



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

L. Thomas Curdts
Colorado State University Research Associate

For Northeast Coastal and Barrier Network
National Park Service
University of Rhode Island
Coastal Institute in Kingston, #102
1 Greenhouse Road
Kingston, RI 02881

January 2017

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Curdts, L. T. 2017. 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. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	ix
Appendices.....	ix
Acknowledgments.....	xi
1. Purpose.....	1
2. Scope and Applicability.....	3
3. General Considerations.....	5
3.1 Pre-deployment considerations.....	5
3.1.1 HOBO® water level data logger models.....	5
3.1.2 Cleaning.....	5
3.1.3 Logger testing.....	5
3.1.4 Duration of deployment and sampling interval.....	5
3.1.5 Atmospheric pressure.....	7
3.2 Deployment considerations.....	7
3.2.1 Site location.....	7
3.2.2 Mounting options.....	7
3.2.3 Reference point(s).....	7
4. Data Processing.....	11
4.1 Electronic file naming standards.....	11
4.1.1 Raw HOBO® data files.....	11
4.1.2 Processed HOBO® data files.....	11
4.2 Downloading and storing logger data.....	11
4.3 Initial Logger Configuration and Data Processing with HOBOWare.....	12
4.3.1 Configure the HOBO® data logger (Adapted from HOBOWare User's Guide).....	12
4.3.2 Open data file with HOBOWare Pro.....	13
4.3.3 Perform barometric compensation (Taken largely from Onset's Barometric Compensation Assistant User's Guide).....	14
4.3.4 Export data.....	16

Contents (continued)

	Page
4.4 Using Aquarius software to process and archive water level data	18
4.4.1 Setting up Aquarius	18
4.4.2 Creating Aquarius “locations”	22
4.4.3 Appending data.....	24
4.4.4 Hot Folders	33
4.4.5 Data correction	34
4.4.6 Calculating marsh flooding events and tidal statistics.....	44
4.4.7 Generating Custom Reports	52

Figures

	Page
Figure 1. HOBO® U20 Water Level Data Logger. Photo from OnsetComp.com.	1
Figure 2. Bucket test procedure for testing water level data logger.....	6
Figure 3. Well diagram showing CP to water distance, or reference measurement.	9
Figure 4. HOBOWare Pro Export Settings.....	12
Figure 5. HOBOWare Pro plot setup.....	13
Figure 6. HOBOWare Pro Data Assistants page.	14
Figure 7. HOBOWare Pro Barometric Compensation dialogue box.....	15
Figure 8. HOBOWare Pro data plot.....	16
Figure 9. HOBOWare Pro Date/Time Display Preferences.....	17
Figure 10. HOBOWare Pro Export window.....	18
Figure 11. Desktop shortcut to access Aquarius.	19
Figure 12. RemoteApp warning window.....	19
Figure 13. Smart card PIN prompt.....	19
Figure 14. Initial access screen to Aquarius computer.	20
Figure 15. System tray showing the Aquarius icon.	20
Figure 16. Aquarius server selection window.....	21
Figure 17. Aquarius login window.....	21
Figure 18. Main Aquarius Springboard window.....	22
Figure 19. Aquarius Springboard menu bar.....	22
Figure 20. Incomplete Aquarius Springboard Location Manager window.....	23
Figure 21. Completed Aquarius Springboard Location Manager window.	24
Figure 22. Aquarius Springboard location list.	24
Figure 23. Aquarius Springboard Append Logger File Wizard.....	25
Figure 24. Aquarius Springboard Append Data: select file type.	26
Figure 25. Aquarius Springboard Append Data: define first data row.	27
Figure 26. Aquarius Springboard Append Data: select the Date/Time format.....	28
Figure 27. Aquarius Springboard Append Data: Date/Time format selection results.	29
Figure 28. Aquarius Springboard Append Data: absolute pressure format.	29

Figures (continued)

	Page
Figure 29. Aquarius Springboard: complete the Append Data Wizard.	31
Figure 30. Aquarius Append Logger File window.	32
Figure 31. Append confirmation message.	32
Figure 32. Go to Data Sets button.	33
Figure 33. Hot Folder processing results.	33
Figure 34. Aquarius Correction Control tools.....	34
Figure 35. HOBOWare Pro plot showing pre- and post-submersion data tails.	35
Figure 36. Components of the Aquarius Data Correction tool.	36
Figure 37. Records selected with the Mark Region tool.	36
Figure 38. Applying the Delete Region correction.	37
Figure 39. Aquarius Apply Correction window.....	37
Figure 40. Aquarius corrected data.	38
Figure 41. HOBOWare Pro plot showing data anomalies (see red arrows) due to tidally induced atmospheric exposure.	39
Figure 42. HOBOWare Pro plot showing data anomalies due to instrument malfunction.....	39
Figure 43. Graph of water level data before correcting for drift.....	41
Figure 44. Graph of water level data after correcting for drift.....	41
Figure 45. Aquarius multi-point drift correction tool.	43
Figure 46. Aquarius drift correction control results.....	43
Figure 47. Well diagram showing sensor to marsh distance and flooding events.	44
Figure 48. Two options for opening the Aquarius Location Manager.....	45
Figure 49. Create new “calculated derived” data set.	45
Figure 50. Select the input data set in Data Set Details window.	46
Figure 51. Validate the formula.	47
Figure 52. Choose Water Level to set the parameter.	47
Figure 53. Completed form for creating a “calculated derived” data set that will be used to determine marsh flooding events.	48
Figure 54. Newly created “calculated derived” time series data set	49

Figures (continued)

	Page
Figure 55. Choose WaterLevelNAVD88 to set the parameter for calculating tidal statistics.....	50
Figure 56. Completed form for creating a “calculated derived” data set that will be used to compute tidal statistics.....	51
Figure 57. Select the Flood Stats Report in the Reporting Toolbox.	52
Figure 58. Set report parameters in Reporting Toolbox.	53
Figure 59. Report format options.....	53
Figure 60. Title page and graph from the Aquarius NCBN Tidal Flood Stats Report.....	54
Figure 61. Statistics and tabular data from the NCBN Marsh Flood Stats Report.	54
Figure 62. Select the Tidal Stats report in the Reporting Toolbox.	55
Figure 63. Title page and graph from the Aquarius NCBN Tidal Stats Report.....	56
Figure 64. Statistics and tabular data from the NCBN Tidal Stats Report.....	56
Figure B 1. HOBO data logger and auxiliary components.	59
Figure B 2. Select appropriate units.....	59
Figure B 3. Select Device/Launch.	60
Figure B 4. Select and launch device.	60
Figure B 5. Examine and fill out fields in Launch Logger window.....	61
Figure B 6. Launching Logger status window.	61
Figure B 7. Device status window.	62
Figure B 8. Select Device/Readout.	63
Figure B 9. Stop logger.	63
Figure B 10. Readout Logger status window.....	63
Figure B 11. Plot setup window.....	64
Figure C 1. Drilled holes and connection point (CP) in top of well casing.....	66
Figure C 2. Water level sensor in a wetland (Rachel Carson National Wildlife Refuge, Maine).	68
Figure C 3. Barometric sensor attached to bird nesting box (Rachel Carson National Wildlife Refuge, Maine).	68
Figure C 4. Water level housing next to a wetland (Jamaica Bay, Gateway National Recreation Area).	69

Figures (continued)

	Page
Figure C 5. Water level sensor and PVC housing (Fire Island National Seashore).	69
Figure C 6. WL logger installation in the marsh.	70
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).	71
Figure C 8. Water level logger installation in the bottom of tidal creek.....	72
Figure D 1. Example of a Blank form (v5).	75
Figure D 2. Example of a completed form (v4).	76

Tables

	Page
Table 1. Data parameters that will be archived in Aquarius	3
Table 2. Parameters for Aquarius configuration file.....	30

Appendices

	Page
Appendix A. Reference Resources	57
Appendix B. HOBO® Quickstart Guide	59
Appendix C. Water Level Logger Installation Guide	65
Appendix D. Water Level Logger Field Data Sheet.....	75

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' Aquarius¹ 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.

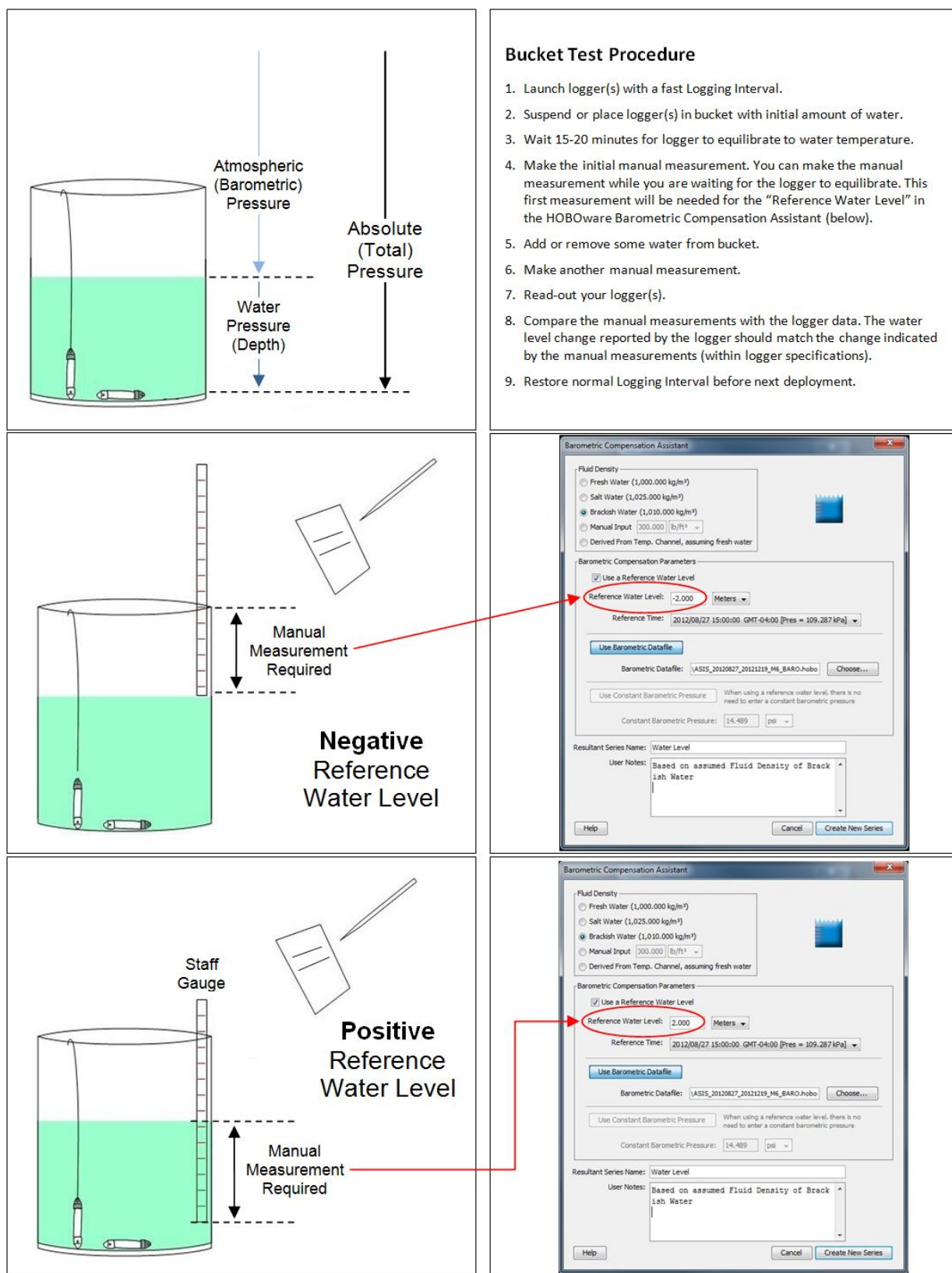


Figure 2. Bucket test procedure for testing water level data logger.

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 points 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 specifications², 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.

² See *Appendix 1. Reference Resources* for a link to the specifications of the HOBO® U20 and U20L water level loggers

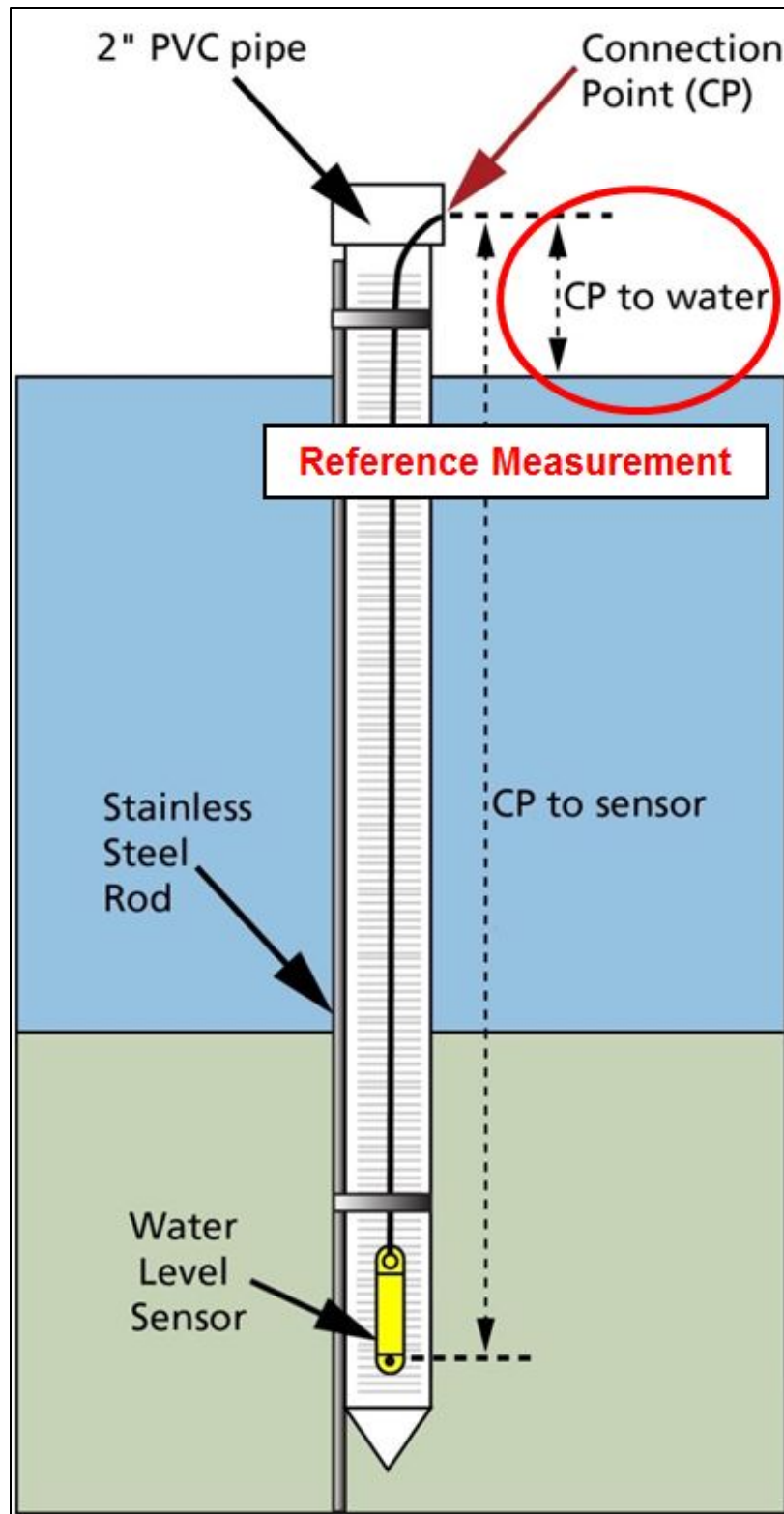


Figure 3. Well diagram showing CP to water distance, or reference measurement.

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 HOBOb® data files

HOBOb® 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 HOBOb® 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 HOBOb® 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 HOBOb® shuttles or field computers and copied to the NCBN file server upon returning to the office. Data download from the HOBOb® data logger requires a HOBOb® shuttle, coupler and USB cable that provides a connection to a computer (see *Appendix B. HOBOb® 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 HOBOWare® 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 HOBOWare® 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 HOBOWare® 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 HOBOWare® data logger (Adapted from HOBOWare User's Guide)

To configure a HOBOWare® data logger for deployment, perform the following basic steps (see *Appendix B. HOBOWare® 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:

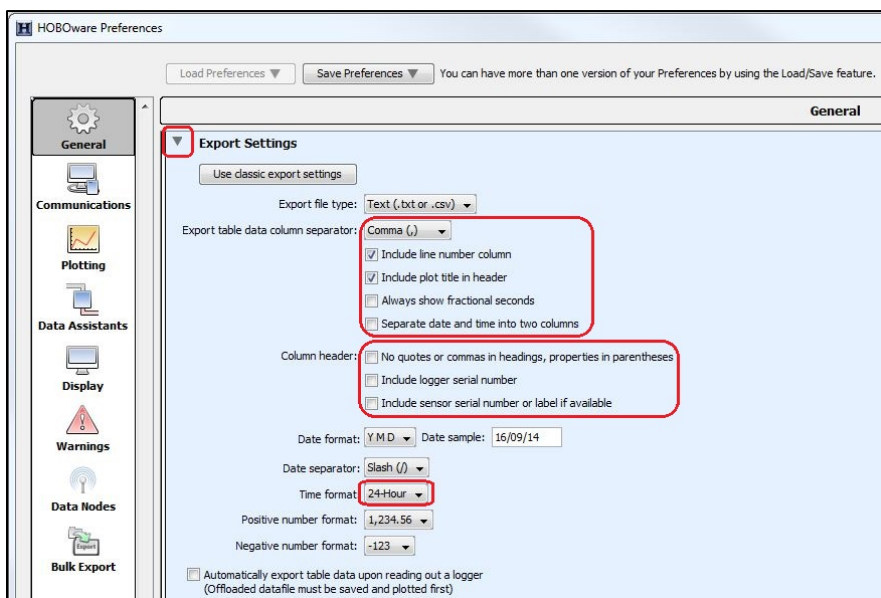


Figure 4. HOBOWare Pro Export Settings.

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*.

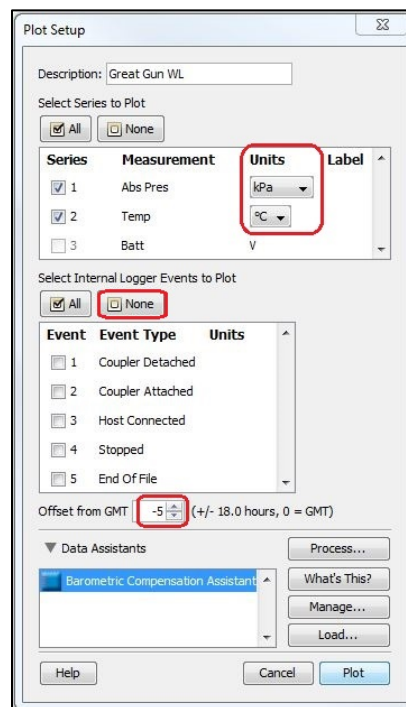


Figure 5. HOBOWare Pro plot setup.

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).

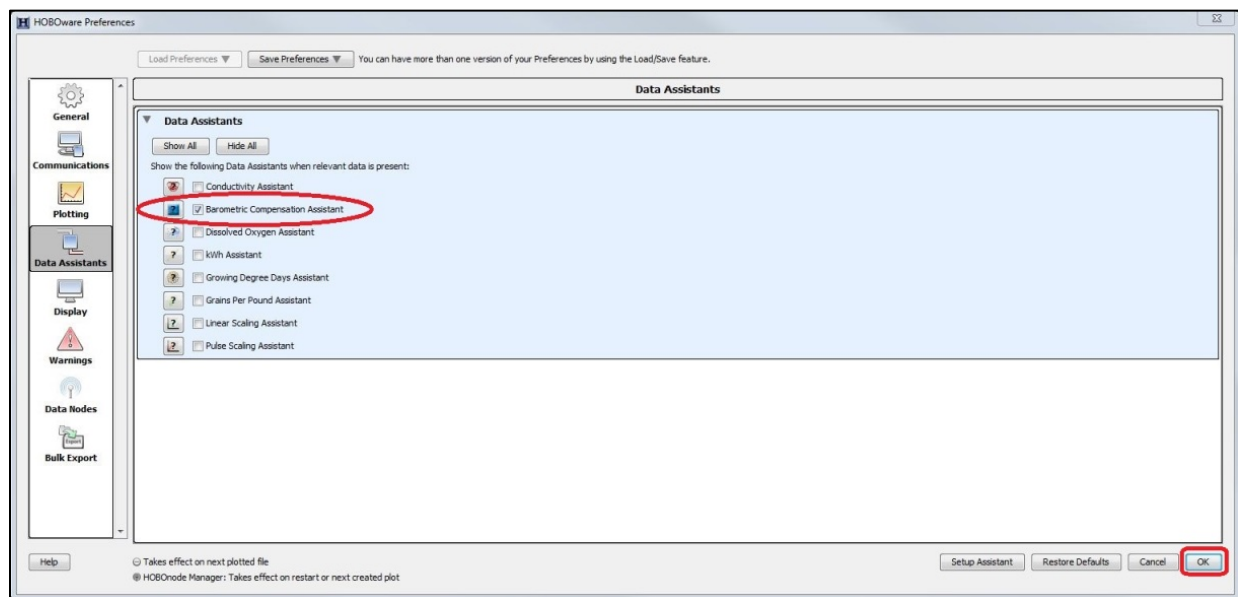


Figure 6. HOBOWare Pro Data Assistants page.

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).

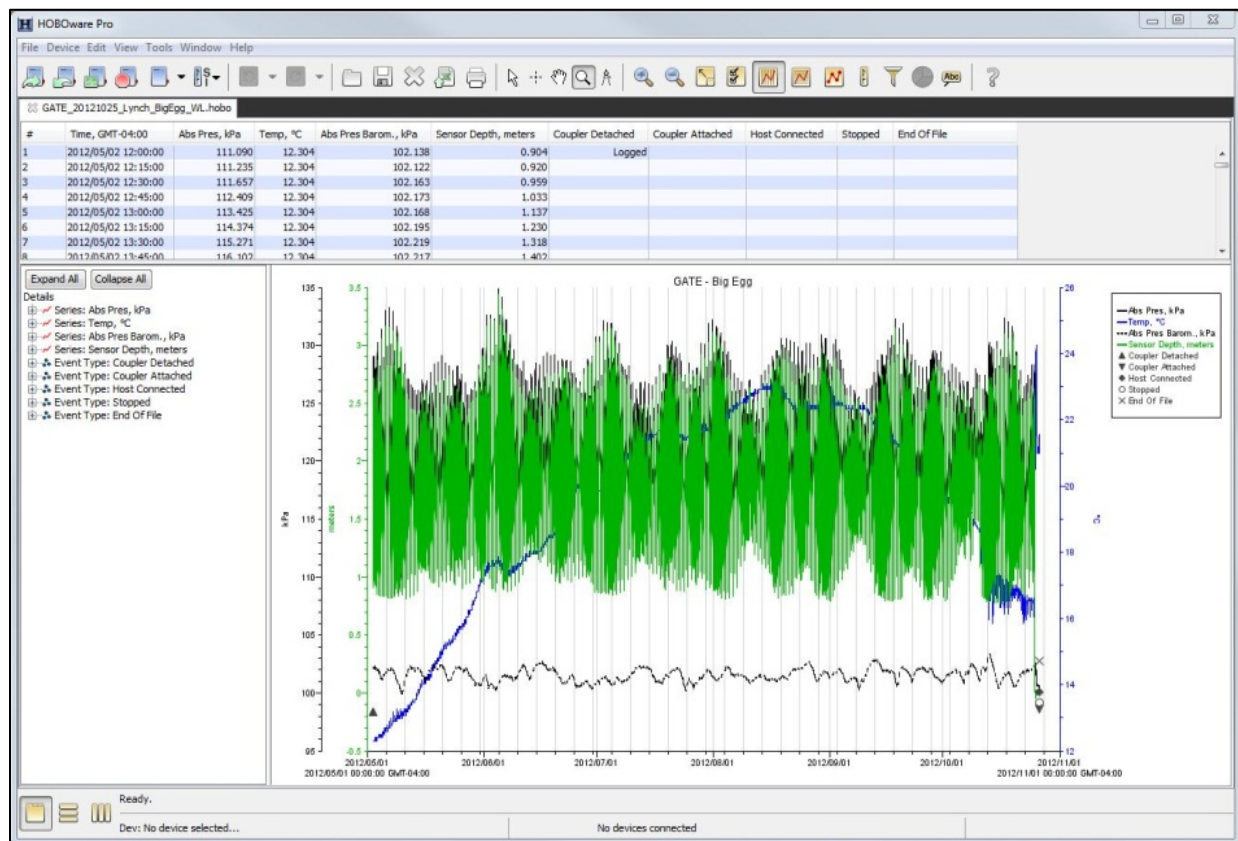


Figure 8. HOBOWare Pro data plot.

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.

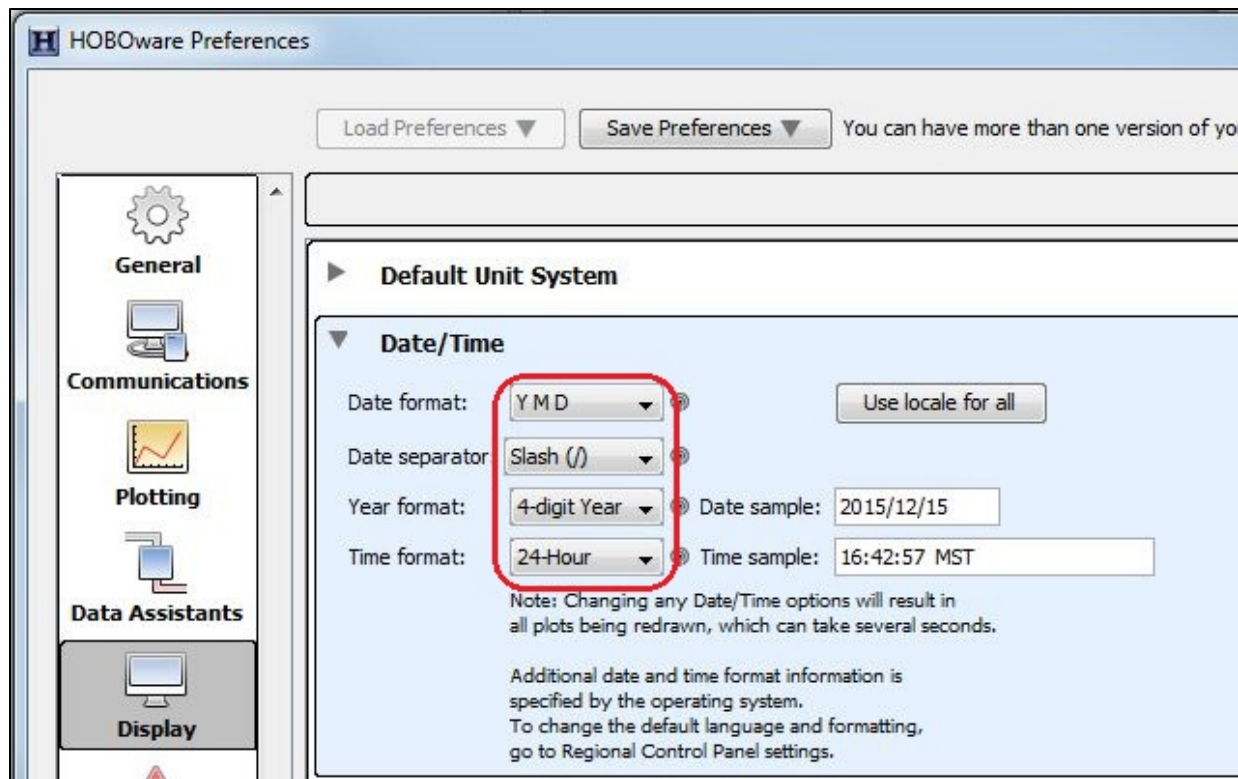


Figure 9. HOBOWare Pro Date/Time Display Preferences.

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.

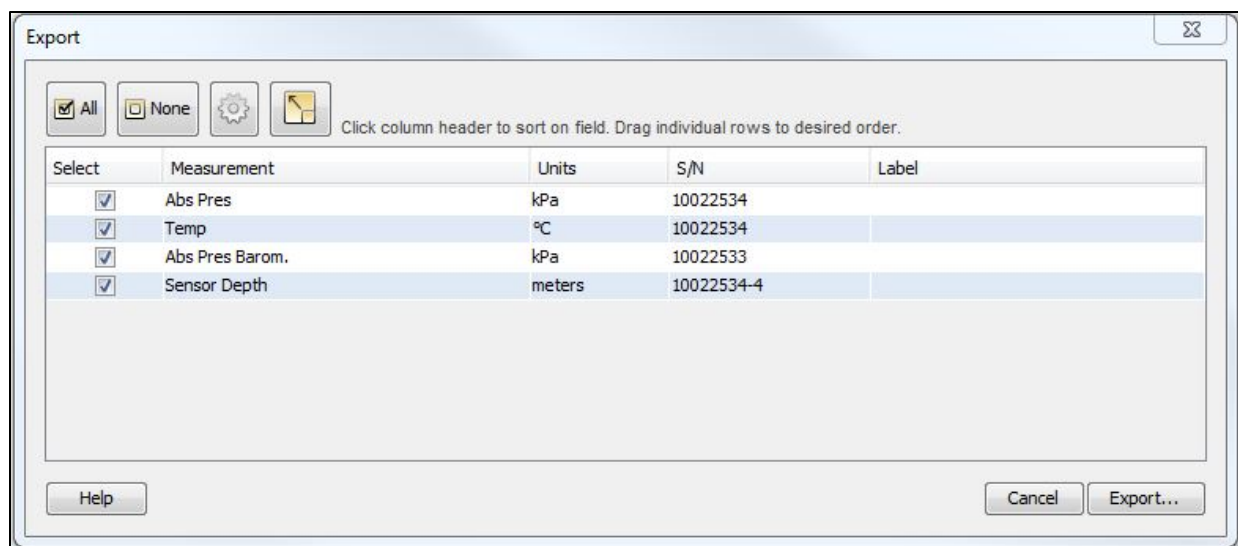


Figure 10. HOBOWare Pro Export window.

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 HOBOWare® 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).

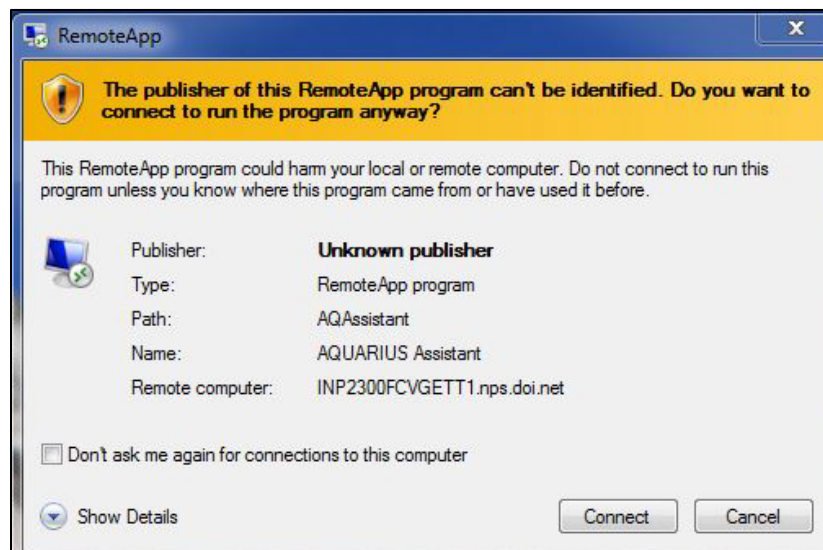


Figure 12. RemoteApp warning window.



Figure 13. Smart card PIN prompt.

Upon entering the correct password you will gain access to the server running Aquarius (Figure 14).

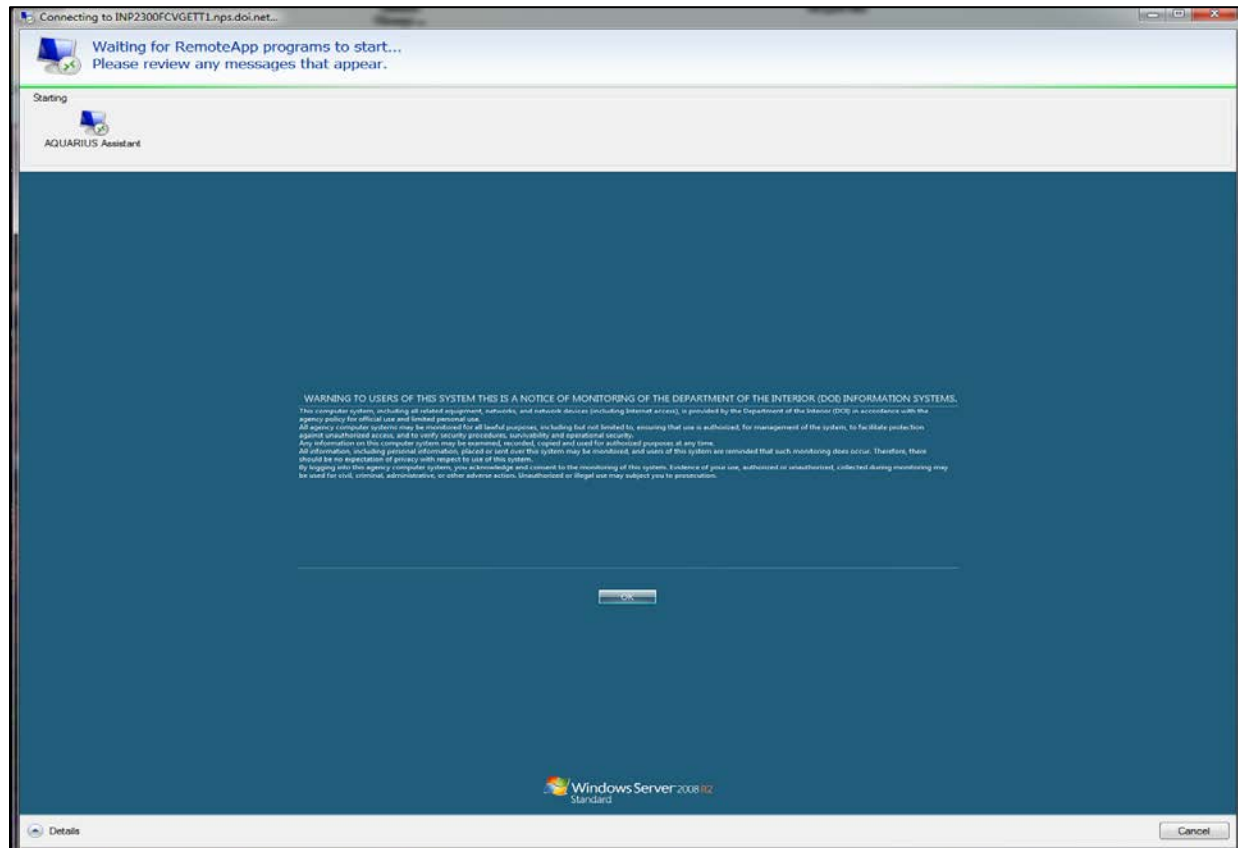


Figure 2. Initial access screen to Aquarius computer.

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).

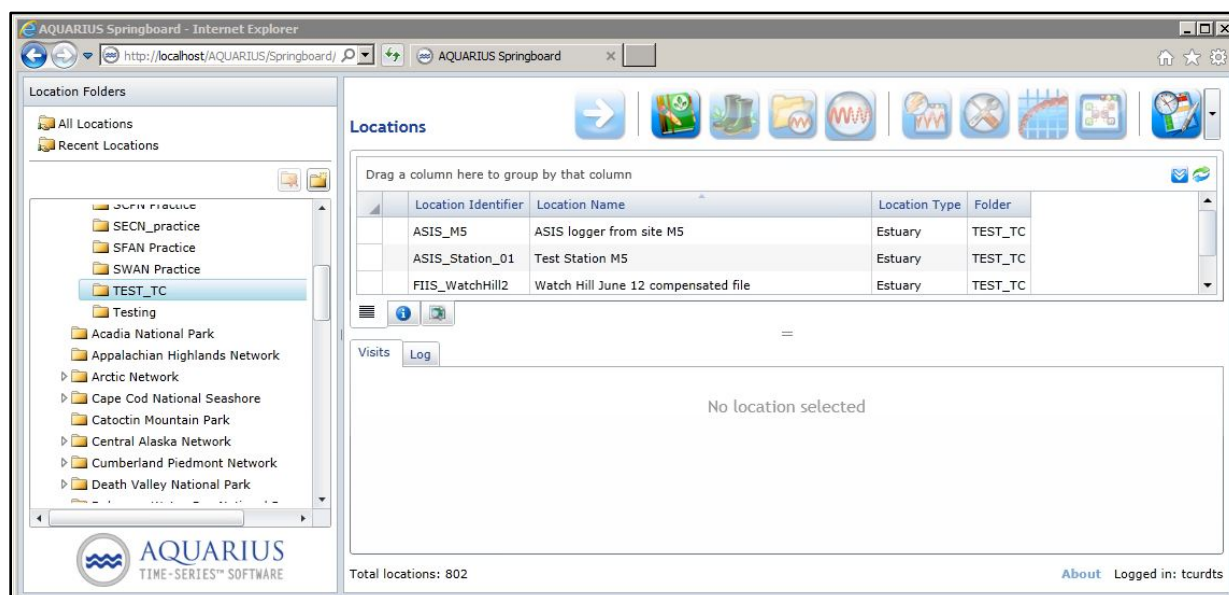


Figure 6. Main Aquarius Springboard window.

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.

The screenshot shows the 'Location Manager' window in an Internet Explorer browser. The window title is 'AQUARIUS Springboard - Internet Explorer'. The address bar shows 'http://localhost/AQUARIUS/Springboard'. The page title is 'AQUARIUS Springboard'. The main content area is titled 'Location Manager' and has a '<New Location>' link. Below this is a tabbed interface with 'General', 'Data Sets', 'User Access', 'Notifications', 'Hot Folder', and 'Analysis & Remarks'. The 'General' tab is active. On the left, there is a box for 'No Location Image Selected' with a camera icon. Below this is a file upload area with a folder icon and the text '[Identifier]'. On the right, the 'Identifier' and 'Name' fields are highlighted in red and have a red asterisk icon. The 'Type' dropdown is set to 'Wetland Estuarine-Emergent'. The 'Source' is 'AQUARIUS Location'. The 'Description' field is empty. The 'Position' checkbox is unchecked. The 'Geo Datum' is 'WGS 84'. The 'Latitude' and 'Longitude' fields are empty. The 'Elevation' field is empty with a unit dropdown set to 'm'. The 'Time Zone' is 'EST (UTC-05:00)'. Below these fields is the 'Additional Attributes' section, which includes dropdowns for 'Park Name', 'Sensitivity', and 'Status', and text boxes for 'Waterbody Code', 'Waterbody Name', 'Gage Number', 'Date Established', and 'Travel Directions'. At the bottom, there is a checkbox for 'Make Location Visible in Aquarius WebPortal'.

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.

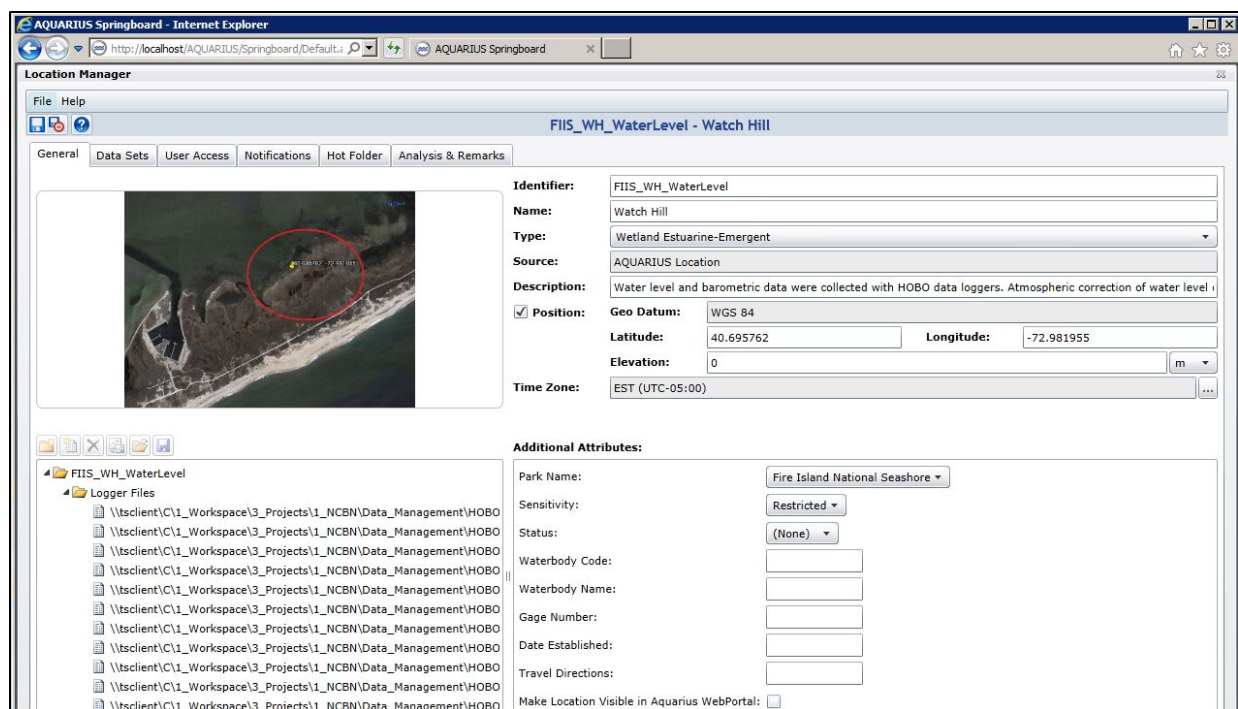


Figure 8. Completed Aquarius Springboard Location Manager window.

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.

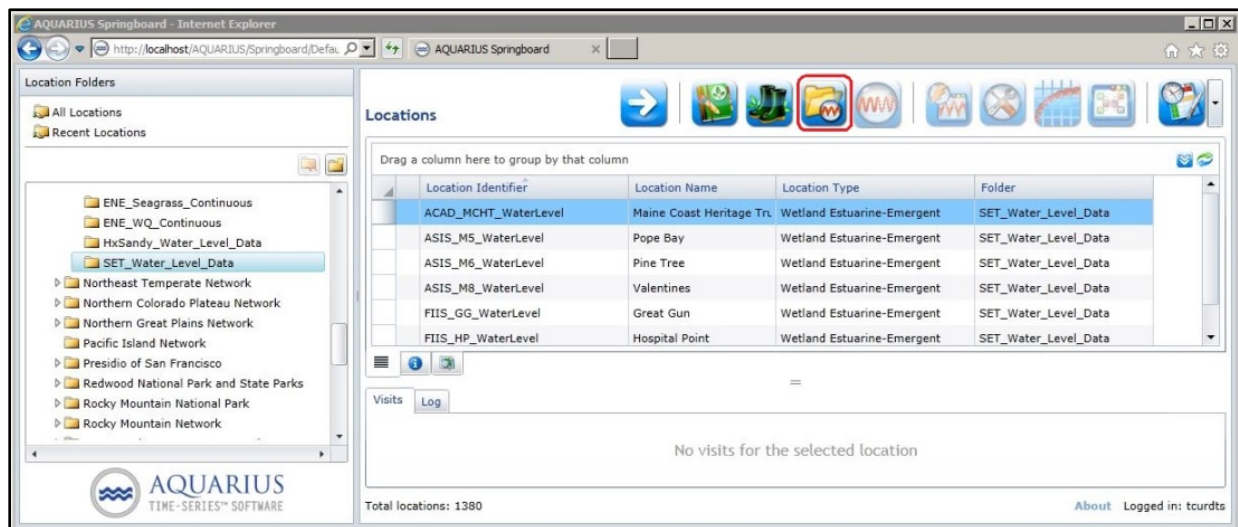


Figure 9. Aquarius Springboard location list.

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.

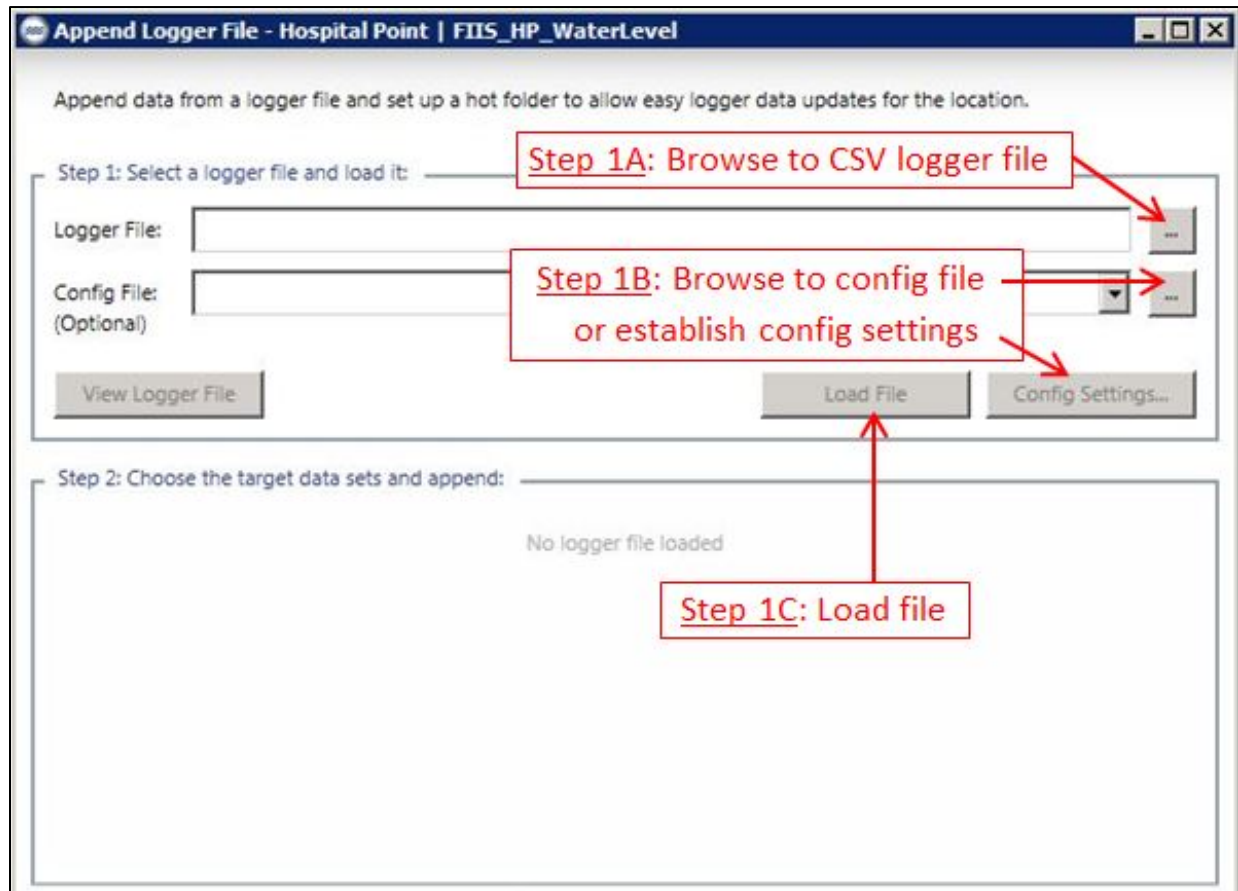


Figure 10. Aquarius Springboard Append Logger File Wizard.

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 HOB0[®] 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.

Time Series - Import from File Wizard

Step 2 of 4 Import Options

Start import at row:
 Number of headers:

Skip line character(s):
 Skip column character(s):

Not a Number:
 Character(s) to discard:

Delimiters
☐ Fixed width ☐ Tab ☐ Semicolon
☒ Comma ☐ Space ☐ Other(s):

1	2	3	4	5	6
Plot Title: Gre...		1	2	3	4
#	Date Time, GMT-05:00	Abs Pres, kPa	Temp, °C	Abs Pres Barom., kPa	Sensor Depth, meters
1	2012/06/21 11:00:00	101.082	31.370	101.074	0.001
2	2012/06/21 11:15:00	101.054	32.600	101.048	0.001
3	2012/06/21 11:30:00	101.062	33.326	101.050	0.001
4	2012/06/21 11:45:00	101.045	34.479	101.022	0.002
5	2012/06/21 12:00:00	101.010	35.009	101.004	0.001
6	2012/06/21 12:15:00	101.013	35.971	101.003	0.001
7	2012/06/21 12:30:00	100.988	35.971	100.978	0.001
8	2012/06/21 12:45:00	105.713	23.292	100.957	0.480
9	2012/06/21 13:00:00	105.439	19.758	100.947	0.454
10	2012/06/21 13:15:00	105.168	18.521	100.930	0.428
11	2012/06/21 13:30:00	104.912	17.855	100.903	0.405
12	2012/06/21 13:45:00	104.664	17.475	100.896	0.380
13	2012/06/21 14:00:00	104.456	17.189	100.857	0.363
14	2012/06/21 14:15:00	104.236	16.903	100.884	0.338
15	2012/06/21 14:30:00	104.041	16.618	100.833	0.324

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).

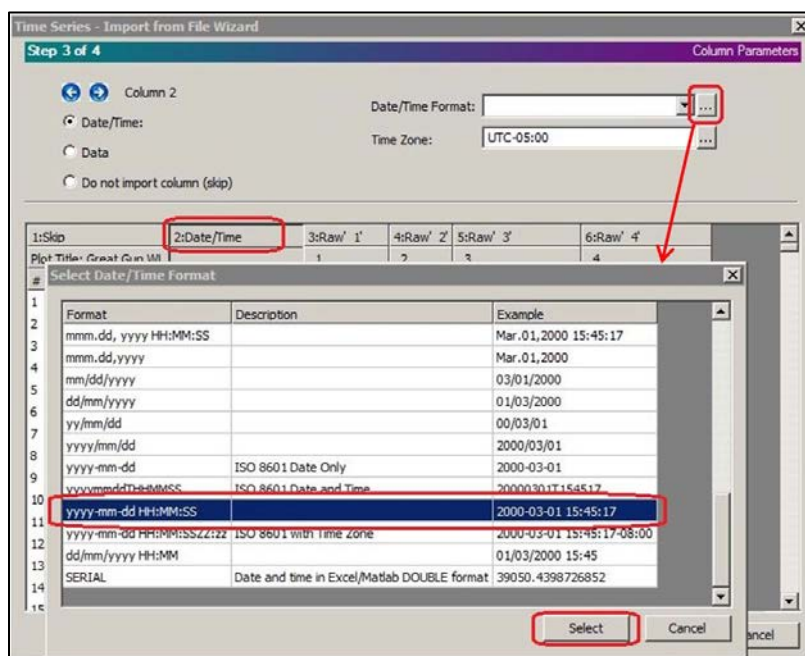


Figure 13. Aquarius Springboard Append Data: select the Date/Time format.

Time Series - Import from File Wizard
Step 3 of 4
Column Parameters

Column 2

☒ Date/Time: Date/Time Format: yyyy-mm-dd HH:MM:SS Time Zone: UTC-05:00

☐ Data

☐ Do not import column (skip)

1:Skip	2:yyyy-mm-dd HH:MM:SS	3:Raw' 1'	4:Raw' 2'	5:Raw' 3'	6:Raw' 4'
Plot Title: Great Gun WL		1	2	3	4
#	Date Time, GMT-05:00	Abs Pres, kPa	Temp, °C	Abs Pres Barom., kPa	Sensor Depth, meters
1	2012/06/21 11:00:00	101.082	31.370	101.074	0.001
2	2012/06/21 11:15:00	101.054	32.600	101.048	0.001
3	2012/06/21 11:30:00	101.062	33.326	101.050	0.001
4	2012/06/21 11:45:00	101.045	34.479	101.022	0.002
5	2012/06/21 12:00:00	101.010	35.009	101.004	0.001
6	2012/06/21 12:15:00	101.013	35.971	101.003	0.001
7	2012/06/21 12:30:00	100.988	35.971	100.978	0.001
8	2012/06/21 12:45:00	105.713	23.292	100.957	0.480
9	2012/06/21 13:00:00	105.439	19.758	100.947	0.454
10	2012/06/21 13:15:00	105.168	18.521	100.930	0.428
11	2012/06/21 13:30:00	104.912	17.855	100.903	0.405
12	2012/06/21 13:45:00	104.664	17.475	100.896	0.380
13	2012/06/21 14:00:00	104.456	17.189	100.857	0.363
14	2012/06/21 14:15:00	104.236	16.903	100.884	0.338
15	2012/06/21 14:30:00	104.041	16.618	100.822	0.324

<< Back Next >> Cancel

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.

Time Series - Import from File Wizard
Step 3 of 4
Column Parameters

Column 3

☐ Date/Time:

☒ Data Raw

☐ Do not import column (skip)

Parameter: Absolute Pressur Int. Type: 1 - Inst. Values

Units: kPa Grade: <unspecified>

Gap Tolerance: 16 Minutes Approval: <unspecified>

Label: kPa

1:Skip	2:yyyy/mm/dd HH:MM:SS	3:Raw'kPa'	4:Raw'°C'	5:Raw'kPa '	6:Raw'meters'
Plot Title: Watch Hill WL					
#	Date Time, GMT-05:00	Abs Pres, kPa	Temp, °C	Abs Pres Barom., kPa	Sensor Depth, meters
1	2012/06/21 11:00:00	110.238	20.901	101.074	0.925
2	2012/06/21 11:15:00	110.414	20.805	101.048	0.946

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

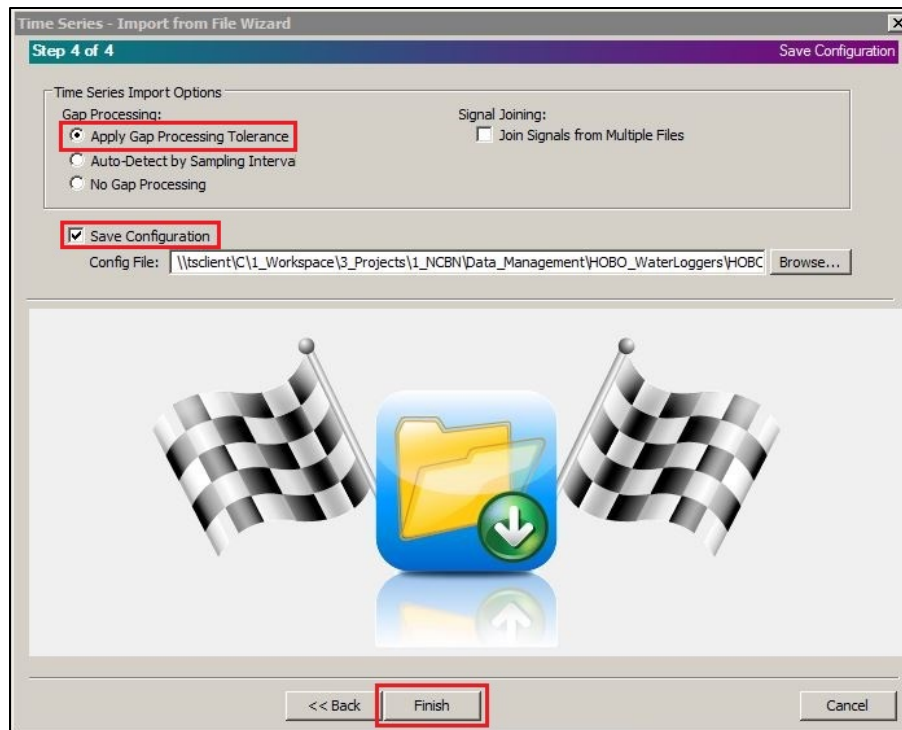


Figure 29. Aquarius Springboard: complete the Append Data Wizard.

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.

Append data from a logger file and set up a hot folder to allow easy logger data updates for the location.

Step 1: Select a logger file and load it:

Logger File: \\tsclient\C\1_Workspace\3_Projects\1_NCBN\Data_Management\HOB0_WaterLoggers\HOB0_Data_Lynch' ...

Config File: \\tsclient\C\1_Workspace\3_Projects\1_NCBN\Data_Management\HOB0_WaterLoggers\HOB0_Data_Lyr' ...
(Optional)

View Logger File Load File Config Settings...

Step 2: Choose the target data sets and append:

Label	Paramet	Units	# Points	From	To	Append to	Status
kPa	Absolute F	kPa	17008	5/2/2012 12:00:00 PM	10/26/2012 3:19:07 PM	Create New Time	
°C	Water Tem	°C	17008	5/2/2012 12:00:00 PM	10/26/2012 3:19:07 PM	Create New Time	
kPa	Atmos Pre	kPa	17008	5/2/2012 12:00:00 PM	10/26/2012 3:19:07 PM	Create New Time	
meters	DepthFron	m	17008	5/2/2012 12:00:00 PM	10/26/2012 3:19:07 PM	Create New Time	

Create Hot Folder... Manage Hot Folder... Append

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](http://\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.

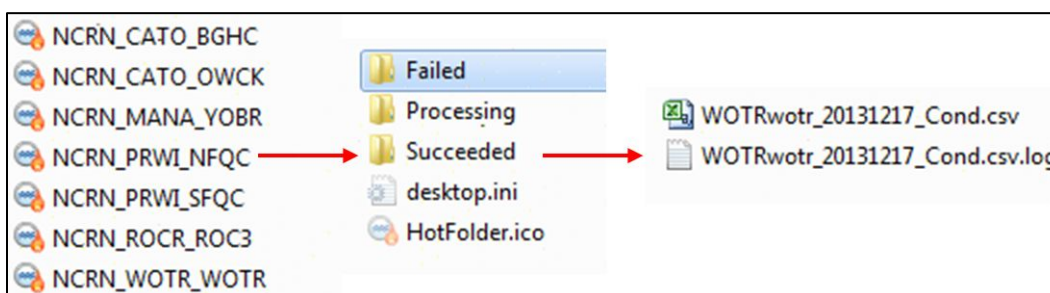


Figure 19. Hot Folder processing results.

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.

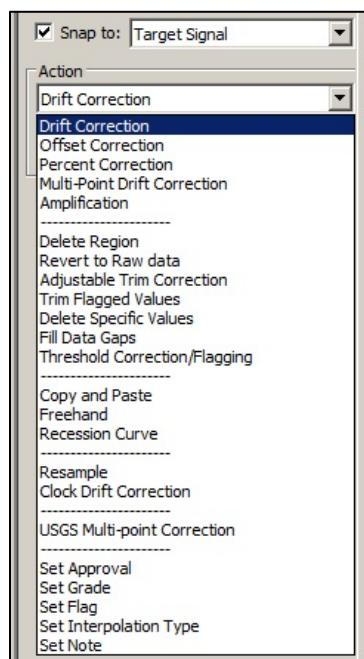


Figure 20. Aquarius Correction Control tools.

4.4.5.1 Trim pre- and post-deployment tails

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.

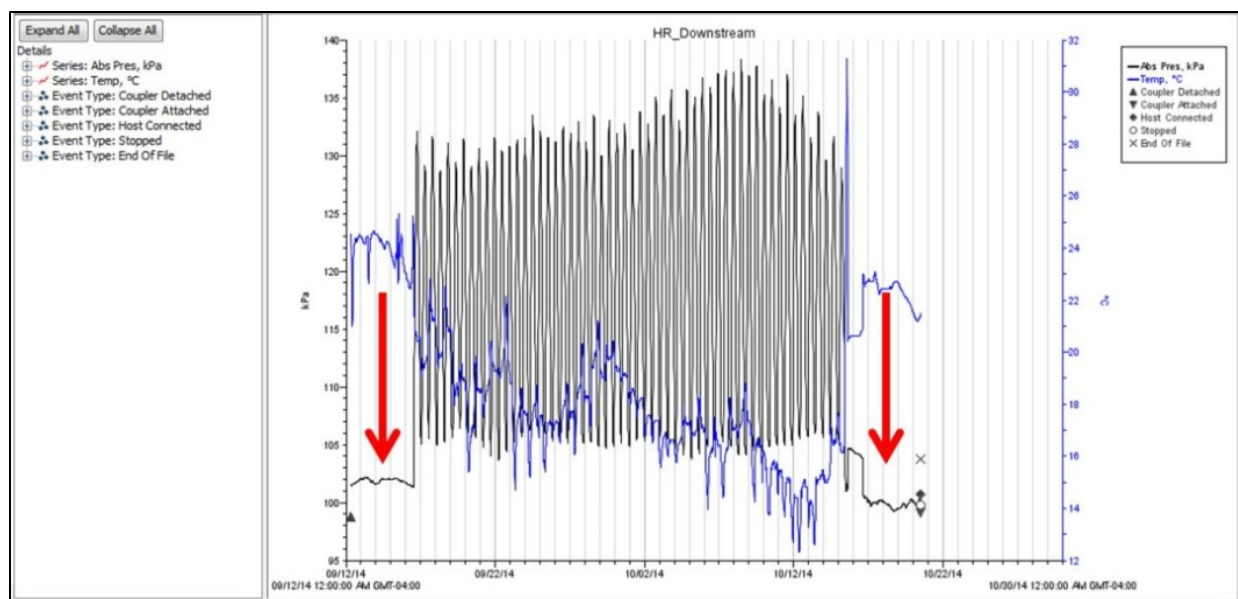


Figure 21. HOBOWare Pro plot showing pre- and post-submersion data tails.

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*.

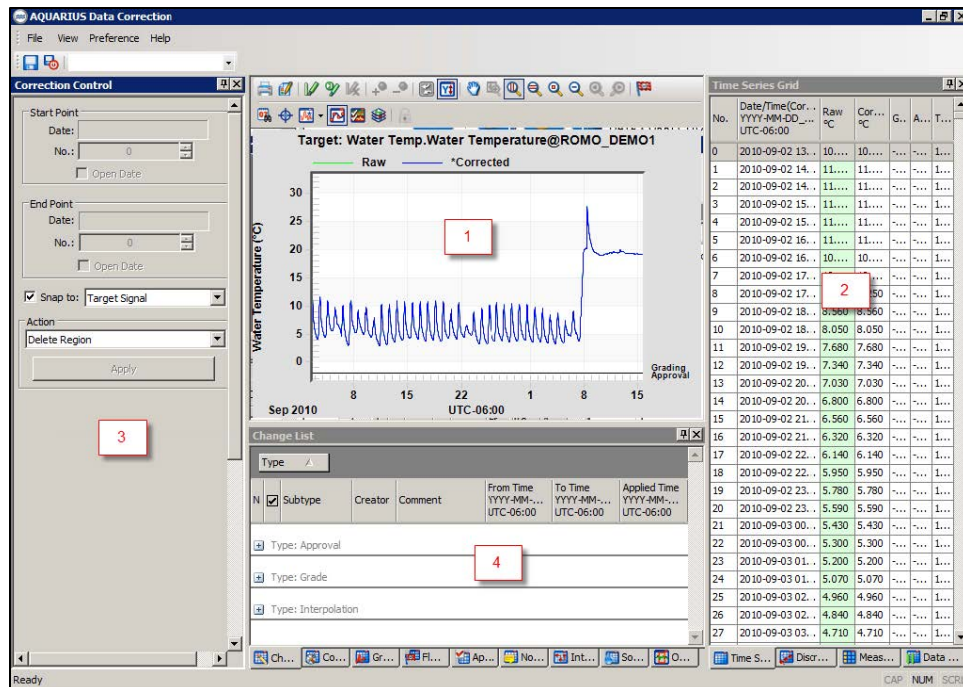


Figure 22. Components of the Aquarius Data Correction tool.

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).

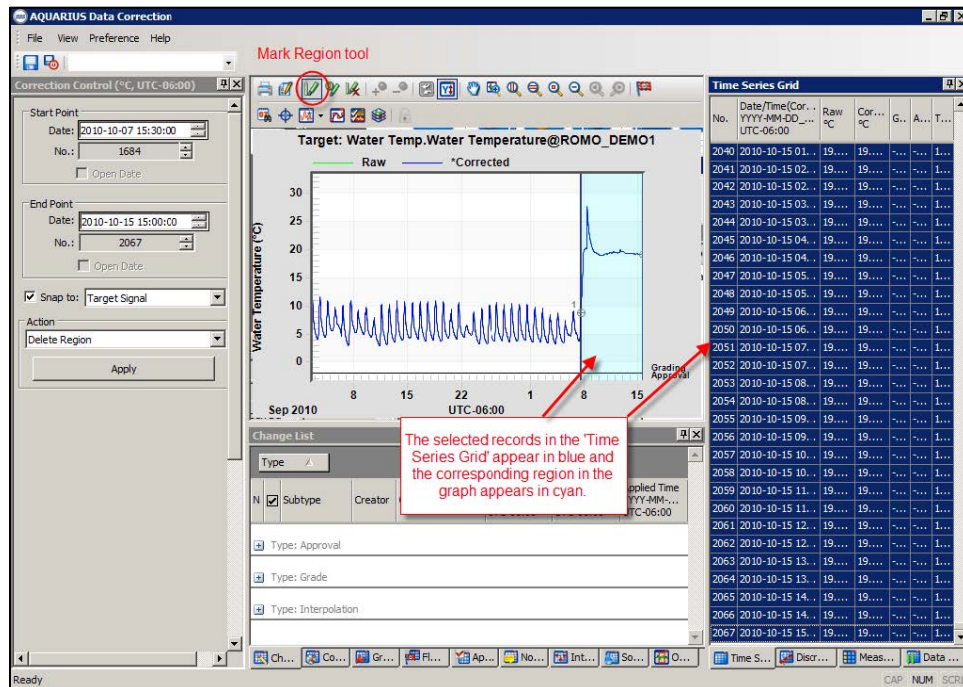


Figure 23. Records selected with the Mark Region tool.

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).

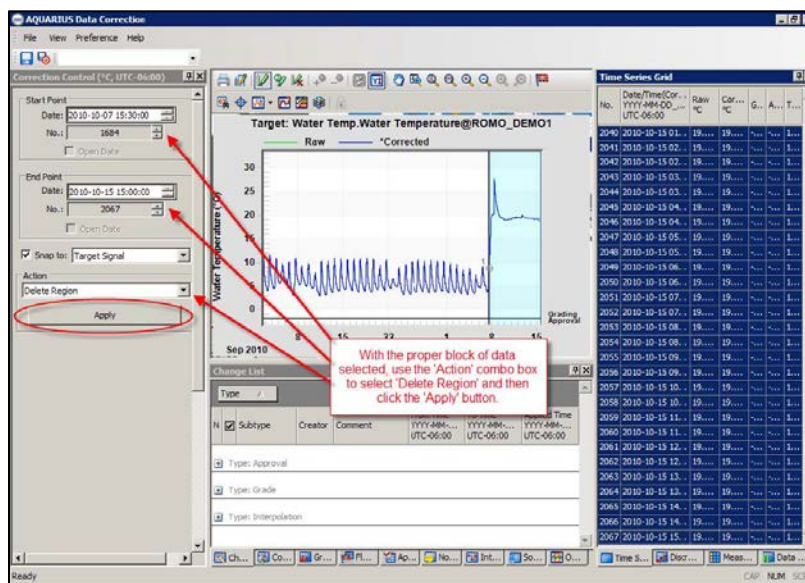


Figure 38. Applying the Delete Region correction.

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.

The 'Apply Correction' dialog box shows the following fields: 'User Name' (dtucker), 'From Time' (2010-10-07 15:30:00), and 'End Time' (2010-10-15 15:00:00). The 'Processing Priority' section has radio buttons for 'Pre-processing', 'Normal' (selected), and 'Post-processing'. The 'Comment' text area contains 'Sensor out of water' and is highlighted with a red border. Below it, the 'Saved Comments' section shows a list with 'Sensor out of water' and a red message: 'You can select previously saved comments from here.' At the bottom are 'Cancel' and 'OK' buttons.

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.

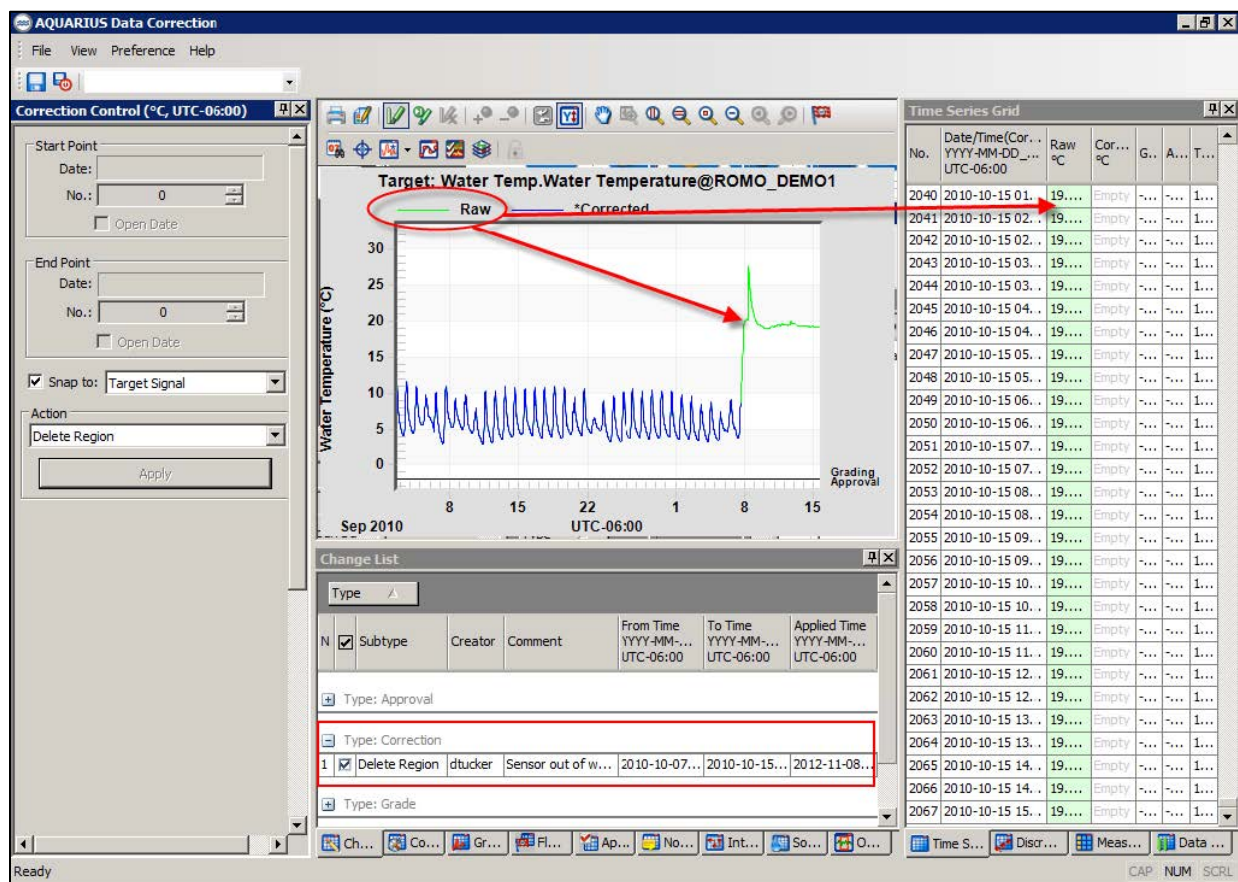


Figure 24. Aquarius corrected data.

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.

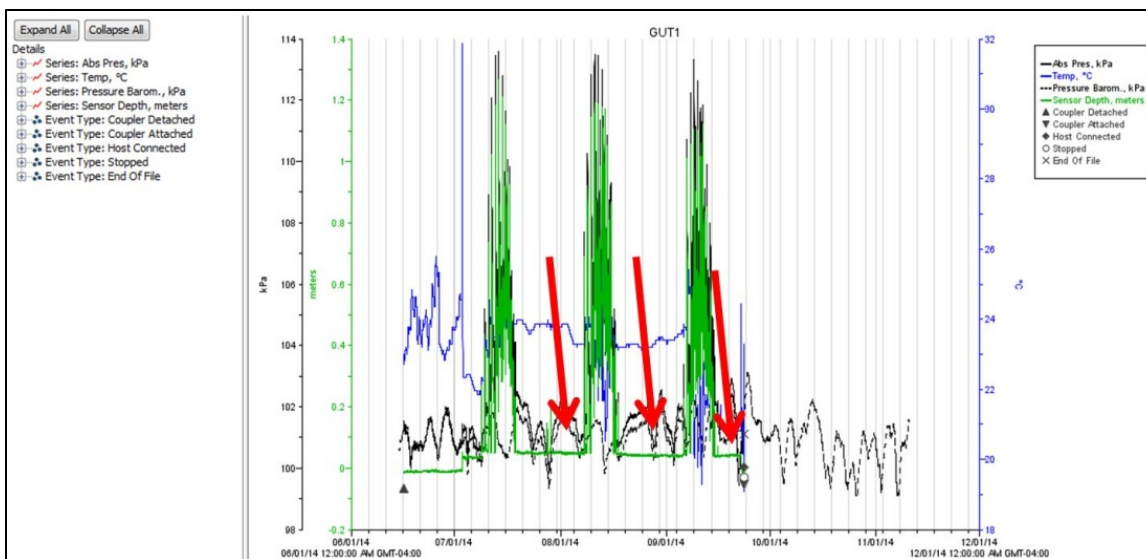


Figure 25. HOBOWare Pro plot showing data anomalies (see red arrows) due to tidally induced atmospheric exposure.

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.

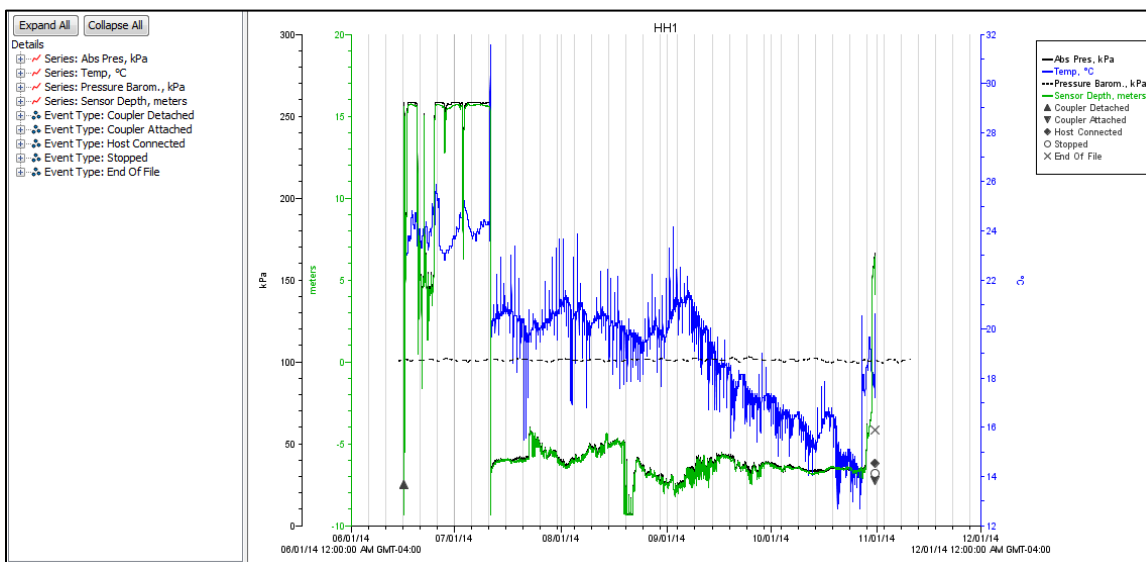


Figure 26. HOBOWare Pro plot showing data anomalies due to instrument malfunction.

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.

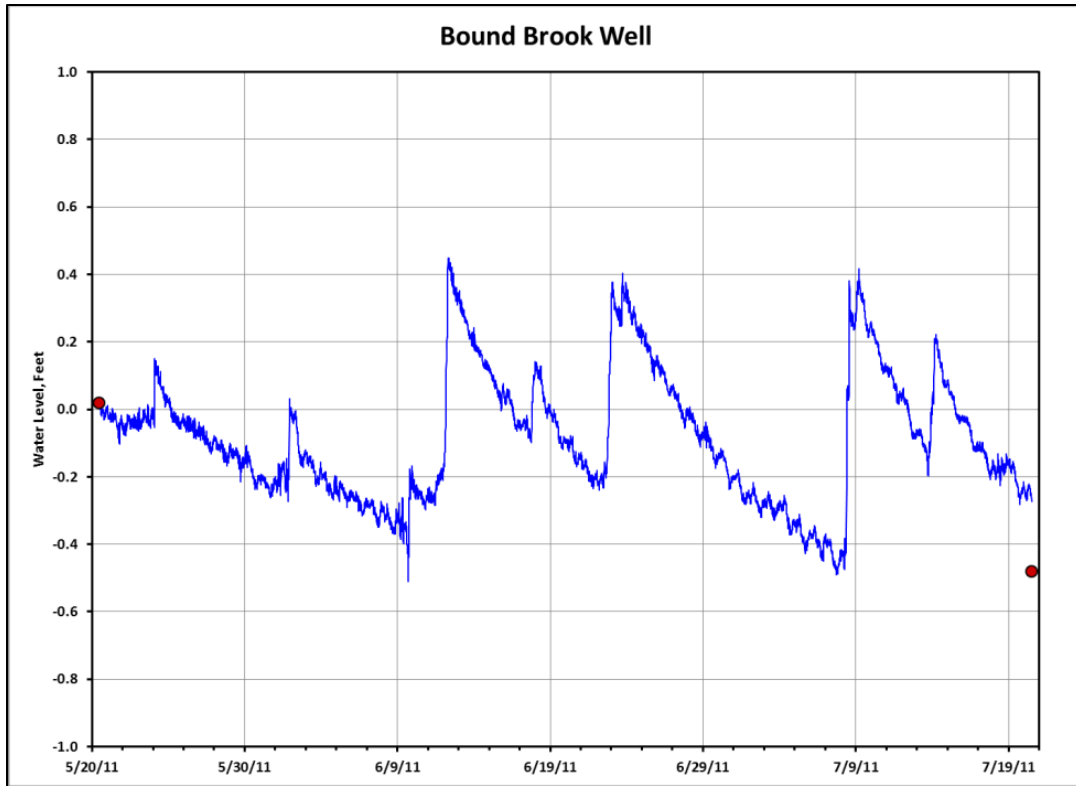


Figure 27. Graph of water level data before correcting for drift.

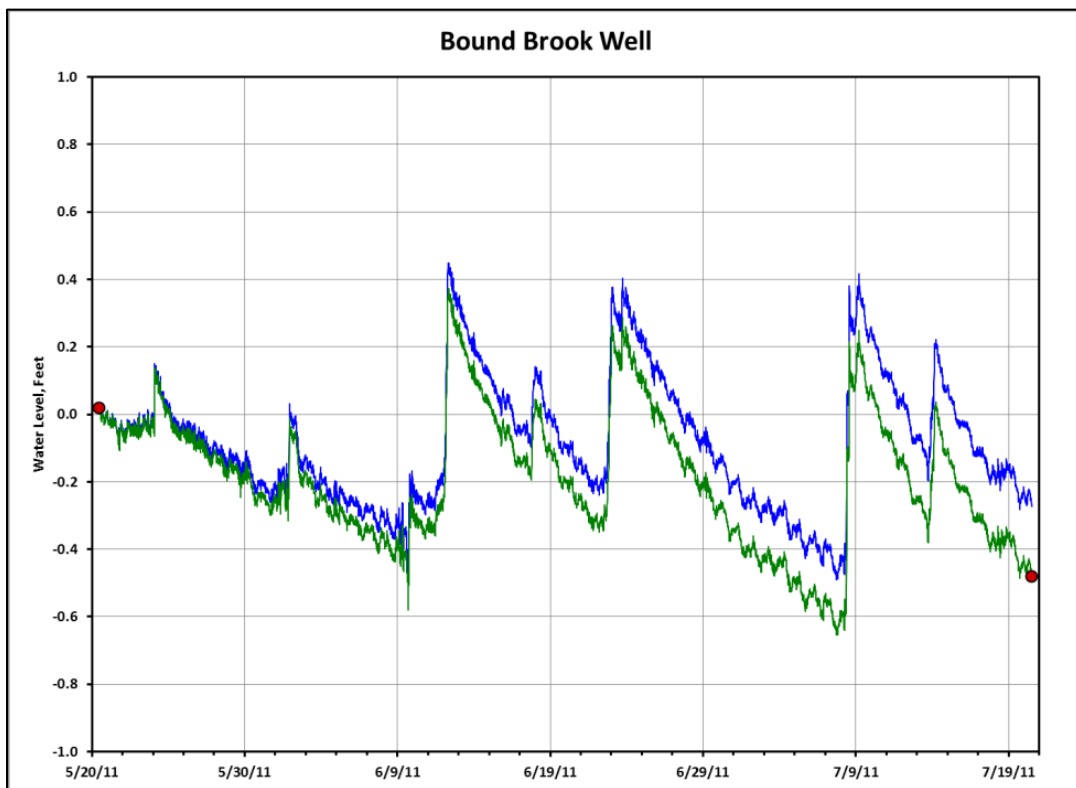


Figure 28. Graph of water level data after correcting for drift.

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*.

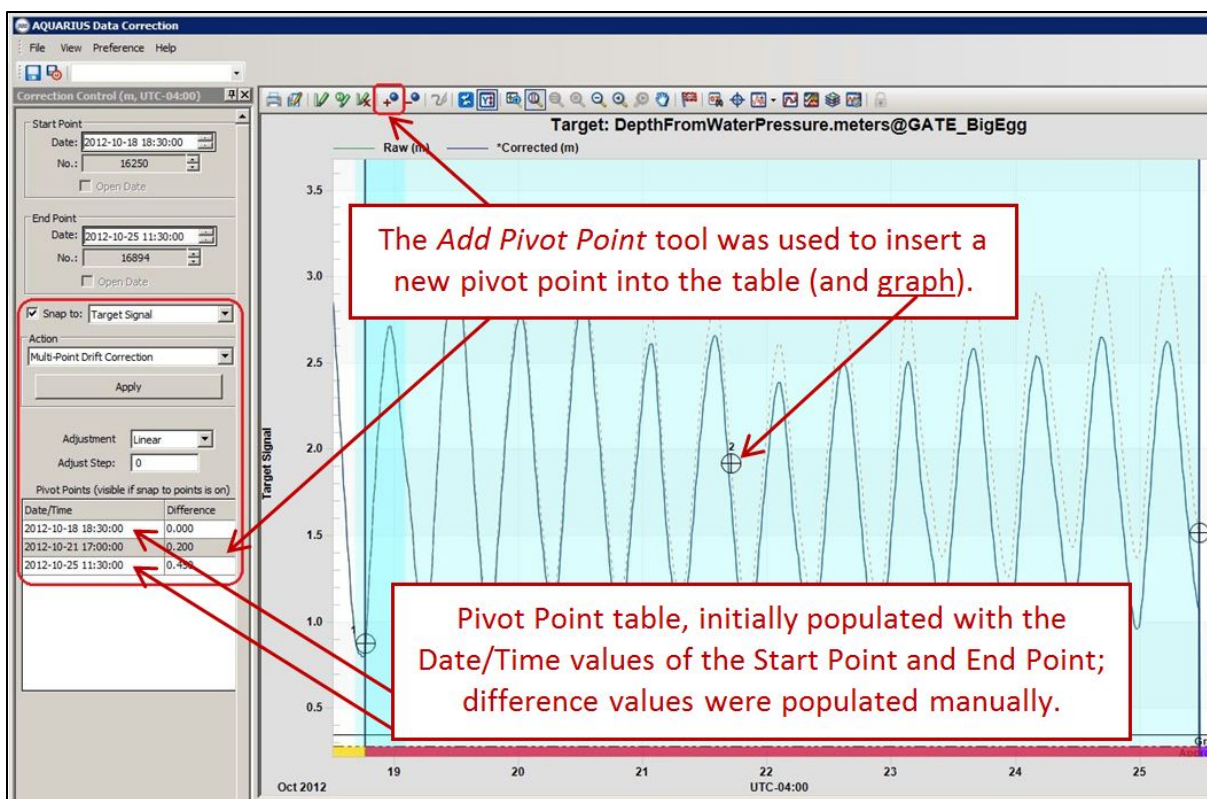


Figure 29. Aquarius multi-point drift correction tool.

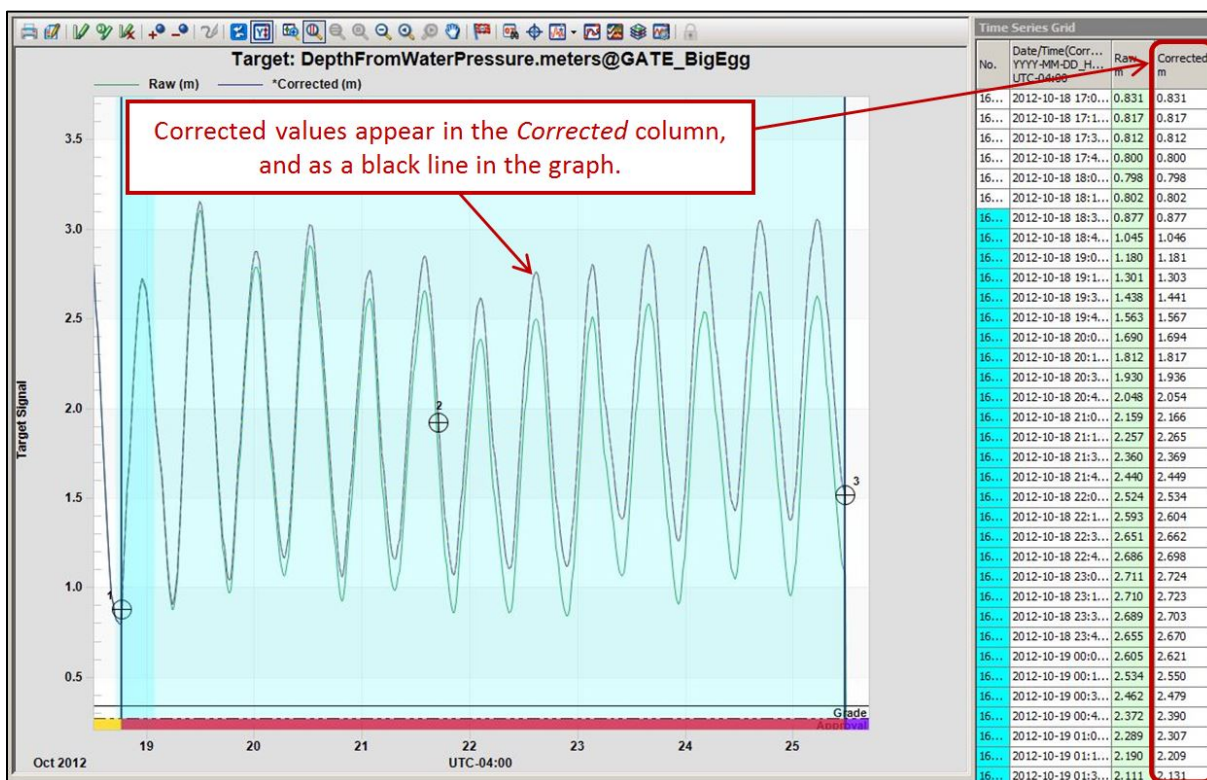


Figure 30. Aquarius drift correction control results.

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

$$\text{Sensor to Marsh Distance} = \text{CP to Sensor} - \text{CP to Marsh Surface}$$

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).

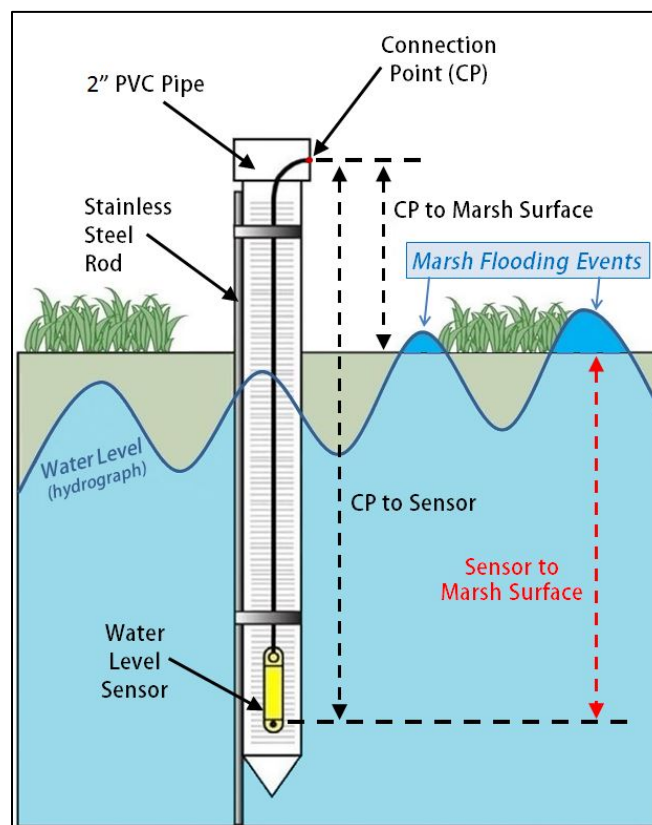


Figure 31. Well diagram showing sensor to marsh distance and flooding events.

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).

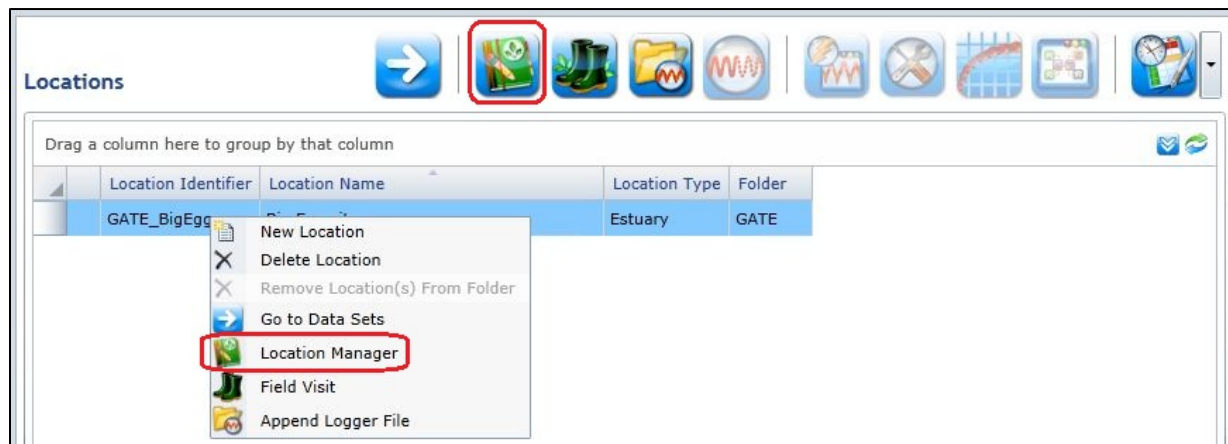


Figure 48. Two options for opening the Aquarius Location Manager.

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.

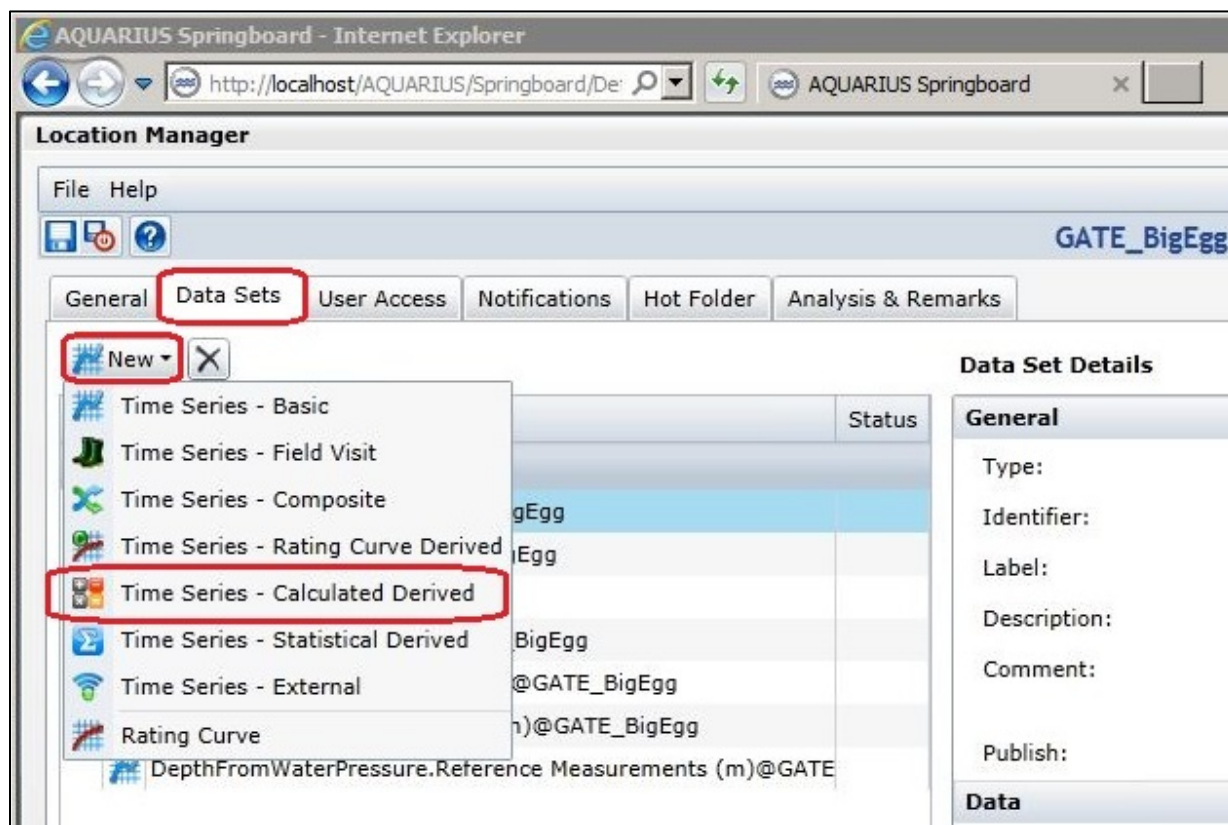


Figure 49. Create new “calculated derived” data set.

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).

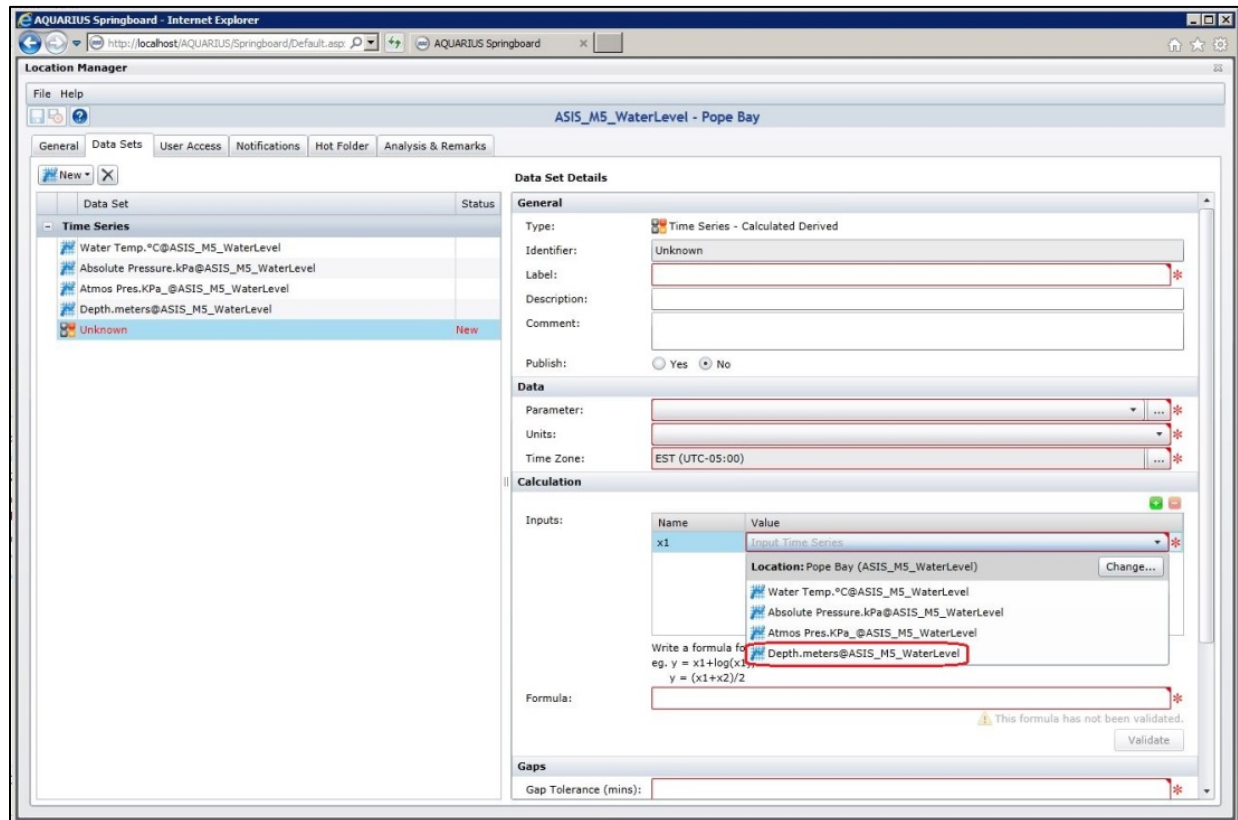


Figure 32. Select the input data set in Data Set Details window.

At the bottom of the *Calculation* section, in the *Formula* box, type:

$$y = x1 - [\text{sensor-to-marsh distance}]$$

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).

Calculation

Inputs:

Name	Value
x1	Depth.meters@ASIS_M5_WaterLevel

Write a formula for y in terms of x1 and x2:
 eg. $y = x1 + \log(x1)$;
 $y = (x1 + x2) / 2$

Formula: $y = x1 - 1.547$

⚠ This formula has not been validated.

Validate *

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.

Set Parameter

Search: Water level

Parameter	Description
- Length	
Water Level	Water Level
WaterLevelNAVD88	Water Level in NAVD88
WLE_MSL	Water Level Elevation (MSL)

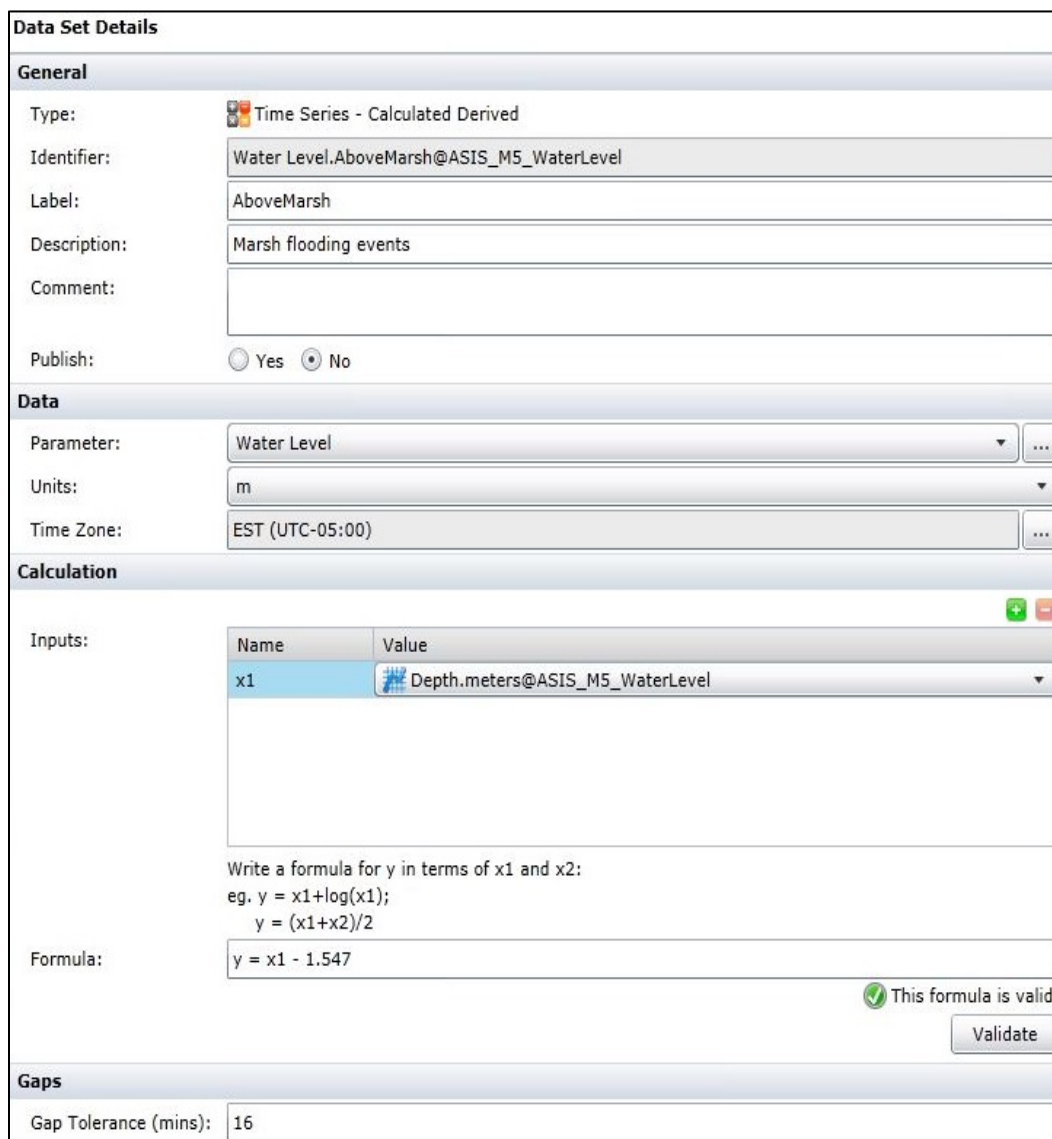
Collapse All OK Cancel

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.



Data Set Details

General

Type:  Time Series - Calculated Derived

Identifier: Water Level.AboveMarsh@ASIS_M5_WaterLevel

Label: AboveMarsh

Description: Marsh flooding events

Comment:

Publish: ☐ Yes ☒ No

Data

Parameter: Water Level

Units: m

Time Zone: EST (UTC-05:00)

Calculation

Inputs:

Name	Value
x1	 Depth.meters@ASIS_M5_WaterLevel

Write a formula for y in terms of x1 and x2:
eg. $y = x1 + \log(x1)$;
 $y = (x1 + x2) / 2$

Formula: $y = x1 - 1.547$

 This formula is valid.

Gaps

Gap Tolerance (mins): 16

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).

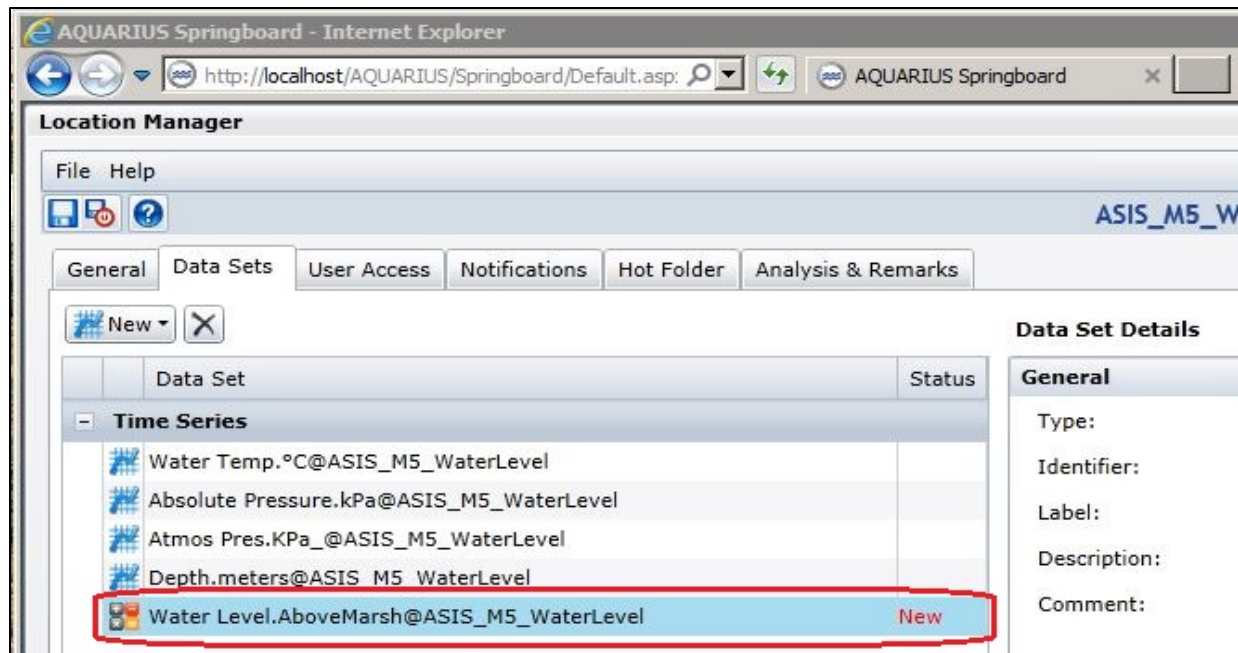


Figure 36. Newly created “calculated derived” time series data set

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.

$$\text{NAVD88 Sensor Elevation} = \text{NAVD88 CP Elevation} - \text{CP to Sensor Distance}$$

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:

$$y = x1 + [\text{NAVD88 Sensor Elevation}]$$

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.

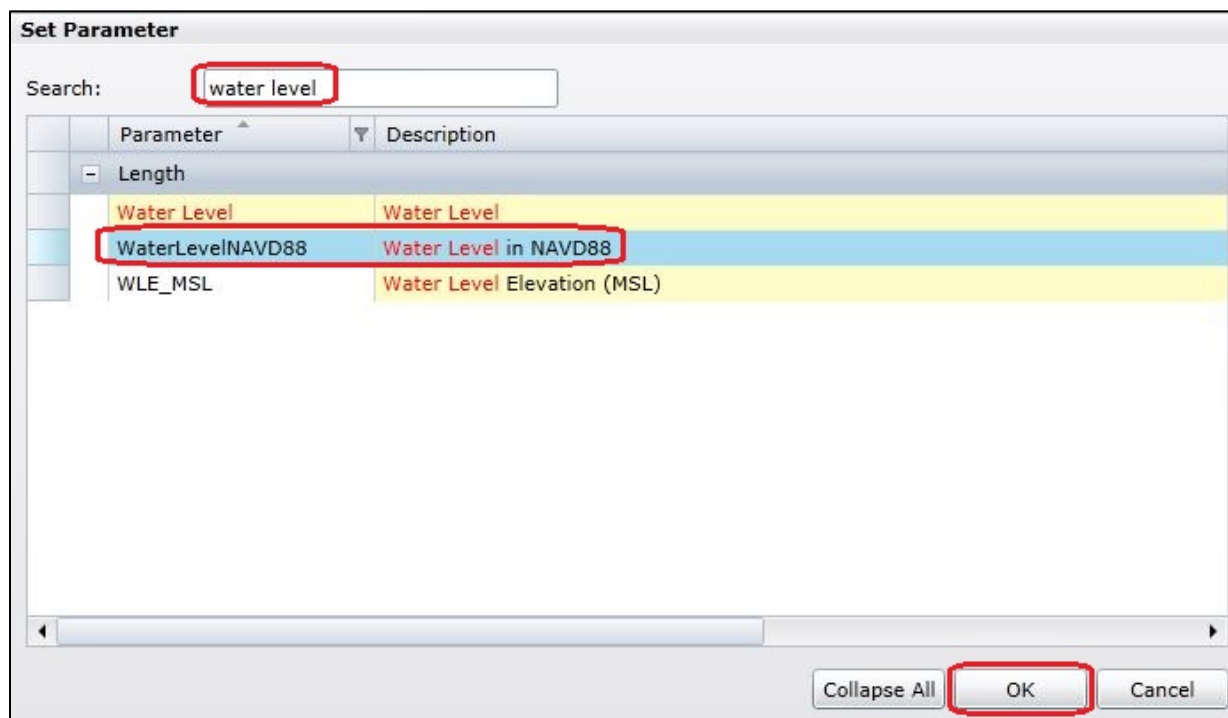
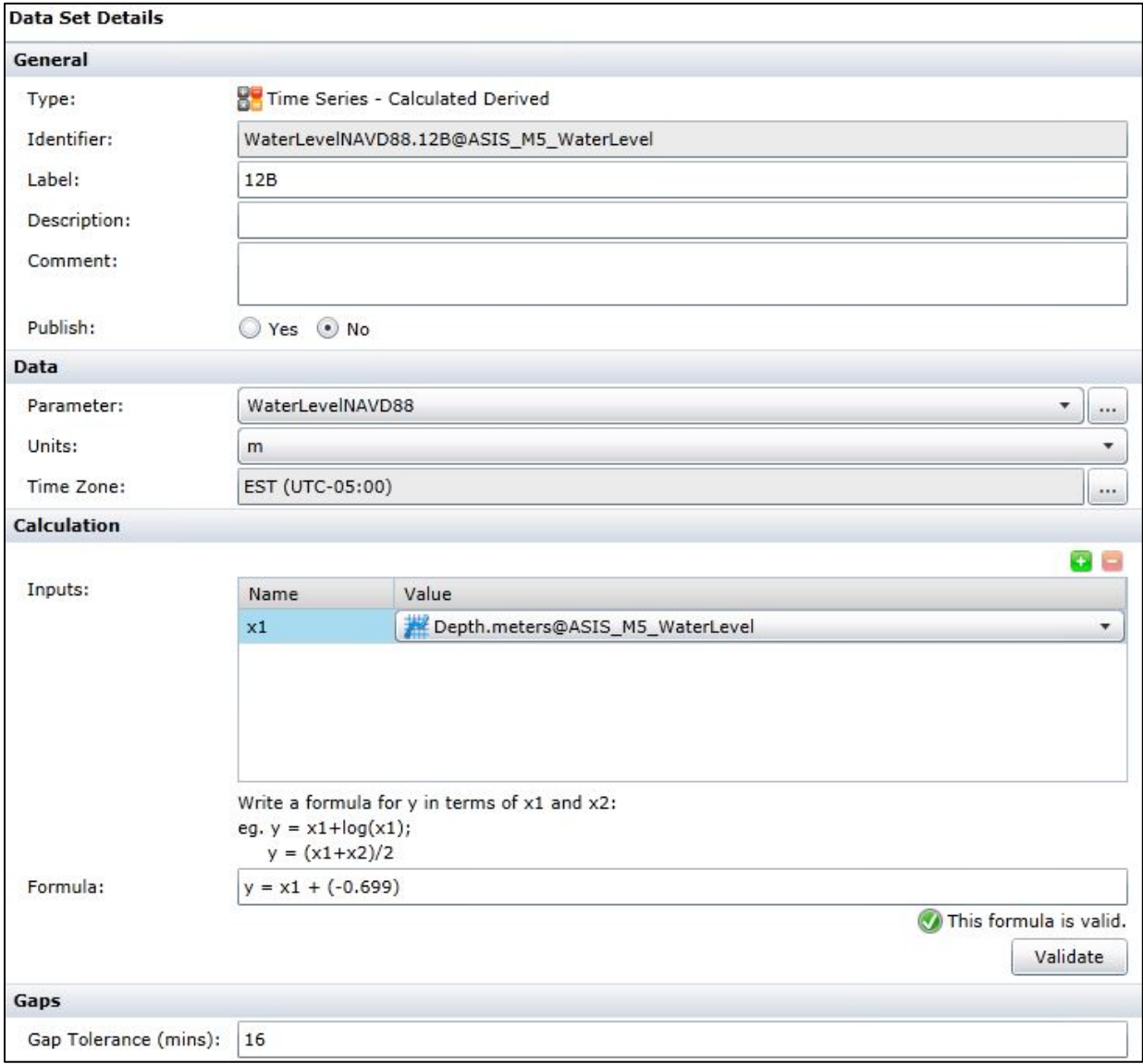


Figure 37. Choose WaterLevelNAVD88 to set the parameter for calculating tidal statistics.

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.



Data Set Details					
General					
Type:	 Time Series - Calculated Derived				
Identifier:	WaterLevelNAVD88.12B@ASIS_M5_WaterLevel				
Label:	12B				
Description:					
Comment:					
Publish:	☐ Yes ☒ No				
Data					
Parameter:	WaterLevelNAVD88				
Units:	m				
Time Zone:	EST (UTC-05:00)				
Calculation					
Inputs:	<table border="1"> <thead> <tr> <th>Name</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>x1</td> <td> Depth.meters@ASIS_M5_WaterLevel</td> </tr> </tbody> </table>	Name	Value	x1	 Depth.meters@ASIS_M5_WaterLevel
Name	Value				
x1	 Depth.meters@ASIS_M5_WaterLevel				
Write a formula for y in terms of x1 and x2: eg. $y = x1 + \log(x1)$; $y = (x1 + x2) / 2$					
Formula:	$y = x1 + (-0.699)$				
 This formula is valid. <button>Validate</button>					
Gaps					
Gap Tolerance (mins):	16				

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.

4.4.7.1 Generate Report on Marsh Flooding Statistics

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).

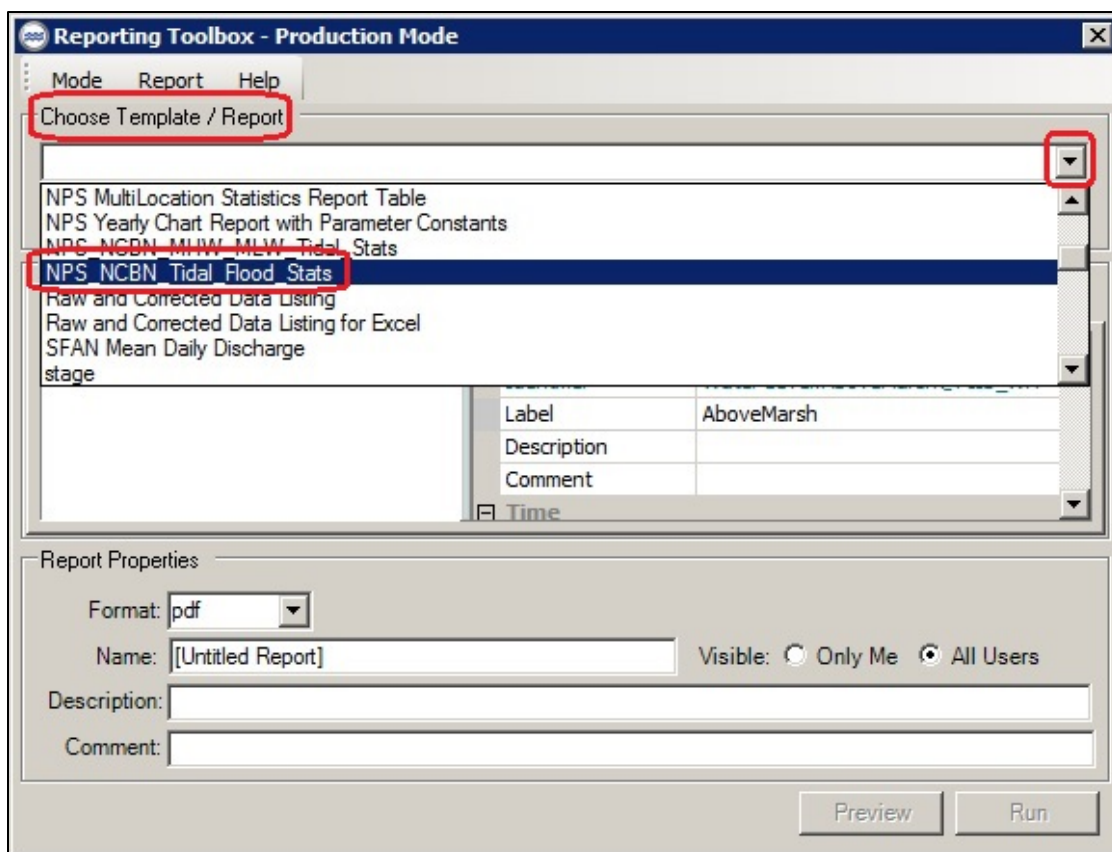


Figure 39. Select the Flood Stats Report in the Reporting Toolbox.

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.

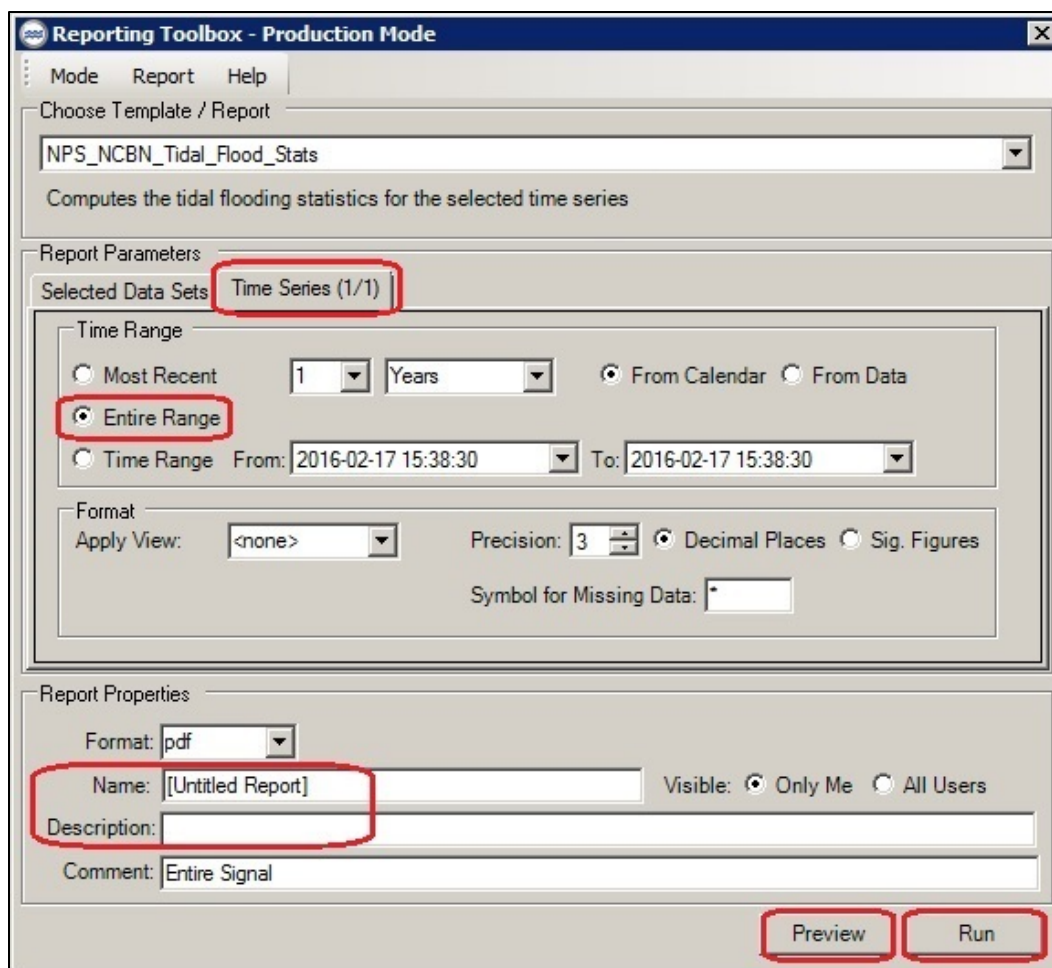


Figure 58. Set report parameters in Reporting Toolbox.

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).

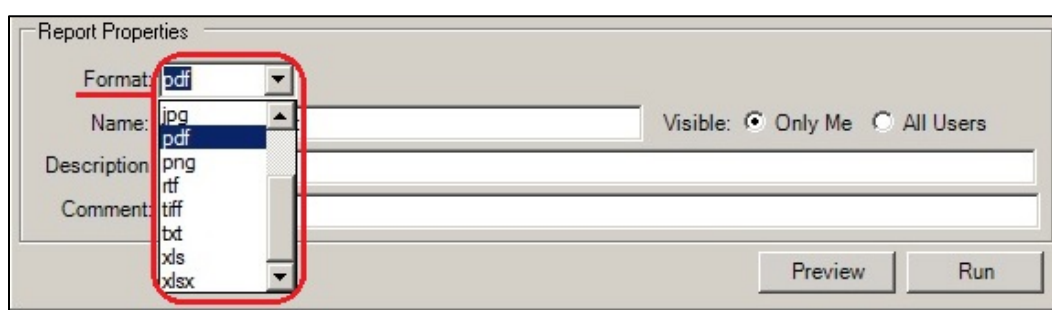


Figure 59. Report format options.

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).

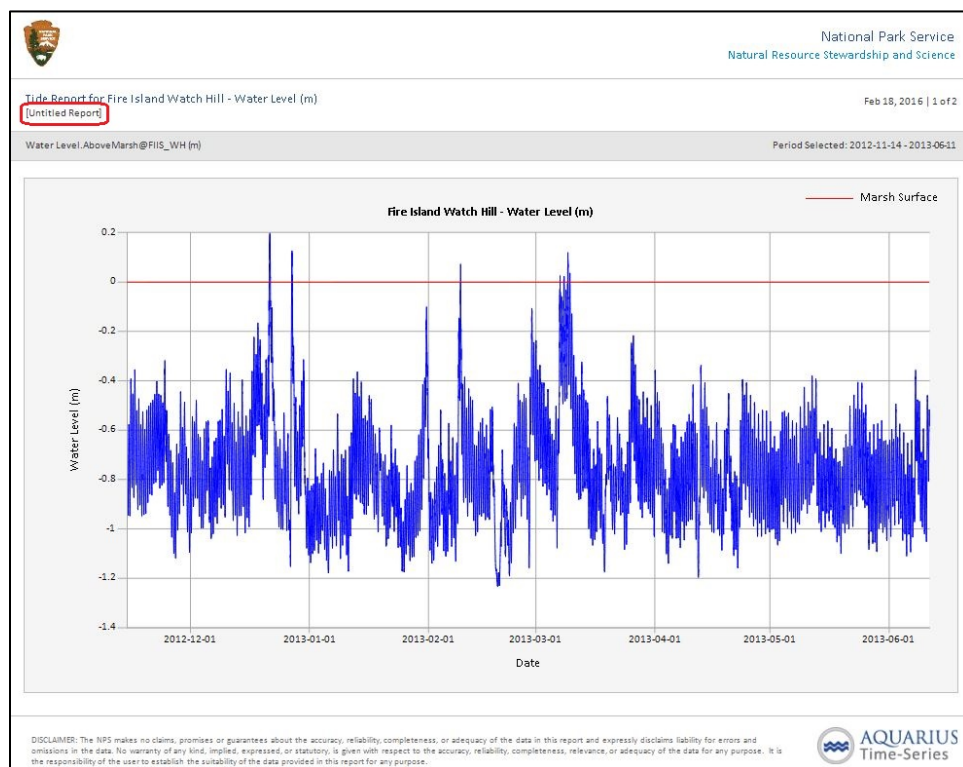


Figure 40. Title page and graph from the Aquarius NCBN Tidal Flood Stats Report.

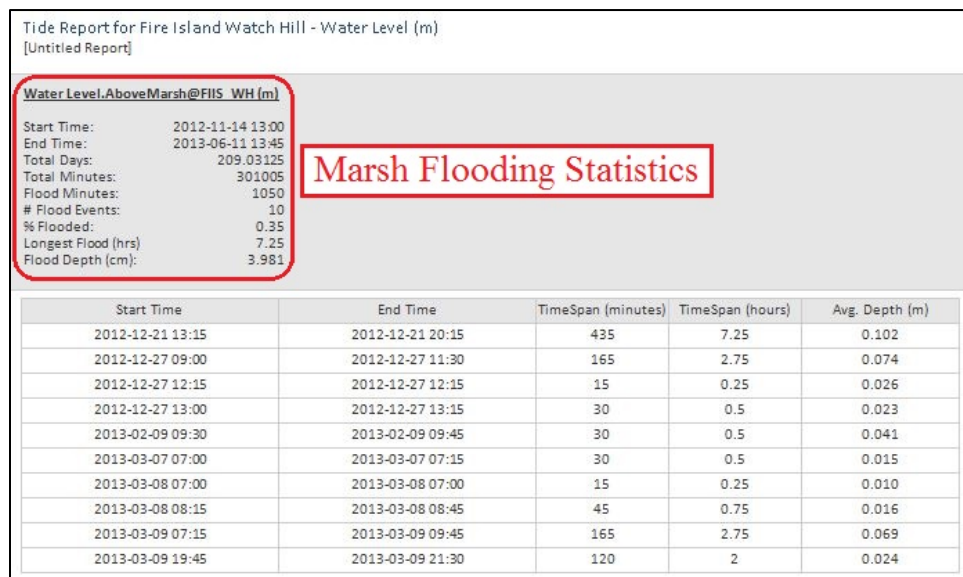


Figure 41. Statistics and tabular data from the NCBN Marsh Flood Stats Report.

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.

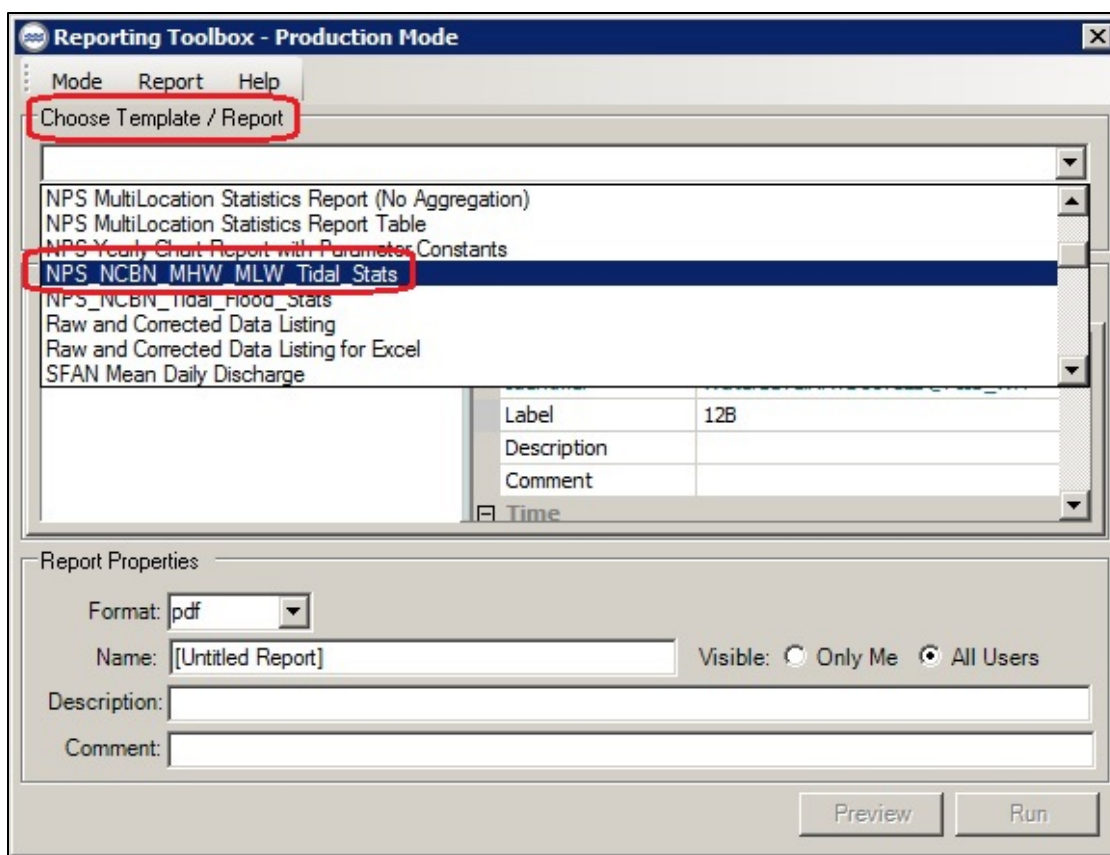


Figure 42. Select the Tidal Stats report in the Reporting Toolbox.

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.

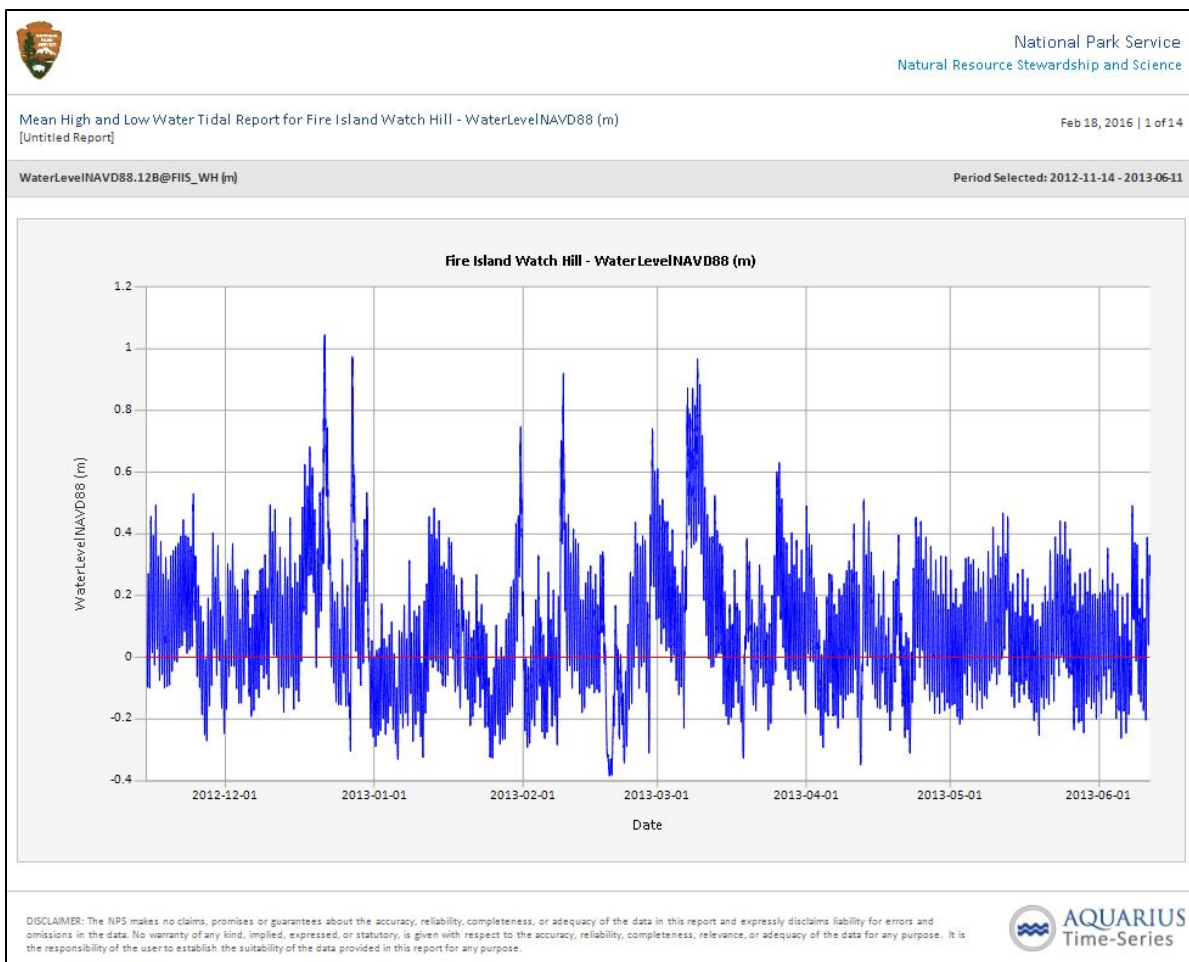


Figure 43. Title page and graph from the Aquarius NCBN Tidal Stats Report.

Mean High and Low Water Tidal Report for Fire Island Watch Hill - WaterLevelNAVD88 (m)
[Untitled Report]

Feb 17, 2016

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

- HOBOWare-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
 - HOBOWare® U20 Water Level Logger Manual: http://www.onsetcomp.com/files/manual_pdfs/12315-F-MAN-U20.pdf
 - Specifications for HOBOWare® U20 Water Level Loggers: <http://www.onsetcomp.com/files/data-sheet/Onset%20HOBOWare%20U20%20Water%20Level%20Data%20Loggers.pdf>
 - Specifications for HOBOWare® U20L Water Level Loggers: <http://www.onsetcomp.com/files/data-sheet/Onset-HOBOWare-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.

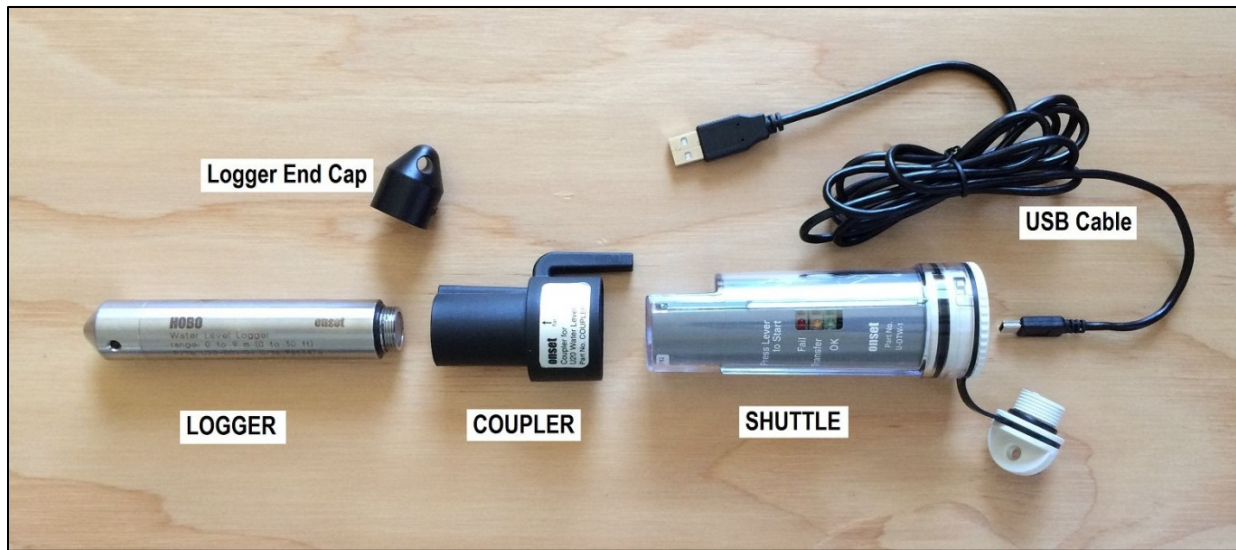


Figure B 1. HOBO data logger and auxiliary components.

3. Make sure appropriate units are selected (US or SI (=metric)) on the main menu bar (Figure B 2).

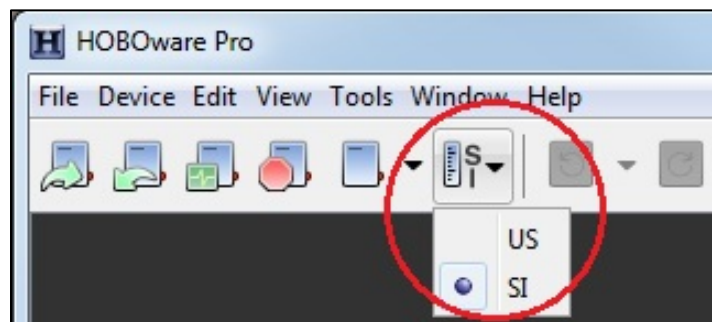


Figure B 2. Select appropriate units.

4. Under the “Device” menu, select “Launch” (Figure B 3).

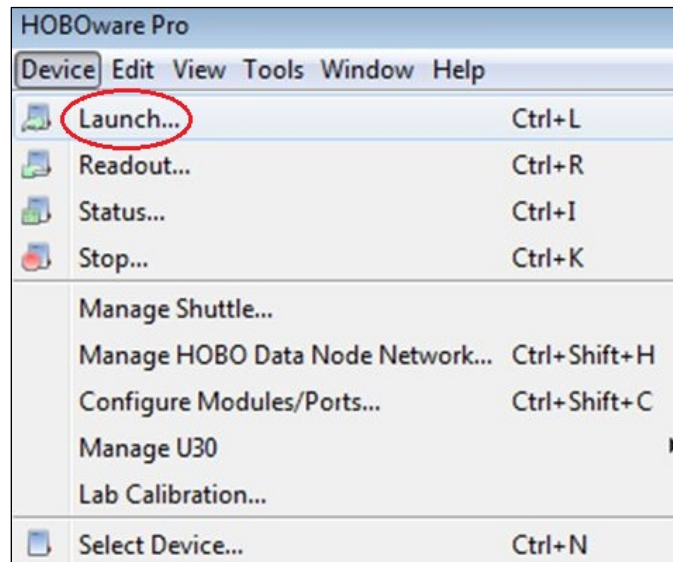


Figure B 3. Select Device/Launch.

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.”

Launch Logger

HOB0 U20-001-01 Water Level

Description: FIIS_WatchHill_Water1
Serial Number: 9883476
Deployment Number: 19
Battery State: GOOD

Sensors

Configure Sensors to Log:

- ☒ 1) Absolute Pressure <Enter label here>
- ☒ 2) Temperature <Enter label here>

Deployment

Logging Interval: 1) 15 minutes
Samples: 21656
Logs until: 225.6 days

Start Logging: On Date/Time 06/11/15 04:00:00 PM

☐ Skip launch window next time

Figure B 5. Examine and fill out fields in Launch Logger window.

7. The Launching Logger status window will appear (Figure B 6).

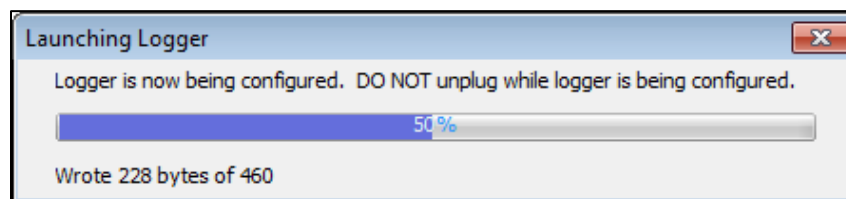


Figure B 6. Launching Logger status window.

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).

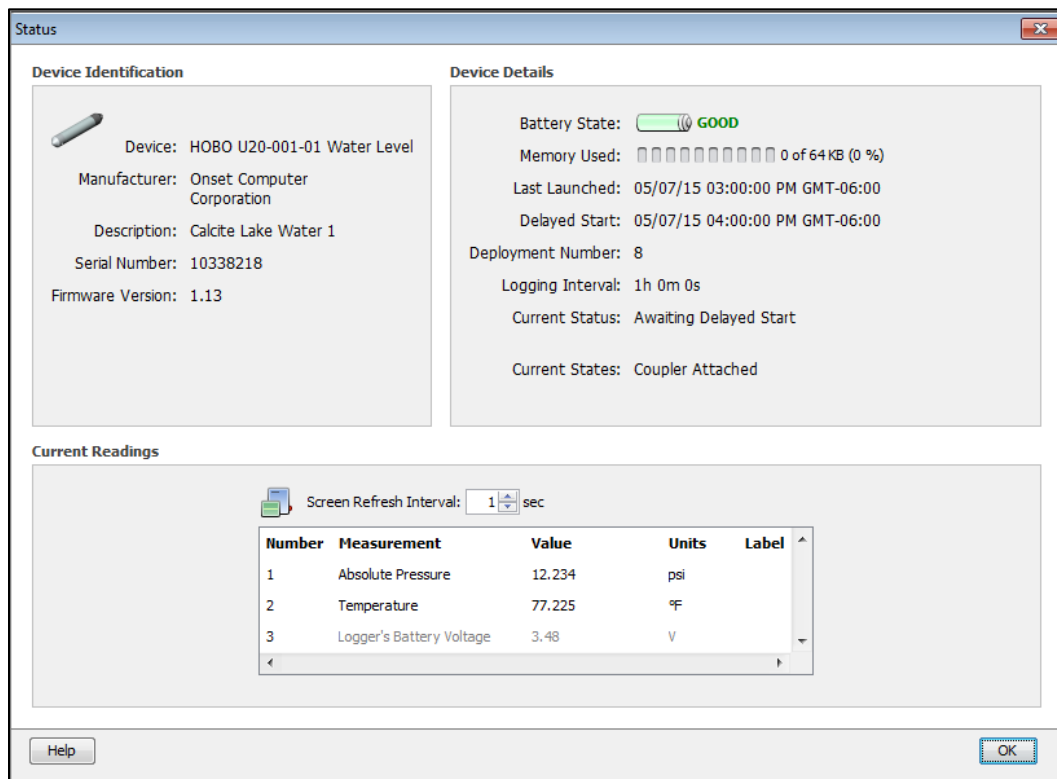


Figure B 7. Device status window.

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).

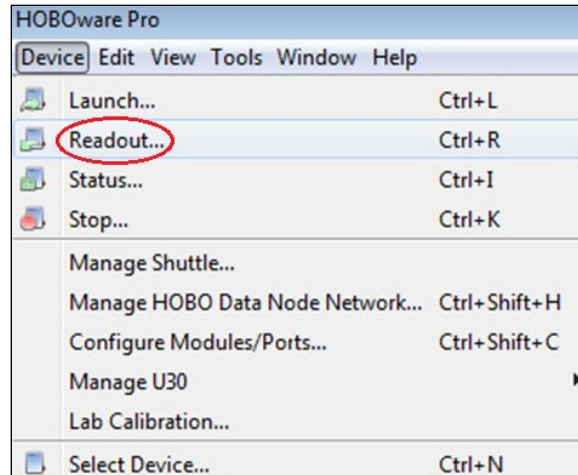


Figure B 8. Select Device/Readout.

5. Select device and hit “OK” (Figure B 4).
6. Stop the logger (Figure B 9).

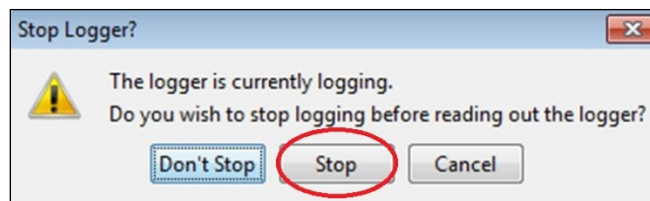


Figure B 9. Stop logger.

7. The Readout Logger status window will appear (Figure B 10).

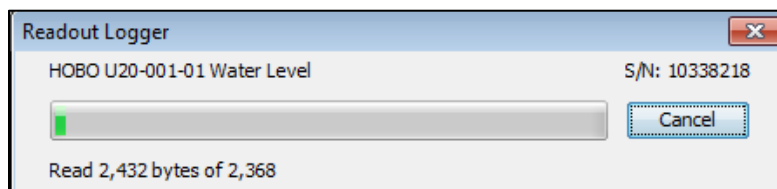


Figure B 10. Readout Logger status window.

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.

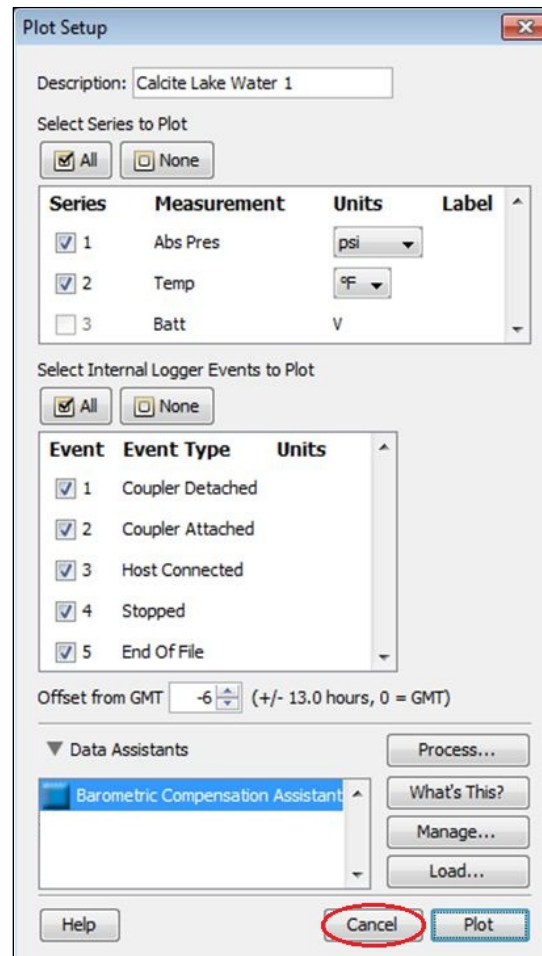


Figure B 11. Plot setup window.

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.

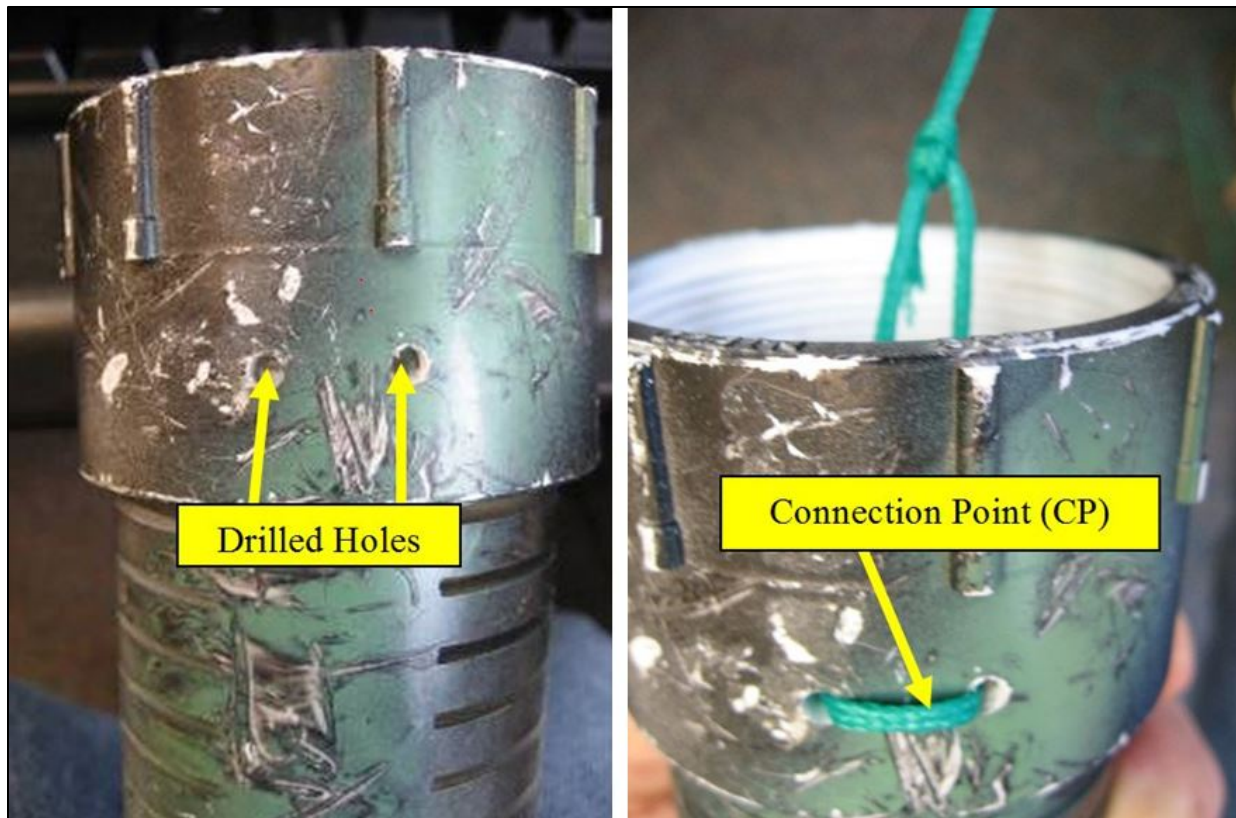


Figure C 1. Drilled holes and connection point (CP) in top of well casing.

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.

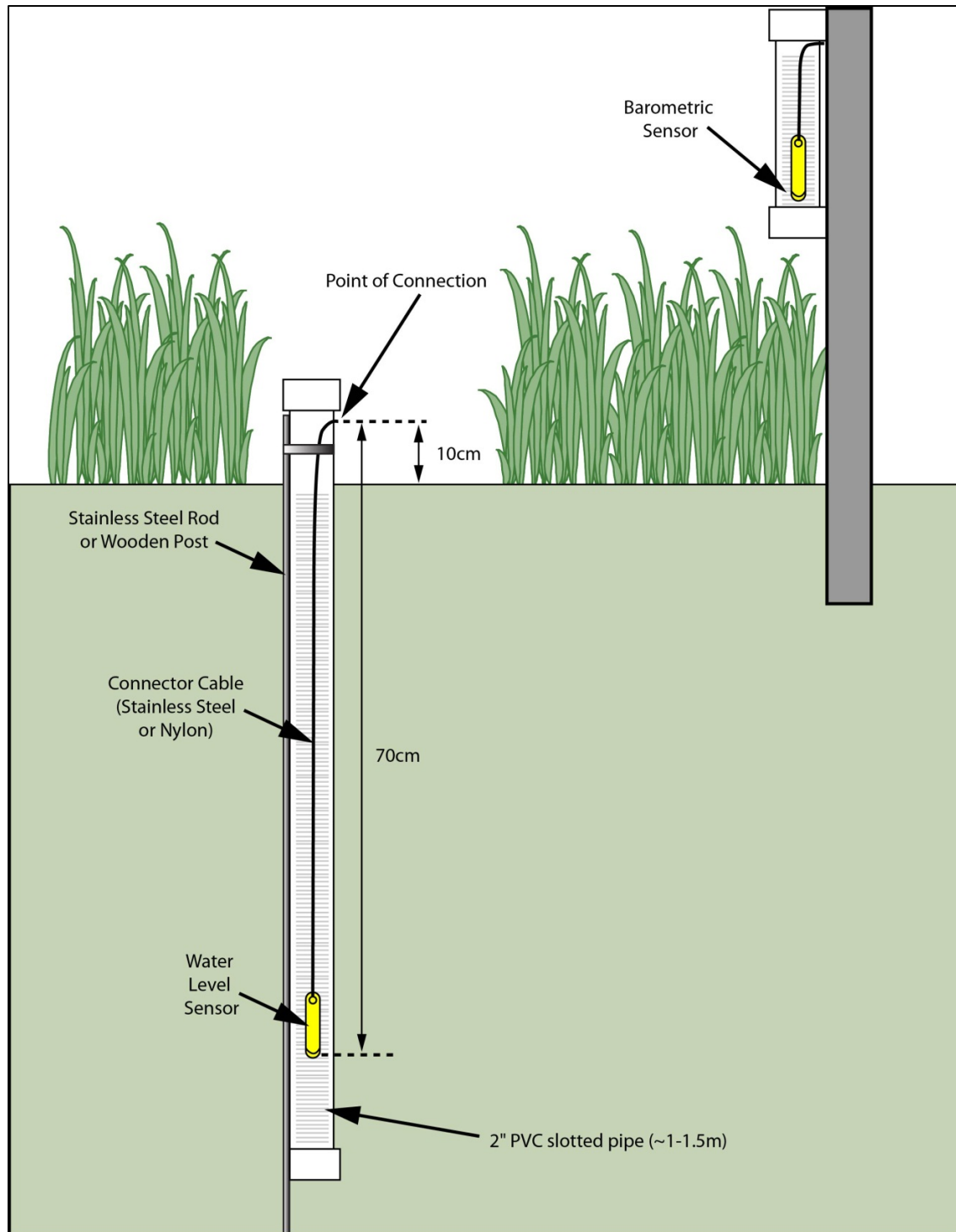


Figure C 6. WL logger installation in the marsh.

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.

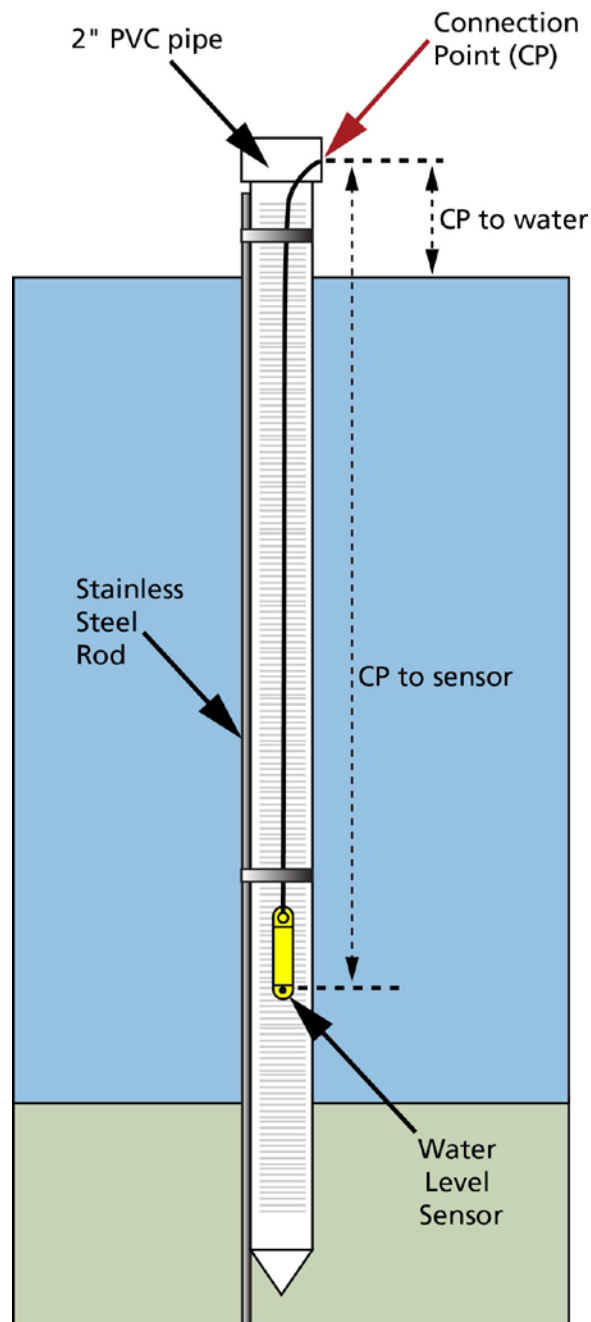


Figure C 7. Water level logger installation in a tidal creek or on the edge of a wetland (some of the PVC housing is exposed).

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.

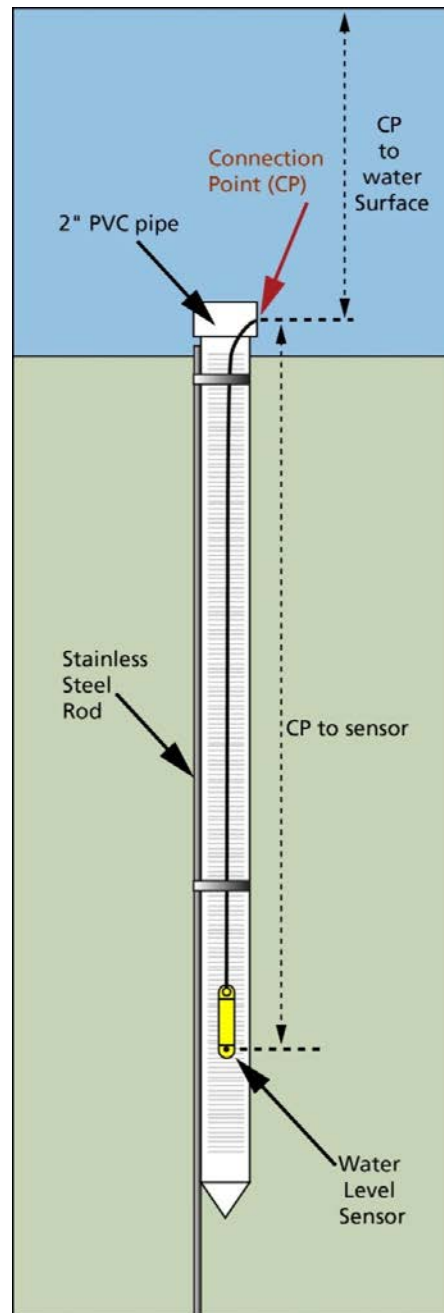


Figure C 8. Water level logger installation in the bottom of tidal creek.

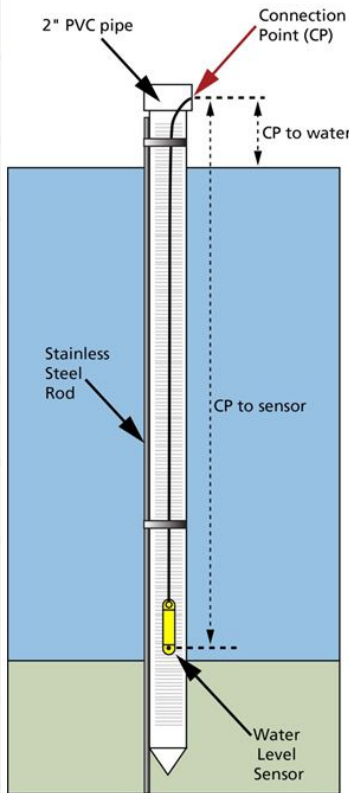
Questions about logger installation:

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 ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:		Personnel:			
2)	☐ Deploy Logger ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:		Personnel:			
3)	☐ Deploy Logger ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:		Personnel:			
4)	☐ Deploy Logger ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:		Personnel:			
5)	☐ Deploy Logger ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:		Personnel:			



2" PVC pipe

Connection Point (CP)

CP to water

Stainless Steel Rod

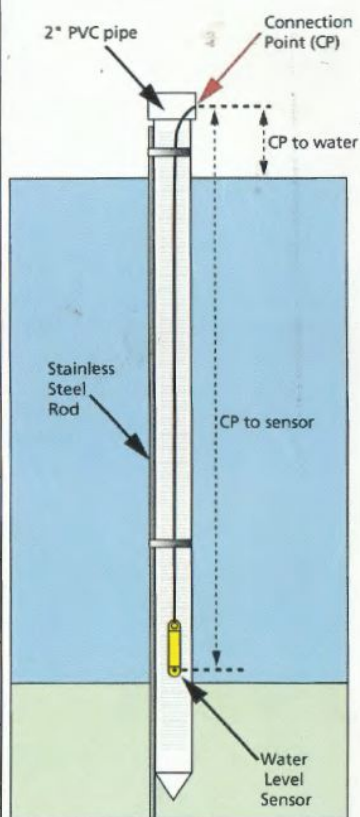
CP to sensor

Water Level Sensor

* 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 ASIS		Site Developed Area	
Date	Action	Sensor info	CP to Sensor	CP to water	Time
1) 9/24/14	☒ Deploy Logger ☐ WL check ☐ Dump Data ☐ 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 ☐ WL check ☒ Dump Data ☐ Remove Logger	PLASTIC 10527256	S6	-18cm	1245pm
Notes: TOP COLLAR TO CP = 3cm JIM WIND TOP CAP TO CP = 5cm					
3) 4/24/15	☒ Deploy Logger ☐ WL check ☒ Dump Data ☐ Remove Logger	10527256		-14cm	1245pm
Notes: 3cm from CP to top of PVC collar Dumped & redeployed logger - Jim Wind					
4)	☐ Deploy Logger ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:					
5)	☐ Deploy Logger ☐ WL check ☐ Dump Data ☐ Remove Logger				
Notes:					



2" PVC pipe

Connection Point (CP)

CP to water

Stainless Steel Rod

CP to sensor

Water Level Sensor

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

EXPERIENCE YOUR AMERICA TM