer; salinity data sheets; clipboard; pencil; deionized (DI) water; handheld GPS unit; printed map of stations; watch; tide chart or knowledge of the day's tide schedule; hip waders or at least mud boots; Sharpie pen.

Notes:

- Pore water salinity must be measured within 2 hours +/- of local low tide.
- Sites are sampled at least once per month at each monitoring site during the sampling season (April – October).
- Monitoring can be performed by a lone individual; a second may assist with recording as resources permit.

Field instructions:

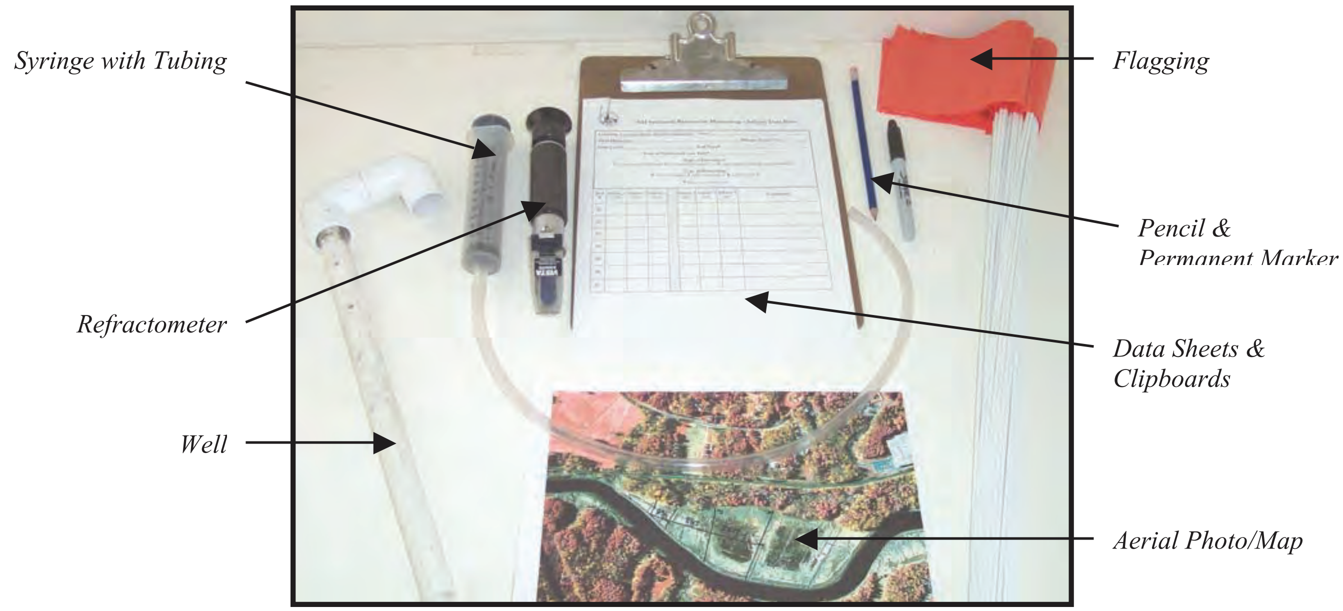
1. Prepare site-specific pore water salinity data sheet to document a site visit.
2. Using the map and/or GPS, locate and arrive at a pore water sampling station.
3. Calibrate the refractometer using distilled or DI water. The reading should be zero PPT (0 ‰). Rinse tubing with DI water.
4. Remove U-shaped cap from the top of the pore water well. Insert tubing to the well, so that the tubing hits the base of the well, then lift ~ 5 cm off the bottom.
5. Withdraw sample by pulling on the syringe. Remove the tubing from the well and replace well cap. Note the sample time on the data sheet.
6. Shake the syringe and/or tubing to mix the sample.
7. Lift the refractometer's daylight sample plate, and place several drops from the sample onto the face of the prism. Close the daylight sample plate cover.
8. Take a salinity reading while holding the refractometer facing toward the sun. Record measurement.
9. Repeat steps 7 and 8 twice more, so that there are three readings total.
10. Note any pertinent observations associated with the sample, such as presence of mud in the sample, or a dry well. If a well is muddy, remove the well, rinse it out, and reset the well. Wait 24 hours before sampling.
11. Discharge tubing and syringe.
12. Repeat steps 5-11 by taking a surface water sample from the adjacent channel.
13. Continue on to next station.
14. Salinity should be sampled once per month at each marsh site during the sampling season.
15. Make a note if the well or stakes are missing or broken. Replace if possible.

SOURCE: Bottitta, G. and K.Whiting-Grant. 2004. A Volunteer's Handbook for Monitoring Maine Salt Marshes. Ducks Unlimited and Maine Sea Grant Extension. Pp. 41-42. https://www.seagrant.umaine.edu/files/pdf-global/04saltmon.pdf

How Should Salinity Be Monitored?

Equipment

Soil salinity is a relatively inexpensive parameter to incorporate into a monitoring program. Wells to obtain soil salinity are constructed from 19mm diameter CPVC plastic pipe with 7 pairs of 4mm holes at sediment depths between 5 to 20cm. The base of the 35cm pipe is sealed and the top is capped with two right angles in sequence. This prevents rain or floodwaters from entering the well while maintaining ambient air pressure.



Sampling Method

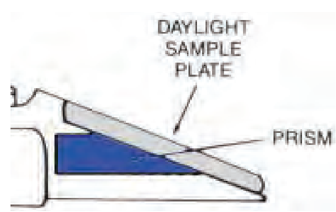
1. Remove the elbow-shaped cap from the well and insert the syringe tubing to the base of the well.

2. Lift the tubing about an inch away from the base to minimize the presence of mud and silt in the sample.

3. Extract a sample from the well by pulling the circular knob at the top of the syringe and drawing as much water into the syringe as possible.

4. Shake the syringe to reduce stratification (layering) in the water.

5. Open the daylight sample plate. Place the end of the tubing onto the refractometer prism and gently push the plunger until a few drops of water fall onto the refractometer.



6. Close the daylight plate so the plate comes into contact with the prism surface. The sample should spread completely over the prism surface. Air bubbles or an insufficient sample will be hard to read. If this occurs, repeat the procedure, applying more of the liquid sample.

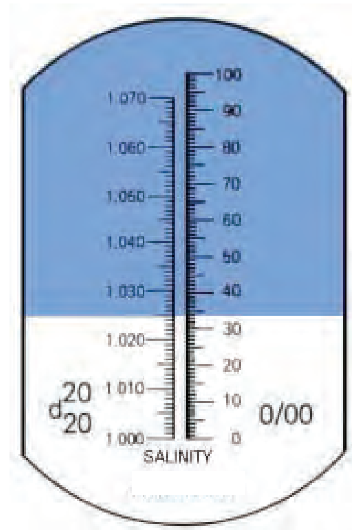
7. Hold the refractometer by the rubber grip and point the prism end of the refractometer to a light source and observe the field of view through the eyepiece. Focus the eyepiece by turning the cross-striped portion of the rubber eyepiece guard either clockwise or counter-clockwise until the scale becomes clearly visible.

8. A horizontal boundary line separating the blue field of view (top) and white field of view (bottom) will appear in the field of vision. Adjust the angle of unit to the light source until line is sharp and distinct. The values on the scale are specific gravity and parts per thousand (ppt).

9. Measure the sample to the nearest parts per thousand (ppt). Record the information in the space provided on the data sheet for "sample 1".

10. Wipe the refractometer prism surface dry and repeat steps 5 and 6 two more times for a total of three salinity readings.

11. Do not allow saltwater to remain anywhere on the unit. When through, wipe clean with damp cloth (fresh water) then wipe dry.



Sediment Elevation

Measuring the surface elevation of the marsh may assess net balances in critical soil processes that allow salt marshes to persist over time. Loss in elevation indicates peat degradation, whereas gains may be due to accretion at the surface or peat development below the surface. Standard survey techniques are unable to measure short-term changes in the sediment elevation (2 to 3 years), but are adequate for documenting long-term change (10 years or greater). Short-term changes in the sediment elevation of salt marshes around the world are being monitored using Sediment Elevation Tables (SET). Installation of the SETs is difficult and requires professionals. In New England, more than 30 stations exist in several salt marshes. Data are collected to provide baseline information, assess projects to restore hydrology, and assess sea level rise.

Monumented cross sections

Reference: Collins *et al.*, 2007 (following pages); Neckles & Dionne 2000 (App. B).

Equipment: Handheld GPS unit, map, digital camera, cross section data sheets, clipboard, pencil, transit instrument/auto level, tripod, stadia rod, rod level, large (6-8”) nail, 300 ft. (decimal) measuring tape reel, hip waders, tide chart or knowledge of the day’s tide schedule.

Notes:

- Measurements require that water levels are sufficiently low for safe channel crossing and preferably, an uninhibited view of channel features; e.g., the lower end of the tide.
- Two people are required for measurements: one on the stadia rod (observer), and one at the level taking readings and recording measurements (recorder).
- Hip waders are necessary to traverse the channel.
- Direction is with regard to flow toward the bay: river right (R), river left (L), upstream (U/S), downstream (D/S).

Field instructions:

1. Using the map and/or GPS, locate cross section monitoring station, including monuments (typ. PVC) that denote the start and end of a transect running perpendicular to the channel.
2. Observer sets up the transect.
    - Insert the nail through the end of the tape reel and into the top of the monument at river L. On data sheet, note transect start location (e.g., Station 1, 0’ at river L).
    - Affix the reel end of the tape to the opposite monument and note the transect length on the data sheet. Ensure the tape is taut before commencing with the survey. Note: Windy conditions may prevent surveys at large channels if the tape is not taut. Either wait for the wind to die down or come back at a later time.
    - With the tape in the foreground, take four photos of the channel: toward river R, river L, U/S and D/S. Ensure camera is level and that the image is taken in landscape format. Note the photo #’s and labels (river R.) on the data sheet.
3. Recorder sets up the level.
    - Draw a sketch of the cross section looking upstream and a second sketch of the general form of the channel. Include vegetation changes, slumped or overhanging banks, pools, and other features. Limit sketches to ~3 minutes apiece.
    - Set up the level equipment. Extend the tripod legs, locking them into place and gently using the foot pads to stabilize the unit. Set the tripod up a few feet from the first stake, looking across at the other stake. Remove the lens cap and attach the level to the tripod, screwing on tightly. Level the instrument by adjusting the 3 wheels so that the bubble is centered.
4. Survey the transect.
    - If a local benchmark / control point is available, measure that point at the start and end of the survey, and note the rod height on the data sheet.
    - Observer starts at 0’ (river L) with the rod placed on the ground immediately next to the monument and facing the level. The rod is held vertical by use of a rod-level, and

the rod is always held on the opposite side of the tape from the observer. The observer calls out the distance along the transect and description. The recorder reads the center crosshair of the level to obtain the stadia rod measurement also records the distance and description.

  - Along the transect, observer sets the rod to document visible breaks in slope/elevation, and significant geomorphic features such as top of channel bank, base of channel bank, water depth, undercut banks, and the thalweg.
  - In the absence of clear breaks in slope or other features, elevations are recorded at a pre-determined interval as follows: (total transect length/20), with observations recorded at this distance along the transect.
  - Transect ends at river R.

5. Pack up the equipment and head to the next cross section.

SOURCE: Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton, and D. Neils. 2007. Stream Barrier Removal Monitoring Guide. Gulf of Maine Council on the Marine Environment. pp. 27-30 www.gulfofmaine.org /streambarrierremoval.

B. MONITORING METHODS

1. Monumented Cross-sections

Purpose

This section describes how to establish and survey permanent (i.e., monumented) stream cross-sections for long-term monitoring. It identifies the equipment needed, describes the basic protocol, discusses the frequency with which the cross-sections should be re-surveyed, and presents some site-specific considerations. This section does not provide detailed instruction on basic surveying techniques, such as conducting a level survey. For a more complete treatment of stream surveying techniques, see Harrelson et al. (1994).

Monitoring Design

Sampling Protocol

1. Define the monitoring reach.

Defining the length of the stream monitoring reach is the first step in conducting cross-section surveys. Upstream of the barrier, the monitoring reach should, at a minimum, include the length of the impoundment and a representative portion of undisturbed reach upstream of the barrier (e.g., a reach length of approximately 10 channel widths). The downstream monitoring reach is less easily defined because the length of reach physically impacted by the barrier, and/or its removal, is not generally known precisely beforehand.

Minimum Equipment

- ❑ Automatic level (surveyor's level) or laser level
- ❑ Leveling rod in English (to tenths and hundredths) or metric units, preferably 25-foot length
- ❑ Measuring tape in same units (300 ft or 100 m)
- ❑ Field book with waterproof paper
- ❑ Data sheets (see Appendix E)
- ❑ Pencil
- ❑ Permanent marker
- ❑ Two-way radios
- ❑ Topographic maps and/or aerial photographs
- ❑ Chaining pins
- ❑ Flagging tape
- ❑ Machete
- ❑ Wood survey stakes
- ❑ 4 ft (1.2 m) steel rebar stakes
- ❑ Hacksaw
- ❑ Small sledge or mallet
- ❑ Spring clamps
- ❑ GPS
- ❑ Compass

Karla Garcia / NOAA Restoration Center

Installing a monument.

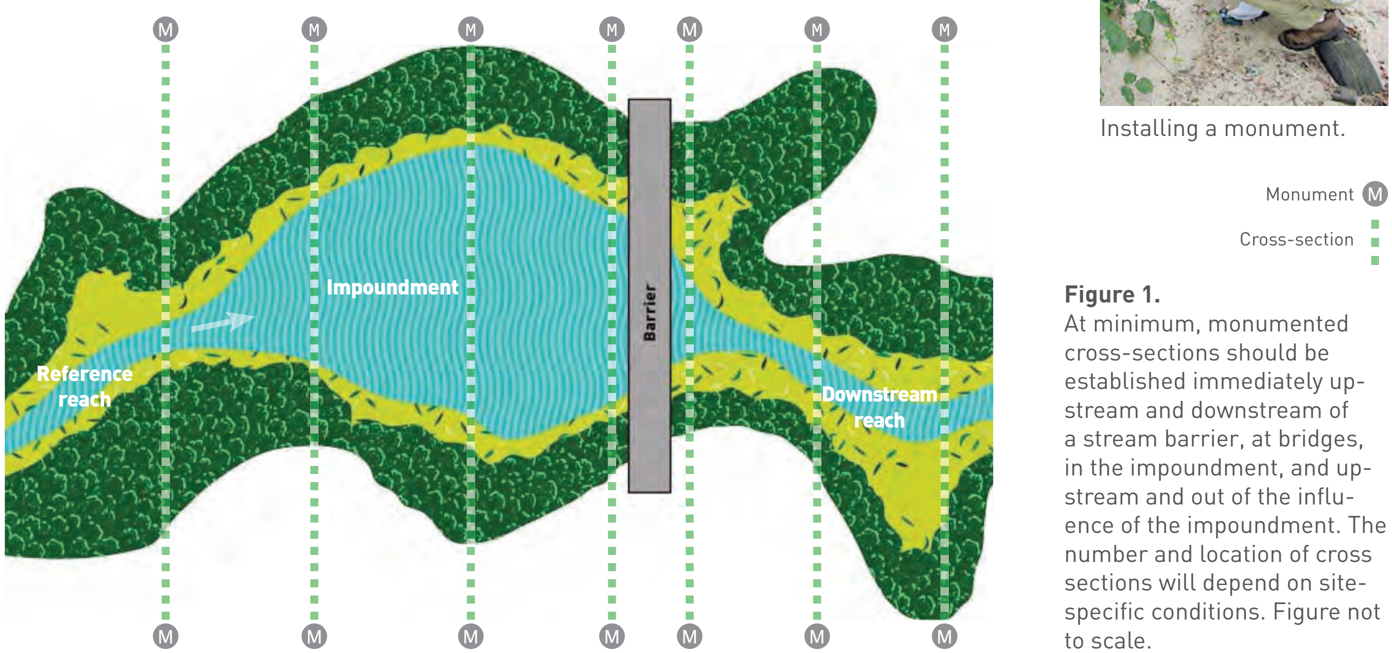


Figure 1.
At minimum, monumented cross-sections should be established immediately upstream and downstream of a stream barrier, at bridges, in the impoundment, and upstream and out of the influence of the impoundment. The number and location of cross sections will depend on site-specific conditions. Figure not to scale.

This length can be estimated, or the downstream limits can be identified based on other project considerations such as downstream habitats of concern, infrastructure, or locations of hydraulic or geomorphic controls such as bridges, outcrops, or knickpoints.

2. Determine number and location of cross-sections.
Once the length of the monitoring reach has been identified, the monitoring team must determine the number of cross-sections needed to adequately represent that reach. The most easily identifiable locations are those areas where infrastructure in the floodplain is likely to be impacted by the project. For example, cross-sections should be established immediately upstream and downstream of the barrier and at bridges within the identified project reach. There also should be cross-sections representing the impoundment (see Site Specific Considerations below), at least one in the undisturbed reach upstream of the impoundment, and at any locations judged to be sensitive to disturbance or of high habitat value. The engineering and geomorphic analyses used to plan the barrier removal should be consulted to identify critical locations. If present in the monitoring reach, cross-sections should be established at existing, monumented cross-sections and/or stream gage locations (Figure 1).

The choice of other cross-section locations should be based on the number of physically homogeneous stream reaches within the monitoring reach—those with similar slopes, bed and bank material, floodplain/terrace sequences, riparian vegetation, and channel-forming processes (Simon and Castro, 2003). For example, the number of cross-sections representing pools, riffles, meander bends, straight reaches, and flow divergence should closely approximate their proportion in the entire monitoring reach. Identification of these sub-reaches or cross-section types should begin with a pre-field inspection of available topographic maps, aerial photographs, surficial/bedrock geology maps, soil surveys, and other relevant information. In addition to subsequent field inspection, you may want to perform and plot a longitudinal profile to use in selecting cross-section locations (see section IV.B.2). Reviewing these data will be valuable for identifying reaches with similar physical characteristics and dominant processes.

3. Locate and establish the cross-section monuments.
At each cross section, establish the permanent markers for both endpoints by driving a ½-inch-diameter, 4-foot rebar stake either flush with the ground or ½ inch above the surface. You may want to cover the tops of the stakes with colored plastic caps available from survey suppliers and use different colors to distinguish different cross-sections (Harrelson et al., 1994). Be sure to note the color associations in the field book. The cross-sections should be straight and perpendicular to the bankfull flow direction, and they should extend across the floodplain/riparian zone to the first terrace or as far as practicable.

To facilitate locating each cross-section for future surveys, establish the horizontal position of the monuments via GPS and one other method. You can fix the position of monuments by taking a bearing and measured distance to the benchmark (see step 4 below), or by triangulating between the monument, benchmark, and another permanent feature on site (e.g., large, healthy tree or bedrock outcrop) (Harrelson et al., 1994; Miller and Leopold, 1961). If the benchmark is not visible from a given cross-section, triangulate with two permanent features. The GPS coordinates of each monument will facilitate mapping the cross-section locations in GIS. Once located, depict the cross-sections on a scaled map or aerial photograph of the project area.

4. Locate or establish the benchmark.
Once the cross-sections have been established, you must either locate, or establish, a local benchmark for the site. This is a permanent marker of known, or assumed, elevation that functions as survey control and the survey starting point. The U.S. Geological Survey (USGS) and other entities historically involved in developing geodetic control networks have benchmarks throughout the country. If one is available at your site, use it. They are typically found on stable site features such as bedrock outcrops; the tops of large, embedded boulders; and bridges.

In the event that a USGS or other geodetic control benchmark is not present in reasonable proximity to the project area, you will need to create a local, or project, benchmark. This offers the opportunity to establish it in a location that is advantageous for the survey; that is, locate it at a point relatively high on the site and visible from most, or at least many, of the permanent cross-sections. You can do so by driving a rebar stake 3 or 4 feet into the ground, chiseling a mark in an outcrop feature or stable boulder, or other means described by Harrelson et al. (1994). Be sure to describe its location in the field book and establish its coordinates with GPS. Always record the horizontal datum employed by the GPS (e.g., NAD 83). If you establish a benchmark, it is conventional to assign it an arbitrary elevation of 100 feet. Alternatively, the benchmark can be tied into an established vertical datum (e.g., NAVD

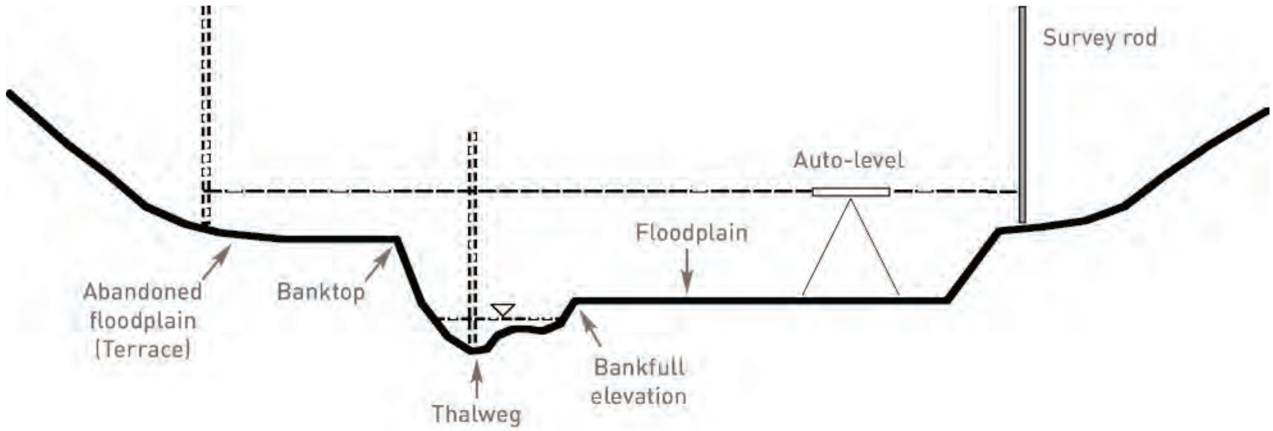


Figure 2. Basic channel and valley features of an unimpacted (reference) stream reach. Note that some features, such as the bankfull elevation, will not be identifiable in the impacted project reach or in all reference reaches.

88) or referenced to mean sea level for projects in areas subject to tidal influence. The horizontal and vertical datums used for the cross-sections should be used also for the longitudinal profile.

5. Set-up the survey instrument and tape.
If possible, set up the survey level in a location from which the local benchmark and all points of one or more cross-sections are visible. Though one or more cross-sections might be shot from one instrument station, to complete all cross-sections for your site you may need to set up two or more instrument stations. From each new instrument station you will need to take backsights on the benchmark (see below), if it is visible, or from turning points if it is not (Harrelson et al., 1994). A machete can be useful to trim low-hanging branches or other vegetation and decrease the number of times you need to move the instrument, but you should avoid cutting large amounts of vegetation for this purpose to minimize property and habitat impacts. At each cross-section, stretch a tape as taut as possible between the monuments. It can be attached to the monument itself with spring clamps, to a shorter rebar stake driven next to the monument with 6 inches exposed for easier attachment, or with chaining pins (Harrelson et al., 1994).

If you are using an optical surveyor's level (auto-level), the person operating the level will make and record the rod readings while the rod person will choose the survey points and call out the lateral distances to the level operator. Lateral distances are referenced to the left bank monument, which is the cross-section zero (left bank is referenced as the left bank looking in the downstream direction). A third person dedicated to recording all readings and descriptions in the field book is recommended and will be necessary for surveying the impoundment with a boat (see Site Specific Considerations below). One advantage of using a laser level is that one person can execute the cross-section survey (or two for impoundment surveys).

6. Survey the cross-section.
Begin with a rod reading on the benchmark. This "backsight" will be added to the elevation of the benchmark to establish the "height of instrument" (HI). All "foresights" on cross-section locations will be subtracted from the HI to obtain the elevation of those points (Harrelson et al., 1994). The first foresight will be taken at the left bank monument. From there, take readings at all breaks in slope and especially at significant geomorphic features as you make your way across the valley (e.g., bankfull, bank top, bank toe, bar tops, edge of water, thalweg), describing each feature in the notes for the respective reading (Figure 2). Capture features such as woody debris and bank-failure deposits, and record in the notes important changes in substrate type.

Also make notes about the nature of the vegetation, especially its structure (e.g., trees, shrub, herbaceous; see Section II.B.7 for the riparian plant community structure method), and be sure to record the locations where discrete changes occur. Adequately characterizing the complexity of the cross-section will typically require a minimum of 30 to 40 rod readings. Larger floodplains and more complex geometry can require many more. Record the horizontal distances to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Cross-section elevations are also recorded to hundredths of feet.

Bear in mind that identifying a bankfull channel will be most applicable to the cross-section(s) upstream of the hydraulic influence of the impoundment that represent the un-impacted channel reach. The bankfull channel is adjusted to an approximately 1.5- to 2-year recurrence interval discharge and the prevailing sediment transport conditions (Leopold et al., 1964). Because water flow and sediment discharge conditions will, in most cases, be changing at a barrier removal site, a persistent bankfull channel likely will not be identifiable in the monitoring reach. This may also be true of the reference reach, especially in watersheds with changing land use. See Harrelson et al. (1994) for a good discussion about field identification of the bankfull channel. The USDA Forest Service Stream Systems Technology Center (2003) also produces a video specifically geared towards field identification of the bankfull channel in the eastern United States (www.stream.fs.fed.us/publications/videos.html).


Karla Garcia / NOAA Restoration Center

Monument at a cross-section.

Sampling Frequency

Pre-removal surveys are essential for comparison with post-removal data to assess channel and floodplain response. Pre-removal surveys may be most easily accomplished if the impoundment can be drawn down before removal (see Site Specific Considerations below), such as during project feasibility studies. In any case, for efficiency purposes, selection of the long-term monitoring cross-sections and pre-removal data collection should be integrated with any planned feasibility work. As a general guideline, post-removal re-surveys should occur annually, or every other year, for at least 5 years. However, sampling frequency and duration should reflect project objectives and site conditions. For example, sites with great amounts of loose sediment may require more frequent sampling over a longer period than sites with bedrock channels or beds dominated by coarse materials. At a minimum, the frequency should conform to any regulatory requirements. The monuments should be recoverable for much longer so that longer-term studies of channel evolution are possible.

Site-specific Considerations

Some of the pre-removal cross-sections will need to traverse the impoundment. The determination of whether cross-section data in an impoundment can be acquired by wading or using watercraft must consider the depth of the impoundment and suitability of sediment for wading. Impounded sediments may be unconsolidated, fine-grained material with saturated interstitial spaces, making them very soft and incapable of supporting a wader. In such conditions, it will be necessary to obtain the data from a boat. Depending on the nature and depth of the impoundment, surveying cross-sections within it can be accomplished either by employing the methods described in the previous section and taking rod readings at fixed intervals from a small boat, or by using a fathometer from a boat navigated along the transect and integrating the readings with the rod readings on shore via GPS positioning. If you are taking rod readings from a small boat, you will need to take care in positioning the rod and try to make sure the rod rests on top of the sediments and does not sink into soft substrate. At least two people are needed for boat work—one to work the survey rod and the other to station the boat.

Analysis and Calculations

The data from a cross-section survey are elevations and distances. Horizontal distances are recorded to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Cross-section elevations are recorded to hundredths of feet. These data should be recorded in standard level-survey notation (see Cross-Section Survey Data Sheet in Appendix E). Harrelson et al. (1994) also provide a nice graphic example of proper field book notation for level surveys. The horizontal and vertical datums of the survey must always be recorded (see Site Information Data Sheet in Appendix E). The distances and elevations can be plotted manually on graph paper as 'x' and 'y' coordinates, respectively, or brought into a spreadsheet program for plotting and analyses.

Additional Information

Harrelson et al. (1994) provide an excellent reference for basic survey techniques and for specific information on conducting cross-section and longitudinal profile re-surveys. We strongly recommend that readers with minimal experience consult this reference. It also is a useful review for those with more experience.

Longitudinal channel profiles

Reference: Collins *et al.*, 2007 (following pages)

Equipment: Hip waders (mud boots ok for the person at the transit), transit instrument, tripod, stadia rod, rod level, compass, data sheets, clipboard, and pencils.

Notes:

- Longitudinal profiles must be conducted at low tide.
- Two people are needed: observer handles the rod, recorder handles the transit.
- Prior knowledge of benchmarks (elevation control points) in the field is necessary.

Field Instructions:

1. Set up the transit instrument on its tripod in a spot with clear visibility to both sides of the structure, the channel reach to be surveyed, and a local benchmark / control point. Often, set up is along a road shoulder; be visible and wear a safety vest.
2. Position tripod legs and lock into place, pushing the feet firmly into the ground. Level the transit, adjusting the wheels until the bubble is in the center of the circle.
3. Turn the instrument toward a benchmark (e.g., nail on a telephone pole). Set the level angle at zero. Take a compass bearing on the benchmark and record magnetic angle from the level to the benchmark. Record height at the top cross hair, the mid cross hair, and the lower cross hair, as well as the angle (being 0 degrees at the first benchmark). Repeat with additional benchmarks if available. Fill out other information on the data sheet.
4. The person with the stadia rod should walk toward the beginning of the transect starting with the location of the downstream cross section (typically, Station 1). The stadia rod should be positioned in the thalweg (deepest part of the channel) throughout the survey.
5. When in position, the recorder reads the rod height at all three cross hairs, and the angle.
6. The person with the stadia rod moves upstream by approximately 20 feet at a time, or at obvious elevation breaks, while the transit records all data. If there is a sharp change in the channel grade, position the stadia rod at closer increments so the change can be captured in the transit readings.
7. Continue upstream until the road/structure is reached noting visible changes in the channel such as a sandy bottom, muddy bottom, rocks etc.
8. Once at the structure, get a reading at the outlet invert. Note height of top of pipe/structure above the invert as well as water depth. On top of the road, survey the road crown height (typically in the road center). Go to other side of the structure and get the same measurements working upstream.
9. Continue up the channel using the same method as before making sure to stay in the thalweg and measure visible changes in elevation.
10. At a minimum, observer continues measurements until the first cross section upstream (typically, Station 2). Once recorder is unable to take a reading through the auto level, the profile is done.

SOURCE: Collins, M., K. Lucey, B. Lambert, J. Kachmar, J. Turek, E. Hutchins, T. Purinton, and D. Neils. 2007. Stream Barrier Removal Monitoring Guide. Gulf of Maine Council on the Marine Environment. pp. 31-32 www.gulfofmaine.org /streambarrierremoval.

2. Longitudinal Profile

Purpose

This section describes how to survey the longitudinal profile of the channel thalweg at your monitoring reach. It identifies the equipment needed, outlines the basic protocol, discusses the frequency with which the profile should be re-surveyed, and presents any site-specific considerations. As with the monumented cross-section method (see Section IV.B.1), this section does not provide detailed instruction on basic surveying techniques. See Harrelson et al. (1994) for a more complete treatment of this subject.

Monitoring Design

Sampling Protocol

1. Define the monitoring reach.

This must be accomplished before surveying the longitudinal profile and the cross-sections. See Section IV.B.1 for general guidelines. Your longitudinal profile should extend the length of the monitoring reach, beginning at a stable channel feature (e.g., riffle) upstream of the impoundment. Your profile should always begin upstream of the uppermost cross-section and should continue to the lowermost cross-section and include survey shots at the thalweg of all monumented cross-sections.

Minimum Equipment

- ❑ Automatic level (surveyor's level), laser level, or total station
- ❑ Leveling rod in English (to tenths and hundredths) or metric units, preferably 25-foot length
- ❑ Measuring tape in same units (300 ft or 100 m)
- ❑ Field book with waterproof paper
- ❑ Data sheets (see Appendix E)
- ❑ Pencil
- ❑ Permanent marker
- ❑ Two-way radios
- ❑ Topographic maps and/or aerial photographs
- ❑ Chaining pins
- ❑ Flagging tape
- ❑ Machete
- ❑ Wood survey stakes
- ❑ Small sledge or mallet
- ❑ Spring clamps
- ❑ Compass

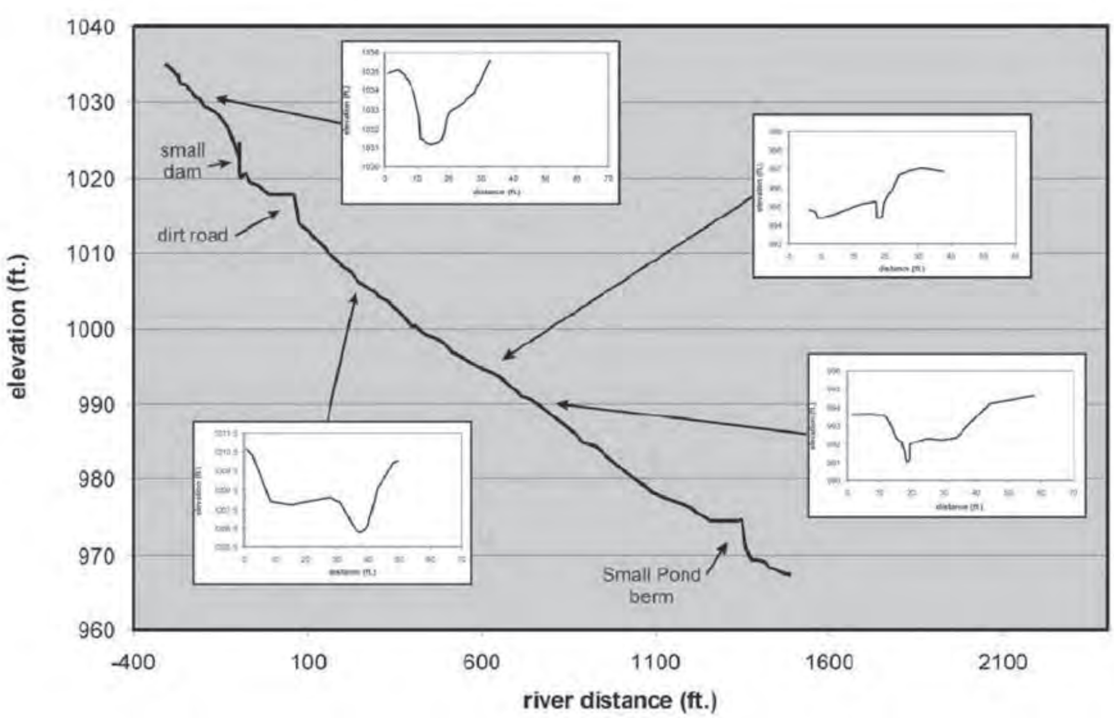


Figure 3. A longitudinal profile surveyed pre-project at Kamrath Creek, Wisconsin. The survey points for a channel bed longitudinal profile are taken at the deepest point in the channel, i.e., the thalweg (see Figure 2). Profile plot courtesy of Brian Graber.

2. Set up the survey instrument.
If possible, set up the level in a location from which the benchmark, and as much of the monitoring reach as possible, is visible (See Section IV.B.1, step 4, for information on benchmarks). You may want to consider setting up the instrument in the channel, if the flow and bed conditions permit (Harrelson et al., 1994). Choose instrument locations carefully to minimize the number of times you need to reposition.

3. Establish the stationing.
Downstream distance should be measured along the channel thalweg. A straightforward method is to station the channel with a baseline along one bank. The downstream distance of each survey shot is measured as the right-angle projection from that location to the baseline on the bank.

The baseline can be established by two people measuring along the stream thalweg with a tape, while someone on shore drives, and clearly marks, wooden survey stakes at regular intervals (commonly a channel width). The purpose of the stationing stakes is to make estimating distances easier. They do not necessarily mark the locations of actual survey shots. See Harrelson et al. (1994) for further information on stationing. Using a total station with a GPS interface, if available, can make stationing unnecessary and considerably simplify profile completion. These units can "fix" the horizontal position of survey shots in known datums such as NAD 83 for subsequent plotting in GIS and calculating distances. Total stations and laser levels are also advantageous for profile surveys because of the long distances over which they can obtain shots (Simon and Castro, 2003).

4. Survey the profile.
Begin with a rod reading on the benchmark to determine the height of the instrument (HI) (see Section IV.B). Then take readings along the thalweg (i.e., deepest part of the channel) at important bed features (e.g., pools, riffles, bedrock sills, woody debris), measuring downstream distance using the baseline. Include enough shots to well define each feature (Simon and Castro, 2003). It is particularly important to determine the highest elevation at pool-riffle (and/or run) transitions.

Along with distances and elevations, record in the field book details about the feature being measured and the locations of important changes in substrate type. Also, take elevations of the water surface at each bed elevation measurement. This can be done easily by taking the elevation of the water's edge closest to the thalweg along the projection to the baseline. Move the instrument as needed to complete the profile.

Sampling Frequency
As with the cross-section surveys, a pre-removal longitudinal profile may be accomplished most easily during an impoundment draw-down and should be integrated with any planned feasibility work (see Site Specific Considerations below). As a general guideline, post-removal re-surveys should occur annually, or every other year, for at least 5 years. However, sampling frequency and duration should reflect project objectives and site conditions. At a minimum, the frequency should conform to regulatory requirements. Note that follow-up surveys should trace the post-barrier removal thalweg, which may not be in the same horizontal position as the pre-removal thalweg.

Site-specific Considerations
A portion of the pre-removal longitudinal profile will run through the impoundment. As with the cross-sections, this may require a boat and should be done with great care. See Site Specific Considerations under Section IV.B.1 for general guidelines and considerations.

Analysis and Calculations
The data from a longitudinal profile survey are elevations and distances. Horizontal distances are recorded to tenths of feet (0.1 ft) and elevations of benchmarks and turning points to hundredths of feet (0.01 ft). Profile elevations are recorded to hundredths of feet as well. These data should be recorded in standard, level survey notation (see Longitudinal Profile Survey Data Sheet in Appendix E). Harrelson et al. (1994) also provide a nice graphic example of proper field book notation for level surveys. The horizontal and vertical datums of the survey must always be recorded (see Site Information Data Sheet in Appendix E). The distances and elevations can be plotted manually on graph paper as 'x' and 'y' coordinates, respectively, or brought into a spreadsheet program for plotting and analyses (Figure 3).

Additional Information
Harrelson et al. (1994) is an excellent reference for basic survey techniques and for specific information on conducting cross-section and longitudinal profile re-surveys. We strongly recommend that readers with minimal experience consult this reference. It also provides a useful review for those with more experience.

Vegetation

Reference: Neckles and Dionne, 2000.

Equipment: Graduated 300ft. (decimal) tape reel, 1 meter quadrat (PVC), camera, hip waders, handheld GPS, compass, site map, vegetation transect cover sheet, vegetation plot data sheet, vegetation transect summary, magnifying glass, field guide(s), Ziploc bags, clipboard, and pencils. Vegetation identification guide (Tiner 2009, *Field Guide to Tidal Wetland Plants of the Northeastern United States and Neighboring Canada*).

Notes:

- Vegetation monitoring is best conducted during low-mid tides.
- Feasible with one person, but optimal with two in the following roles:
  - Observer: identifies plant species, describes cover type and estimates percent cover
  - Recorder: assists observer with tape, photos, filling data sheets.
- Prior knowledge of transect length, location (start and end points), magnetic direction, and plot distances along the transect needed for replication (Vegetation Transect Summary).

Field Instructions:

- Prior to sampling:
  - At each station, fill out Vegetation Transect Cover Sheet.
  - Locate transect, using information in Transect Summary Form (Access form/report)
    - Locate start of station transect at channel edge using site map and GPS unit.
    - Locate end of transect at upland edge using compass bearing, GPS unit, and markers/descriptions
  - Run tape reel from transect start at the channel edge (0'), to channel end at the upland, or 300', (whichever is shorter).
  - Take photo (landscape orientation) of view from channel to upland.
- Proceed with sampling at pre-determined plot distances along the transect.
  - Place quadrat on opposite side of tape, with quadrat running parallel to tape beginning at the plot distance.
  - Use percent cover estimates. For cover estimates less than 1 percent ("present"), use >1%
  - Record findings on Vegetation Plot Data Sheet.
  - For unknown species in the marsh, take a sample in a plastic bag and ID back at the office. Note on data sheet any samples taken, and ID the sample at the office
  - For unknown species at the upland edge, photograph, and note photo ID number, and ID back at the office
- Proceed to next plot by walking on the opposite side of the tape from what is being measured.
- At conclusion of sampling:
  - Take photo (landscape orientation) of view from upland back to channel.
  - Reel in tape.
- Proceed to next station.

Ecosystem Indicator: Vegetation

Work Group Participants

Summary by: Ted Diers, NH Coastal Program, and Charles Roman-USGS, Sarah Allen-Normandeau Assoc., Bruce Carlisle-MA CZM, Carolyn Currin-NOAA, Pam Morgan-UNH, Frank Richardson- NH DES., Peter Shelley-Conservation Law Foundation, Lee Swanson-NB DNR.

Rationale

The goal of vegetation monitoring is to track trends in plant abundance and species composition of the marsh community over time. A protocol for monitoring restoration projects must be capable of detecting changes in the vegetation of the restoring marsh and a reference marsh in the years following restoration actions, and of determining whether and how the vegetation of the restoring marsh differs from that of the reference system over that time period. In addition, frequently the purpose of a restoration project focuses on a specific plant species such as *Phragmites australis* or *Spartina alterniflora*. In these cases, more detailed information on individual species of concern may be warranted. The methods described below should be applied routinely to the marsh plant community in general, with additional data collected on species of concern as appropriate.

Core Variables

- **Abundance:** cover class per m^2, by species
- **Composition:** identity of species per m^2
- **Height of species of concern:** mean height of 3 tallest individuals of each species of concern per m^2
- **Stem density of species of concern:** # shoots per m^2, plots restricted to species of concern, by species

Sampling Methods

Plots

The general marsh community and species of concern are sampled using 1 m^2 quadrats. All sampling should be accomplished at the time of maximum standing biomass, in mid-summer (mid-July through August).

At each plot, take the following measures:

1) Identify all plant species (i.e.,species composition).

2) For each species, estimate percent cover by visual examination. Estimate percent bare ground as well.

   The estimate should be an integer number that can be categorized within standard Braun-Blanquet cover classes (<1%, 1-5%, 6-25%, 26-50%, 51-75%, >75%). Estimating cover by visual examination can be somewhat subjective; however, it has been demonstrated that these measures of cover are comparable to the more time intensive, quantitative measures of relative abundance, such as point intercept counts (Kent and Coker 1992).

3) Measure and then average the height of the tallest three individuals of each species of concern within each plot.

In addition, for plots restricted to species of concern (see Sampling Design, below), determine the stem density by species within a subsampled area of the plot.

Photo stations

Photographs taken from permanent stations can provide qualitative information on the changes in the plant community over time. Stations should be indicated on maps and with permanent field markers. The stations should include views of the restoration activity or structures. Two kinds of photo stations should be established – landscape or panoramic views and close-ups of plots. Landscape photos are taken at several compass bearings to cover a panorama of the entire marsh. For stands at the site of a tidal restriction, bearings showing the downstream marsh are desirable as well. Landscape photographs should include a person or an object for height scale. Close-ups are oblique views of a select number of the permanent vegetation plots. The corners of the plots should be identified with orange flagging and the photo taken from a height of about 1.2 m (4 ft). Photos should be taken at the time of vegetation sampling.

Salt marsh hay-
Spartina patens

Robert Shetterly

Sampling Design

Marsh Community

The marsh plant community should be sampled using permanent plots positioned along transects in a systematic sampling design, following Elzinga et al. (1998). Use of permanent plots (re-sampled at each sampling interval) allows the application of powerful statistical tests for detecting change. Systematic sampling allows relatively easy positioning and relocation of quadrats and insures a fairly uniform distribution of quadrats throughout the study area.

Volunteers using transect to monitor vegetation

The marsh study area, or areas, should be identified and mapped. This may include a marsh that is bisected by a causeway, with one marsh area under the influence of reduced tidal exchange and another area open to full tidal exchange. Within each marsh study area, transects will be established perpendicular to the main marsh tidal creek; transects begin at the creek bank and extend to the upland. So that transects are dispersed fairly uniformly across the marsh, transects are positioned randomly within contiguous marsh segments. Divide the marsh into equal-sized segments along the axis of the main tidal creek, and randomly locate transects within marsh segments. Quadrats are then systematically located along transects. For each transect, the location of the first quadrat is selected randomly within the low marsh zone, or within the first 3 meters if no zone is apparent. Subsequent quadrats are located at consistent distance intervals along the transect. Given that the transects are established in a random manner, and assuming that there is adequate spacing between quadrats (>10 m) to insure that the plant communities of nearby quadrats are not correlated with each other, each quadrat can serve as a single sample unit (similar to a simple random sampling design).

The map or aerial photographs should be used to lay out the marsh segments, transects within segments, and quadrats along transects to achieve an appropriate dispersion of sample plots. In the field, the exact starting location of transects and quadrats can be determined using a random numbers table and meter tape.

What should be the total number of 1 m^2 quadrats sampled within each marsh area? This question should be resolved before the transects and quadrats are established. The ideal way to determine the appropriate number of plots required would be to conduct a power analysis. Using this approach, if the variability associated with the measurement and the desired level of change detection (i.e., subtle vs. major changes in the marsh community) are known, then the number of replicates required can be determined. A power analysis specific to New England salt marsh vegetation studies has been completed by the USGS-Biological Resources Division and is under review. Recognizing that this analysis is not yet final, and does not necessarily apply to all Gulf of Maine salt marshes, preliminary findings suggest that twenty plots within each study area of up to 50 ha would be adequate to detect subtle changes over time. Moreover, after several years of data have accumulated from specific restoration and reference sites, the investigator will be able to determine the level of variability at the site and then adjust to an appropriate number of replicates.

Vegetation should be sampled before restoration, 1 and 2 years following restoration, and every 3-5 years thereafter. There are several data analysis techniques that can be applied to detect changes in the vegetation community over time. Ordination techniques, such as Detrended Correspondence Analysis, or an analysis of similarity, are just two of the techniques that can be used (see Kent and Coker 1992).

Species of Concern

There are two ways to monitor species of special concern, such as *Phragmites* or *Lythrum*. First, in the routine vegetation community sampling described above, the height of the 3 tallest plants species of concern should be measured in all quadrats in which it occurs. If species of concern are not adequately represented in the marsh community samples, then a minimum of 5 additional 1 m^2 plots should be permanently established within distinct stands. Data on all core variables are then collected from these plots as well during vegetation sampling.

Surface Water Hydrology (level, temperature, conductivity)

References:
- Curdts 2017, National Park Service: https://irma.nps.gov/DataStore/DownloadFile/563851
- HOBO U20 Water Level Logger Manual: https://www.onsetcomp.com/files/manual_pdfs/12315-E-MAN-U20.pdf
- HOBO Micro Station Quick Start Manual: https://www.onsetcomp.com/files/manual_pdfs/20874-D%20MAN-QSG-H21-USB.pdf
- HOBO Barometric Pressure Smart Sensor Manual: https://www.onsetcomp.com/files/manual_pdfs/12291-F%20MAN-S-BPB.pdf
- HOBO U24 Conductivity Logger Manual: https://www.onsetcomp.com/files/manual_pdfs/15070-C-MAN-U24x.pdf

Equipment:

- Laptop w/ HOBOWare Pro
- Onset HOBO U20 Titanium Water Level Logger(s), range 0-4 m.
- Onset HOBO Conductivity Logger(s)
- Onset HOBO Barometric pressure station (micro station, sensor)
- Clipboard with datasheets & pencils
- Stadia rod (English, decimal feet)
- Auto level with tripod
- GPS
- Camera
- AA batteries
- Needle nose pliers
- Fence posts (short)
- PVC housing
- Zip ties
- Bucket
- Knife/scissors
- Refractometer
- De-ionized water

Data sheets:
- HOBO Water Level Logger Deployment Data Sheet
- HOBO Conductivity/Salinity Logger Deployment Data Sheet
- HOBO Baro-logger Deployment Data Sheet
- ONSET HOBO logger deployment check list

Notes:
- Equipment installation occurs at low tide, with equipment set at lowest point feasible given site constraints
- Equipment may be deployed by a lone individual, but tying elevations into a vertical datum requires surveying and therefore, two people.

Field Instructions:
Site specific monitoring objectives are outlined in SAPs and will inform deployment location.

Baro-Loggers

- Follow manuals for HOBO micro station and barometric pressure smart sensor to start up
- Use a bungie cord to attach housing and instrumentation to a tree or other structure in a shaded (24 hours) and discreet location. Instrument is sensitive to heat; shade is important.

U20 Water Level Loggers; Conductivity Loggers

- Program instruments (in the office or on site).
    - Set start time to the top of the hour with a sampling interval of 6 minutes to synchronize with Portland Tide Station.
- Deploy instrument(s) in PVC housing affixed to fence post or cinder block using zip/cable ties. Set configuration into the bottom with fence post or cinder block
- Deployment method will depend on local site conditions:

Option 1 – PVC housing affixed to a secure post Manufactured stilling wells are available for purchase. Can also be constructed. CBEP builds stilling wells by cutting 1 ½” (3.5 cm) PVC pipe to a 35cm length then drilling numerous .5 cm holes into the pipe to allow adequate flow and drainage. A comparably drilled cap is then affixed to the base of the well with adhesive. The top cap is drilled with an additional 1 cm wide slit cut to the cap end in order to accommodate the cable. The top cap is temporarily affixed to the well with a zip tie during deployment. Throughout deployment, care must be taken not to kink the instrument cable.

During deployment, the instrument is set into the well, which is first affixed to a secure post with zip/cable ties. The post (fence post or rebar) is then driven into the sediment to a sufficient depth so that the stilling well is above the sediment surface, but the post will also sit securely over the deployment period, and so that the instrument is vertical and the sensors sit at the bottom of the stilling well. The well does not need to be placed in the channel thalweg, and often is better set along the channel bank as this reduces the potential for wrack build-up and fouling over the deployment period.

The other end of the instrument cable, which ends with a large desiccant attachment, will sit in a protective cap affixed to a second fence post that stands above the marsh surface. The purpose of this cap is to protect the cable end from the elements. The cap is constructed of 1.5” PVC pipe cut to a length of approximately 6” / 15 cm with a cap on one end.

The instrument is affixed to the stilling well using zip ties looped through the holes. Once the instrument is immobilized within the stilling well, the cable-end cap is placed over top of the well and secured with a zip tie. The combined unit is then affixed to a green metal fence post approximately .5 - 1m long using plastic zip ties, high enough so that the post can be pushed deep enough to sit securely in the channel sediments. The cable should be affixed to the fence post with a zip tie to prevent catching, but not too tightly. To set the unit into the channel, the base of the fence post is pushed into the sediments of the creek bed during low tide. Site conditions dictate the specific location, but preferably the unit can be deployed at the thalweg where a steep bank rises vertically, ensuring that cable will not dangle loosely. Once the instrument is deployed, loose cable is gently secured to the channel bank and marsh surface using erosion control fabric staples until the foot of a fence post situated on the marsh surface. The loose end of the cable, attached to a large desiccant, is pushed up into the protective PVC cap affixed to the fence post, and attached to the post with a plastic zip tie. The fence post must be set so that the tip of the cable sits above the highest projected tide height for the deployment period. The 3m vertical green metal fence post is installed on the surface of the marsh. Any loose cable should be looped and secured to the fence post above the ground. A sign is often attached to this post to provide a point of contact for curious passersby.

Option 2 – PVC housing affixed to a cinder block

The deployment method is identical to option 1, except that rather than affixing the stilling well to a fence post, the well is affixed to a concrete block (typically, 4” by 8” by 16”) using multiple screw clamps. This unit is then placed in the channel thalweg oriented in line with the channel, so that the instrument lies horizontally on the channel bottom. This low-profile deployment is sometimes optimal for wide, open channels or open mudflat where the instrument may be more exposed to wrack, waves, etc., and where the cable is more likely to get snagged. The block should be staked into the mud with a stabilizer such as rebar, fence posts, or stakes, to restrict lateral movement. Typically, the longer (40’) cable is used for this option, since the length is needed to reach the fence post set in the adjacent marsh surface.

- Complete logger deployment data sheets
    - Record location with GPS, and photograph each instrument
    - Draw schematic of location
    - For U20 water level loggers, survey both the instrument and instantaneous water levels into a known benchmark. Water levels should be surveyed at least twice, and at least 15 minutes apart.
- Total deployment duration should be 4 – 6 weeks to document a full neap/spring tide cycle.
- At removal of U20 water level loggers, survey water levels and record time, if there is water over the pressure transducer. Wait at least 6 minutes prior to actual physically removing the instrument.
- Remove instrument and note time/date of removal, as well as observations (fouling, etc.)

<u>Data processing</u>

- Use HOBOWare to stop recording and download data
- Enter water level observation in NAVD88 at specific data and time to tie the data set into NAVD 88.
- Analyze data using HOBOWare and Excel.
- Record associated metadata in Excel spreadsheet.
- Store raw data and post-processed data separately.