Standing Project Instructions
For Coastal and Great Lakes Water Level Stations

Updated March 2007

Center for Operational Oceanographic Products and Services
National Ocean Service
National Oceanic and Atmospheric Administration

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STANDING PROJECT INSTRUCTIONS
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SECTION 1.0. INTRODUCTION

The National Oceanic & Atmospheric Administration (NOAA) is a bureau of the U.S. Department of Commerce (DOC). The NOAA mission is to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs. The vision to support the NOAA's mission is to move NOAA into the 21st century scientifically and operationally, in the same interrelated manner as the environment that we observe and forecast, while recognizing the link between the global economy and our planet's environment. The NOAA mission faces new urgency, given the intensifying national needs of the environment, the economy, and public safety; to assess and predict environmental changes, protect life and property, provide decision makers with reliable scientific information, manage the Nation's living marine and coastal resources, and foster global environmental stewardship.

The Center for Operational Oceanographic Products and Services (CO-OPS) of the National Ocean Service, an organizational element of NOAA, operates and maintains a network of approximately 196 long-term water level measurement stations as a part of the National Water Level Observation Network (NWLON) around the U.S. coast and in the Great Lakes. CO-OPS installs and operates short-term water level stations in support of a variety of programs including hydrographic and photogrammetry surveys, marine boundary determination, dredging, climate change, long-term sea level rise studies, habitat restoration, and real time navigation systems. The data collected and predictions derived are used to ensure safe, efficient, and environmentally sound maritime commerce. CO-OPS provides a set of water level products, including data and products required by the National Weather Service to meet flood and tsunami warning responsibilities, the National Water Level Observation Network (NWLON), and a national network of Physical Oceanographic Real-Time Systems (PORTS®) in major U.S. harbors.

PORTS® is a partnering effort based on extensive collaboration among NOS and local maritime communities to identify and satisfy user needs to improve maritime safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® comes in different sizes and configurations, each designed to meet local user requirements. PORTS® includes sensors, hardware, and associated communications systems allowing the centralized, real-time, data acquisition and dissemination of water levels, currents, and other oceanographic and meteorological data. The modular design of each PORTS® installation allows the straight forward integration of additional sensors to meet user requirements.

CO-OPS establishes standards for the acquisition and processing of water level and current data; collects and documents user requirements that serve as the foundation for all resulting program activities; designs new and/or improved oceanographic observing systems; develops software to improve data processing capabilities; maintains and operates oceanographic observing systems;

performs operational data analysis/quality control; produces/disseminates oceanographic products; and archives the resulting oceanographic data.

These Standing Project Instructions provide the requirements for installation, maintenance, and removal of water level stations in support of the NWLON, PORTS®, COASTAL Program, hydrographic and photogrammetry survey operations, and reimbursable special projects. These stations provide critical data to support the following activities:

- Ensure safe navigation
- Determine flow rates to support International treaties
- Determine tidal datums for the National Nautical Charting Program
- Determine the baseline from which marine boundaries are delineated
- National Weather Service tsunami/storm surge warning programs
- Coastal resource restoration and management
- Long term sea level trend analyses.

The NWLON supports the following four NOAA Mission Goals: Ecosystem Management, Climate, Weather and Water, Commerce and Transportation

The objective of these Standing Project Instructions is to ensure that systems/sensors are maintained in an effective and consistent manner to collect continuous, reliable, defect-free data.

1.1. General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for tidal waters is Mean Lower Low Water (MLLW) based on the NOAA National Tidal Datum Epoch (NTDE) of 1983-2001 as defined in the Tide and Current Glossary. All tidal datum relationships are referenced to this datum; water level heights are referenced to the individual station datum, and can be corrected for reference to MLLW. In non-tidal areas, special low water datums have been defined for specific areas and are used as chart datum in these locations. In the Great Lakes, a Low Water Datum relative to IGLD 85 is the reference datum.

In some cases where historical sites are re-occupied, every effort shall be made to collect the new data series on the historical Station Datum (SD).

Leveling and GPS connections to geodetic datums are made at each water level station, if practical, as described in Section 4.

1.2. Reference Documents

The following reference documents are referred in various sections of the Standing Project Instructions.

(1) *"NGWLMS Site Design, Preparation, and Installation Manual (NGWLMS Manual), January 1991".*

(2) *"Xpert DCP User's Manual, October 2005." (Latest updated version)*

(3) *"User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987"*.

(4) *"User's Guide for Electronic Levels, Updated January 2003"*.

(5) *"User's Guide for Writing Bench Mark Descriptions, Updated January 2003"*.

(6) *"User's Guide for GPS Observations, Updated March 2007"*.

(7) *"CO-OPS GPS Observations Implementation Plan, January 2003"*.

(8) *"Specifications and Deliverables for Installation, Operation, and Removal of Water Level Stations, March 2007"*.

(9) *"Barometer Calibration Guidelines, Updated January 2002"*.

(10) *"Wind Sensor Alignment Procedure for the R. M. Young Wind Sensors, October 2005"*

(11) *"CO-OPS Water level and Meteorological Site Reconnaissance Procedures, Updated March 2007"*

(12) "*User's Guide for 8200 Acoustic Gauge, NOAA/NOS, Updated August 1998"*.

(13) *"User's Guide for 8200 Bubbler gauge, updated February 1998"*

(14) *"NGWLMS GOES MESSAGE FORMATTING, Phil Libraro 1/2003"*.

(15) *"NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3", November 1997"*.

(16) *"Standards and Specifications for Geodetic Control Networks", Federal Geodetic Control Committee, September 1984.*

(17) *"Spatial Data Modifications and Enhancements, FY 05 Functional Requirements Document, August 2005"*.

(18) *"Revised NGS 3 – Dimensional (3 – D) Rod Mark, National Geodetic Survey, July 1996"*.

(19) *"NWLON/DMS Quality Control Software (QC) Functional Requirements Document, Revised November 2004"*.

(20) *"NOS Hydrographic Surveys Specifications and Deliverables, March 2007"*.

(21) "*Attachment R, Requirements for Digital Photographs of Survey Control, NGS, July 2005*"

(22) "*SOP-06-001 for Upgrading or Installing a New Water Level Station, March 2006*"

(23) "*Water Level Records Evaluation Criteria, May 2006*"

SECTION 2.0. REQUIREMENTS FOR RECONNAISSANCE, INSTALLATION, MAINTENANCE, AND REMOVAL OF WATER LEVEL STATIONS

2.1. Installer

The term installer has been defined as a person or field party that will perform any of the following tasks: reconnaissance, installation, maintenance, repair, or removal of a water level station. The installer of a water level station could be CO-OPS personnel, NOAA ship personnel, Office of Coast Survey (OCS) Navigational Response Teams (NRT), other NOAA personnel, or contractor(s).

2.2. Reconnaissance

The reconnaissance of water level and meteorological stations shall be performed, as appropriate, and when specified in the contract documents, in accordance with Reference 11.

2.3. Sensor Specifications

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), absolute shaft angle encoder (SAE), microwave, or other suitable type as determined (a) after the reconnaissance of the site is completed, (b) final station design is performed, and (c) CO-OPS has approved the site and the type of sensors. CO-OPS' approval of type of water level sensor is required for a project. CO-OPS is currently testing microwave, radar and other types of sensors but these sensors are not used in CO-OPS operational programs yet.

The sensor measurement range shall be greater than the expected range of water level and the installation shall be designed to measure the full range of extreme water level such as highest observed and lowest observed water level data (100 years, if available).

Gauge/sensor systems shall be calibrated prior to deployment, and the calibration shall be checked after removal from operations. The calibration standard's accuracy must be traceable to National Institute of Standards and Technology (NIST). The required water level sensor resolution is a function of the tidal range of the area in which water level data is collected.

For NWLON water level data, the required water level sensor resolution shall be 1 mm or better. For the hydrographic and photogrammetry surveys, for tidal range less than or equal to 5 m, the required water level sensor resolution shall be 1 mm or better; for tidal range between 5 m and 10 m, the required water level sensor resolution shall be 3 mm or better; and for tidal range greater than 10 m, the required water level sensor resolution shall be 5 mm or better.

Currently, the Aquatrak™ self-calibrating air acoustic sensor is used at the majority of the NWLON stations. At stations where the acoustic sensor can not be used due to freezing or the lack of a suitable structure, either a ParoScientific intelligent pressure (vented) sensor incorporated into a gas purge system, or a sump/float with absolute shaft angle encoder (Great Lakes Stations) are used. A microwave air gap sensor is used in selected PORTS® projects.

Known error sources for each sensor shall be handled appropriately through ancillary measurements and/or correction algorithms. Examples of such errors are water density variations for pressure gauges, sound path air temperature differences for acoustic systems, and high frequency wave action and high velocity currents for all sensor types. At a number of NWLON stations, dual orifice gas purged sensors which are mounted a fixed vertical distance apart and connected to two vented ParoScientific pressure transducers are used so that a density correction can be estimated for each sample based on the pressure difference and gravity.

The orientation of the primary sensor shall be carefully documented in elevation (side) view sketches and photographs, as required. Orientation of the protective well (or sump and intake in the Great Lakes) relative to the wave or current modifiers such as nearby pilings, bulkheads, or other structures in the water shall be documented. All features in the vicinity of the protective well such as, pilings, other wells, decking, buildings (tide house), etc., which might cause uneven sun/shading of the well and resulting non-uniformity of temperature inside the well shall also be well documented.

The installer shall have all forms and figures submitted using metric units and referenced to the Station Datum (SD) as applicable. Other references (e.g. orifice zero or tide staff zero) shall also be shown on the forms with reference to the SD.

Redundant water level sensor orifices shall be secured structurally independent of the primary water level sensors. In Great Lakes stations, the Waterlog shaft angle encoder (SAE) shall be used as the redundant water level sensor and shall be set to read the same as the Electric Tape Gauge (ETG) and the primary SAE.

The cable lengths of all water level and ancillary sensors shall be noted in the Site Report to the nearest tenth of a meter. This will assist with the efficient replacement of cables should a failure occur.

2.3.1. Tsunami Data Requirements

For NWLON and other water level stations installed and supporting tsunami detection capabilities for NOAA Tsunami Program shall have 1 minute averaged water level data available in addition to the 6 minute data. The 1 minute averaged data will be mainly coming from the primary sensor during the normal operations. In addition, 15 seconds data from the redundant sensor on redundant DCP shall also be made available in the event of a tsunami, or as per the request of National Weather Service (NWS) Tsunami Warning Centers, and the Pacific Marine Environmental Laboratory of NOAA Office of Atmospheric Research (OAR). The RAM pack and other storage devices may be appropriate for storing the 15 second data.

2.4. Data Collection Platform

The Data Collection Platform (DCP) shall acquire and store water level measurements every 6-minutes. The water level measurements shall consist of an average of three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e. :00, :06, :12, etc.). In addition to the average measurement, the standard deviation of the discrete water level samples and outliers which comprise the 6-minute measurements shall be computed and stored. The 6-minute centered average water level data and the standard deviation provide valuable data quality information regarding each measurement.

For NWLON tide stations, a redundant DCP shall also be installed so that in case of a failure of a primary DCP or sensor, water level data from the redundant DCP or sensor can be retrieved. The redundant DCP also shall acquire and store water level measurements every 6- minutes and the water level measurements shall consist of an average of three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e. :00, :06, :12, etc.).

2.5. GOES Satellite Transmissions

The ability to monitor water level measurement system performance for near real-time quality assurance is essential for operations. Water level data transmitted via satellite in NOS format can be retrieved and monitored by CO-OPS, and in the case of data gaps or gauge problems, corrective actions can be taken immediately. At all sites where access to the GOES satellite is available, and according to CO-OPS policy, the measurement system shall be equipped with a GOES transmitter to telemeter the data to NOS. This section is applicable where water level gauges are installed by CO-OPS or CO-OPS' contractors for NWLON, Tsunami, COASTAL, Special projects, and NOAA in-house survey projects. The section is not applicable for NOAA contract hydrographic or photogrammetry projects.

The data transmissions shall use the message format detailed in Reference 14. This format is currently implemented in the Next Generation Water Level Measurement Systems (NGWLMS), assuring compatibility with the CO-OPS Data Management System (DMS).

The NOS Continuous Operational Real-Time System (CORMS) is a 24 x 7 data monitoring operation. It monitors all water level measurement system data transmitted via GOES to assure the gauges are operating properly. Data that is not transmitted by GOES but is submitted to CO-OPS via diskette, CD-ROM, or such other media, must also conform to the format specified in the above document so that data can be loaded properly into DMS.

The clock accuracy of a satellite radio system shall be adjusted with a GPS clock for NWLON gauges. For a tide gauge that does not have a GPS clock, or that transmits hourly or three hourly, the clock accuracy of a satellite radio system shall be within 5 seconds per month for short term water level gauges so that adjacent satellite channel overlapping does not occur. Non-satellite radio systems shall have a clock accuracy of less than one minute per month.

2.6. Data Transmission Initiation and Station Database Configuration Requirements

Information required for station database configuration at CO-OPS Database Management System (DMS):

(1) Station Number and Name
(2) Installation Date
(3) Latitude/longitude
(4) Platform ID, transmit time, channel
(5) Serial numbers of all DCPs, and sensors.
(6) Level abstract
(7) Sensor offset C1 (SNS) and Datum Offset C2 (DAT) as entered in the DCP for acoustic sensor; and orifice offset(s) for pressure sensors.

The CO-OPS' Requirements and Development Division (RDD) maintains the GOES platform ID list for all water level stations in the NWLON. For new NWLON stations, once the location, type of sensors, and DCP are selected, CO-OPS will assign the platform ID and provide the satellite configuration data for the deployment.

For other types of water level stations, such as subordinate stations installed for hydrographic or photogrammetric surveys, or meteorological (met) only stations, RDD shall also assign platform ids, as appropriate.

RDD will provide station numbers and platform ID assignments in advance for DCP setup and testing if the location (latitude and longitude) of the station/DCP is known, or will provide the information once the location has been determined by field reconnaissance and reported to RDD. RDD can be reached at telephone 301-713-2897, fax: 301-713-4465 or 301-713-4435. Requests for GOES platform IDs shall be submitted to RDD at least 15 days before throughput testing to allow sufficient time to receive radio frequency assignments.

Prior to the installation of a station and initiation of GOES data transmissions in the field, information required for database configuration shall be emailed or faxed, along with a phone call to RDD. See the side bar for information required for station database configuration in the CO-OPS DMS. Test transmissions monitored by the installer during field unit installation may be conducted outside this requirement.

This station information must be configured in DMS for data to be accepted in DMS. Within 24 hours after reporting the above basic information and before the complete inspection package is submitted, the site report shall be forwarded to RDD. This requirement applies to all types of water level stations and all types of sensors where CO-OPS is expected to receive and/or process the data.

CO-OPS is developing a web-based electronic site report that will interact with DMS. As soon as this site report is developed, new procedures and information will be provided.

The effective starting date of all operational sensor data series will be when the data is first received after DMS configuration. It is the responsibility of the installer to ensure that the required documentation is provided to RDD prior to the date when operational sensor data are needed. For the installation of a new acoustic, ParoScientific pressure, or shaft angle encoder sensor(s), perform leveling to the PBM and the acoustic sensor leveling point, sometimes called the Aquatrak™ Leveling Point (AQLP), the ETG, or the orifice staff stop (and measurement to

the orifice zero) in the field, and compute the datum offset (coefficient C2 or also called DAT coefficient for Xpert DCP), or orifice offset(s), as appropriate. Then email or fax a copy of the level abstract (and water level transfer form for Great Lakes stations) to RDD in addition to a phone call to RDD so that sensor parameters can be properly setup in DMS prior to the beginning of the accepted data collection. The above procedure must be followed. If this procedure is not followed in timely fashion prior to beginning of data transmission, data losses may occur. When station sensors are properly configured in DMS, the data is accessible through the CO-OPS' web site at http://tidesandcurrents.noaa.gov.

Changes to the satellite platform ID, or the DCP telephone number, shall be reported to RDD and the supporting Field Operations Division (FOD) office immediately via telephone, email, or fax.

Installer/tester shall follow the appropriate throughput testing requirements as outlined in the SOP-06-001 as referenced in the Reference 22.

2.7. Station Installation

The installation of water level station DCPs and sensors shall be accomplished according to Reference 1, Reference 2, and the manufacturer's instructions, as applicable. Most of the NWLON stations will have the Sutron Xpert System (Xpert DCP and Xpert Dark as redundant DCP) installed within the next year or so.

The installer shall obtain all required permits and permissions for installation of the water level sensor(s), DCPs, bench marks, and utilities, as required. The installer shall be responsible for security and/or protective measures. The installer shall install all components in the manner prescribed by the manufacturer, installation manuals, or as specified by the Contracting Officer's Technical Representative (COTR). The installer must provide CO-OPS with the position of all tide gauges installed before data collection begins, including those that were not specified in the Statement of Work. In cases where gauge location(s) needs to be different than that specified in the Statement of Work, installer shall consult with CO-OPS prior to the installation.

Digital photographs shall be taken of all station bench mark disks in accordance with Reference 21. A minimum of three photos shall be taken: close-up of the disk face; chest or waist level view of disk and setting; and horizontal view of location and direction of view. Photos shall also be taken of station components such as protective wells, staffs, houses, shelters, met towers, DCPs, sensors, etc. One general location photo shall be taken showing the water level station in relationship to its supporting structure and the local body of water. All digital station photo files should be named such that the name of the file will indicate the station number and the type of photo taken. For example, the acoustic sensor photo for DCP1 at Los Angeles shall be named as 94106601 sensor A1.jpg.

The station components and bench mark photographs are required when a new station is installed. The bench mark photographs shall be updated whenever any changes are noticed, such as damaged bench mark disk, or changes to settings, etc, or as requested in the station specific requirements.

A completed water level measurement station installation consists of the following:

(a) The installation of the water level measurement system (water level sensor(s), primary and redundant DCP as appropriate, satellite transmitter, ancillary sensors if applicable, other equipment as necessary and its supporting structure, and a staff if required), as specified in the Annual Station Specific Requirements, or as specified in the contract documents.

(b) The recovery and/or installation of the required minimum number of bench marks and a level connection between the bench marks, Primary Bench Mark (PBM), and the water level sensor(s), or tide staff as appropriate. The minimum number of bench marks or specific marks to be leveled will be specified in the Annual Station Specific Requirements, contract documents, or as specified in Reference 3 (See section 3.3 Levels for additional leveling requirements).

(c) Validation by CO-OPS of complete data transmissions, and proper data ingestion into DMS, as evidenced by the data display on the CO-OPS website.

(d) The preparation of all documentation and forms and submission to CO-OPS (RDD and supporting FOD field office) in timely fashion (refer to Section 5 for requirements for deliverables for water level station documentation and timelines).

Installer shall follow the appropriate sections of the SOP-06-001 as referenced in the Reference 22.

2.8. Maintenance Requirements

Water level station standard annual maintenance shall be accomplished in accordance with the Appendix F of Reference 1, the *"NGWLMS Annual Inspection (AI) Preventive Maintenance Checklist"*, and/or the checklist that is being developed for Sutron Xpert gauges, or as instructed by the Contracting Officer's Technical Representative (COTR), or by the Task Manager (TM). The specific maintenance requirements for each water level station will be specified in the Annual Station Specific Requirements for individual task orders for contracts.

When GOES telemetry and NOS satellite message format are used, such as for NWLON and NOAA in-house hydrographic and photogrammetry surveys where CO-OPS or CO-OPS contractors, Navigational Response Teams (NRT), or NOAA Ships, as appropriate, install the subordinate water levels gauges, then only CO-OPS shall monitor the near-real time water level gauge data daily for indications of sensor malfunction or failure, and for other causes of degraded or invalid data, such as marine fouling, flat data or sloped data. CO-OPS can not monitor the subordinate stations installed for NOAA contract hydrographic/photogrammetry survey projects by NOAA contractors. This monitoring can be performed by accessing the CO-OPS web page (http://tidesandcurrents.noaa.gov). The data over the web are typically available for review within one to four hours after the configuration of the DCP and sensors in DMS, and installations of DCP and sensors in the field once data is reviewed and dissemination is turned on by CORMS.

During annual maintenance visits to a station that has an acoustic sensor, the Aquatrak™ sensor and matching cal tube shall be replaced. For stations where wind sensors are installed, wind sensor nose cones shall be replaced during the annual maintenance. The Ultrasonic wind sensor leads shall be cleaned with a contact cleaner with a zero residue base. All applicable sensor serial numbers shall be verified by the installer (recorded by one person and confirmed by a second person in the field party). Necessary repairs or alterations to the stations and equipment shall be made and documented on the approved site report. Repairs or alterations required by the Standing Project Instructions or Annual Station Specific Requirements, but not completed, shall be documented, along with the reasons for the incompletion, on the approved site report. The report(s) shall be completed by the installer before leaving each station; and reviewed by the field team leader or contractor supervisor after completion of the maintenance visit but prior to submission. The reviewed station package shall then be submitted to RDD and the supporting FOD field office within 1 month after the completion of the maintenance, or as specified in the contract documents.

Approved primer and anti-fouling paint shall be used on all new protective wells and all protective fiberglass/PVC components that will be in water, excluding the acoustic sensor calibration/sounding tube.

For dual orifice pressure sensor configurations, the vertical stability and elevation to the leveling points shall be verified, including the distance between the two orifices. The mounting assembly for the two orifices shall be checked for structural integrity and the orifices shall be cleaned of biofouling.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate approved maintenance forms (refer to Section 5 for requirements for deliverables for water level station documentation and timelines) and retained as part of the water level data record. This documentation shall include, but not be limited to, the following information: date and time (GMT) of start and completion of the maintenance activity; date and time of adjustments in sensor/DCP, datum offset, or time; personnel conducting the work; parts or components replaced; component serial numbers; tests performed and test results; etc.

Proper NOAA identification emblems with an emergency phone number 1 (800)367-6622 shall be placed on all water level gauge house doors or shelters. Emblems which are unreadable should be replaced.

A completed station visit for maintenance (scheduled or emergency) consists of the following:

(a) The maintenance or repair of the water level measurement system (water level sensor(s), primary and redundant DCP as appropriate, satellite transmitter, ancillary sensors if applicable, other equipment as necessary and its supporting structure, and a staff if applicable), and as specified in the Standing Project Instructions, Annual Station Specific Requirements, or as specified in the contract documents.

(b) Only for scheduled maintenance, the recovery and/or installation of the required minimum number of bench marks and a level connection between the bench marks, Primary Bench Mark (PBM), and the water level sensor(s), or tide staff is required. The minimum number of bench marks or specific marks to be leveled will be specified in the Annual Station Specific Requirements, contract documents, or as specified in Reference 3 (See Section 3.3 Levels for additional leveling requirements.)

For emergency maintenance, recovery of bench marks and levels are generally not required, unless the maintenance is done to the AQLP, or orifice(s) for pressure sensor(s), in which case leveling to the PBM and at least 2 other marks are required.

(c) Validation by CO-OPS of complete data transmissions, and proper data ingestion into DMS after the maintenance.

(d) The preparation of all documentation and forms and submission to CO-OPS (RDD and supporting FOD field office) in a timely fashion (refer to Section 5 for requirements for deliverables for water level station documentation and timelines).

The maintenance party shall follow the appropriate sections of the SOP-06-001 as referenced in the Reference 22.

2.8.1. Additional Requirements for Great Lakes Stations

(a) The shaft angle encoders shall be inspected to insure the offset pulleys are not binding. Lift the float tape off of the offset pulley and free spin the unit. If any binding occurs, replace the bearing in the center of the gear. In addition and while the float tape is off of the encoder gear and pulley, spin the encoder shaft to represent both a 2 meter increase and a 2 meter decrease in the readings from the present reading. Then match the reading with the ETG reference and reset the tape back on the gear and pulley. After this process, remember to check the tape at the float connection to ensure that it has not kinked. This rotation procedure will ensure that the oil lubrication around the enclosed encoder bearings remains fluid. NOTE: - This test should only be performed during the time period that the DCP is not calculating the water level reading. This time period, for computing the water level reading, is 90 seconds before and after the allotted 6 minute interval. Also check to see that the float tape length has been installed such that the float neither tops out nor the counterweight bottom out before reaching its extreme limitations.

(b) The float shall be inspected for corrosion and leaks; replace as necessary.

(c) When closing off the intake valve note how many turns it takes to close off the intake as well as how many turns it takes to fully open it. This shall be reported in the remarks on the inspection sheet and on a tag placed on the valve handle. Also note the difficulty in turning the valve such that it can be predicted when the valve would become unusable and need replacement.

(d) When first arriving at a station to perform annual maintenance, check and record the voltage for each battery on all DCP units. Then remove AC power to both the Primary and Redundant systems allowing them to run totally on battery power. After the units have had approximately an hour of transmit loads on the Xpert DCP and at least 2 hours for the 9000 DCP, recheck the voltage. If the battery voltage has dropped significantly (i.e. below 11.7 volts), replace them. Also write the date of installation with permanent marker on each battery, and record same date on the Site Report. Check all marine grade batteries to ensure that adequate water is in each cell. Only use distilled water for replacement.

(e) A water level transfer (inside/outside check) shall be performed at each station and documented on the Site Report. The inside/outside water level must agree to within 0.006 m. The best time to perform a transfer is in the early morning or late evening when the water level is most calm. The above procedure must be followed and actions taken to correct any discrepancies.

(f) When diving at gauge sites measure and report the elevation of intake invert and valve invert on IGLD 85, if not previously noted. NOTE: The invert elevation is the point where the water level can no longer be measured accurately. If the intake has a gooseneck at the end this measurement should be taken at the lowest point in the curve at the top of the gooseneck, not the opening.

(g) Install rubber flaps over all locks on gauge shelters for protection against the weather. The locks shall be inspected and lubricated to enable easy access.

(h) Check gauge houses inside, outside, and around the doorframe for openings in the mortar and caulk as required. Submit a statement of work to FOD for any work recommended for completion by a contractor.

(i) Check gauge house structure, door, and frame for rust and paint chips. Scrape and paint as necessary.

2.9. Ancillary Sensor Metadata

Specific metadata for ancillary sensors is required as detailed below. The installer shall make note of this data in the remarks section of the Ancillary Sensor boxes on the approved Site Report. Metadata documentation shall be completed during the annual inspections, or emergency maintenance visits, as appropriate, for all stations with ancillary sensors. A unique Temporary Bench Mark (TBM) may be selected at each station and all the required measurements can be referenced to that TBM. The TBM must be connected via levels to the PBM. Then RDD will relate the sensor elevations to SD and other datums as appropriate.

Photos shall be taken of the supporting structure and all of the ancillary sensors installed. The photos should include as many of the four cardinal compass directions as possible, with the file name indicating the direction of the view, i.e. 87617241 Met tower looking south.jpg. Photos and sensor elevations must be submitted by CO-OPS to the National Data Buoy Center (NDBC) in a timely manner before NDBC will accept the met data into its quality control process.

Wind sensors shall be aligned according to Reference 10.

Ancillary Sensor	Sensor Elevation Reference Point
Air temperature	Center of the sensor above the station datum and above ground to the nearest centimeter.
Water temperature	Center of the sensor above the station datum as derived from subtracting the distance from the leveling point to the center of the sensor from the C2 value, to the nearest centimeter.
Barometric pressure	Surface of the pressure port above MSL (see Barometer Calibration Guidelines) to the nearest centimeter.
Wind Speed/Direction/Gust	Center of the sensor above the station datum and above ground to the nearest centimeter. Note any major physical obstructions in the vicinity of the sensor.
Conductivity	Center of the loop above the station datum to the nearest centimeter.
Relative humidity	Center of the sensor above the station datum and above the pier/ground surface to the nearest centimeter.
Air gap	Sensor zero above the station datum as determined from trigonometric levels to the nearest centimeter.

2.10. Gauge Removal

The installer shall remove a water level station, if required, and as specified in the Annual Station Specific Requirements, or as specified in the contract documents. A complete removal of the water level measurement station consists of the following:

(a) Closing levels - a level connection between the PBM and all the bench marks in the local leveling network at the station, the water level sensor(s), and/or staff, if applicable.

(b) Removal of the water level measurement system and restoration of the premises, assuming reasonable wear and tear. The property owner shall be thanked for supporting our programs.

(c) The preparation of all documentation and forms and submission to CO-OPS (RDD and supporting FOD field office) in timely fashion (refer to Section 5 for requirements for deliverables for water level station documentation and timelines).

(d) Return of all government equipment to appropriate supporting CO-OPS' FOD field office(s) in timely fashion within 15 days of station removal.

SECTION 3.0. BENCH MARKS AND LEVELS

3.1. Reference Documents

Bench marks and level operations shall be performed in accordance with Reference 3. Electronic/barcode level operations shall be performed in accordance with Reference 4 and the Leica Manual for the NA 3003 level.

Bench mark descriptions shall be written in accordance with Appendix E of Reference 4 for bench marks that are connected using the electronic levels. Descriptions for Great Lakes bench marks shall be written in accordance with the NGS Bluebook, Formats and Specifications of the National Geodetic Survey Data Base http://www.ngs.noaa.gov/FGCS/BlueBook/, since those marks are not published by CO-OPS.

Bench mark descriptions shall be written in accordance with Reference 5 for bench marks that are connected using the optical levels in areas such as in Alaska, Hawaii, and Pacific Island areas, or where electronic levels are not used, or as specified in the contract documents.

Digital photographs of bench marks shall be taken in accordance with Reference 21.

3.2. Bench Marks

Unless specified otherwise in the work order or contract documents, the total number of bench marks in the leveling network shall be a minimum of ten marks for the NWLON stations and a minimum of five marks for subordinate stations installed for hydrographic and photogrammetry surveys, special projects, or contract projects for U. S. Army Corps of Engineers.

Descriptions shall be checked by verifying distances with tape measurements in metric units, verifying cited landmarks and using a compass to confirm directions.

The handheld GPS coordinates of each mark shall be noted at the end of the text description in the HA file (for electronic levels), or noted on the published bench mark sheet or equivalent (for optical levels). The latitude and longitude fields of the bench mark shall be reported in the following format: degrees/minutes/seconds and tenths of seconds. For example, 40 degrees, 45 minutes, 35.2 seconds.

New bench mark sketches shall use CO-OPS' standard bench mark sketch title block, or electronic equivalent. If a digital sketch is used, submit the digital file in JPG format on a disk with the leveling files and photos. If AutoCAD or AutoCAD LT is used to generate the benchmark sketch, both a JPG format and the AutoCAD DWG format shall be submitted.

A minimum of three digital photos shall be taken for all new marks: close-up of the disk face; chest or waist level view of disk and setting; and horizontal view of location and direction of view. The digital file for a bench mark photo shall have the bench mark designation in its file name, followed by the view, with a jpg extension, i.e. CONTAINER setting.jpg, or CONTAINER location NE.jpg.

CO-OPS has photos of nearly all bench mark disk faces, and setting and location shots of less than half the collection of NWLON tidal bench marks. The station specific requirements shall note any additional photos needed to achieve a complete photo gallery of each mark.

If a bench mark is discovered disturbed or mutilated during the visit to a station, include it in the level run to determine if it is holding its elevation relative to the PBM and report it to RDD and the supporting FOD field office. RDD will make a decision and inform the installer via the next set of Station Specific Requirements regarding the action that needs to be taken: destroying the mark, if it is a NOS mark, or dropping the mark from the leveling network for other marks.

Before installing a new mark, perform a 1.6 kilometer (1 mile) radial search from the tide station (DCP) location at NGS web site, http://www.ngs.noaa.gov/datasheet.html to check if any NAVD 88 marks are available that are not part of the local leveling network. Inclusion in the local leveling network of an existing mark(s) that has a NAVD88 elevation, if it is located within a 1.6 KM (1 mile) radius of the station location, is desirable and shall be preferred over installing a new mark. If the bench mark is replaced, then the stamping of the bench mark shall have a new letter designation (assigned by RDD) and present year so that the new stamping is different from the original stamping of the mark, or the stamping of other marks in the local leveling network.

3.3. Levels

The electronic/barcode leveling system shall be the preferred leveling system. See Reference 4 for a description of the various electronic level files required.

Second-order Class I leveling connections shall be made from the primary water level sensor (AQLP or pressure sensor orifice [staff stop], and in the Great Lakes the ETG RM and the Spike RM) to a minimum of 5 bench marks, including the primary bench mark (PBM), on an annual basis. In the case of pressure sensors as primary sensors, the elevation of orifice zero to orifice staff stop (and orifice staff stop to PBM) shall be measured annually.

All of the bench marks in the leveling scheme shall be leveled to within a 2-year period. This may be accomplished by leveling to the PBM and four marks one year, then to the PBM and the remaining marks the next year. In some cases, it may be practical to level to all the marks the second year, to reach the furthest marks from the station. A level connection to CORS reference marks shall also be made once every two years, if those marks are within 1.6 KM (1 mile) leveling distance from the water level station. The installer shall be responsible for ensuring that every mark in the station leveling network is leveled to once every two years.

The two or three meter barcode rods for second order levels shall be used whenever possible at all stations. At stations where three/two meter level rods can not be utilized due to airline size restrictions, justification for use of the third order levels shall be documented on the NGWLMS Site Report. Where Third order rods are used, three-wire level procedures and documentation shall be observed, as appropriate, and Third order closure tolerance is authorized. For stations in AK, HI, and Pacific Island areas the Second order class I leveling requirement is waived and the Third order levels are acceptable.

The primary water level sensor (ETG in the Great Lakes) shall be connected to the station bench marks by levels. The levels shall be run upon sensor installation, in conjunction with annual maintenance levels, if obvious sensor movement is noticed during regular/emergency maintenance, and upon sensor removal. The levels to the sensor(s) shall be spur runs from any bench mark, it is not necessary to have the spur run directly from the PBM to the sensor(s). If the leveling starts at the sensor then it is not considered a spur run.

At great lakes sites where a spike is unavailable for use in performing a water transfer, (see section 3.1, standing project instructions for a description of procedures to perform water transfers), the water level in the sump shall be compared to the water surface outside the sump by differential leveling and the use of the water level transfer program (h2o-tran). a difference exceeding 0.006 meters indicates a possible restriction in flow, which must be corrected. This instruction must be recognized and initialed. note: this procedure can best be accomplished in early morning or late evening when the water is most likely to be calm.

When abstracting the raw level data using the electronic digital level system, the PBM shall always be selected as the starting mark, and the AQLP, orifice staff stop, or ETG, as the case may be, shall always be selected as the ending mark. If the original IN file is edited before processing, the original file shall be stored in a separate subdirectory named "Original IN", and submitted with the edited IN file and other level files.

While using the electronic levels, any changes made to the following code fields require that a new INX file be generated and submitted to RDD: (1) designation, (2) establishing agency, (3) latitude or longitude of the original HA file. Dates of the INX and HA files must be chronologically consistent with the abstract ABS and other files generated. The date of the HA file can not be later than the date of the ABS file.

The table of field distances versus computed distances on the abstract ABS file shall not contain any error messages. The errors indicate incorrect mark positions that shall be corrected in the HA file and a new ABS file without any errors shall be regenerated.

Newly installed barometric sensors shall be included in the level run as a spur. Barometric sensors shall be leveled, or their height otherwise determined in relationship to station datum, during installation, or if the barometer is moved to a new location. Barometric sensors at Great Lakes stations shall be leveled, or their height otherwise determined in relationship to DYNAMIC/IGLD 85. Since small changes in elevation do not change the height correction, the leveling requirement to the barometer every five years is not needed anymore. The elevation of Mean Sea Level (MSL) above Station Datum in the header information for the specific annual requirements for each station is based upon the 1983-01 tidal datum epoch. The Barometer C2 shall be computed to include both the calibration corrections and height corrections. The installer shall ensure that the new elevation is also correct on the Site Report section for calculation of the barometer C2. The barometer C2s shall be updated in the DCPs during the annual inspections. The SSN for the barometric sensor shall be xx10 if it is included in the electronic leveling, where xx is the part number. At Great Lakes stations, the "Barometer

Installation Worksheet – Great Lakes" shall be used to compute the Height of the Barometer above the ETG. Refer to Reference 9 for additional information.

3.4. Datum Offsets and Accepted Orifice Offsets

The leveling connection to an acoustic sensor shall be done at the AQLP. The AQLP is defined as the top shoulder of the mounting plate collar on the calibration tube. In order to facilitate rod holding, a prefabricated leveling fixture may be slipped over the sounding tube to rest on the leveling point. The height of the leveling fixture, as inscribed on the fixture, shall be compensated for in the leveling record (abstract). The level abstract shall show the elevation of the leveling point only. A barcoded rule or stainless steel rule, with metric graduation (mm) and the zero at the end of the rule, as appropriate, may be used in lieu of the leveling fixture by holding the rule directly on the leveling point. In cases where the leveling point is too high for a rod shot, the leveling fixture designed for a down shot shall be utilized and the readings recorded to reflect the down shot. Use of other leveling fixtures and leveling techniques must be approved in advance by RDD.

The leveling connection to an ETG shall be done at the reading mark (RM). A barcoded rule (60 cm scale) or stainless steel rule, with metric graduation (mm) and the zero at the end of the rule, as appropriate, may be used by holding the rule directly on the RM.

The AQLP elevation above station datum is defined as the Datum Offset and is computed by algebraically adding the PBM elevation above Station Datum (SD) to the acoustic sensor elevation above/below the PBM. The Datum Offset is also referred to as Coefficient C2 for the Sutron 9000 DCP and as DAT coefficient for the Sutron Xpert DCP.

The orifice zero elevation for the Paroscientific pressure sensor(s) above or below the SD is defined as the Accepted Orifice Offset and is computed by algebraically adding the PBM elevation above SD to the (sensor) orifice zero elevation above/below the PBM. For dual orifice systems the orifice offsets are established for both "N1" and T1" pressure sensors.

At Great Lakes stations, the Dynamic Height of the ETG RM, plus or minus the Hydraulic Corrector, at all lake stations, defines the IGLD 85 datum offset. In the Great Lakes Rivers and Connecting Channels stations the "Dynamic Height = IGLD 85", Hydraulic Correctors are not applied. This datum offset is applied to the Primary Water Level C2 and should only be changed by RDD after reviewing the abstract and Water Level Transfer.

When using the electronic/barcode leveling system, all five decimal places shall be used to determine the Datum Offset on the approved site report. After adding or subtracting the difference between the leveling point and PBM, to the elevation of the PBM above the SD, round off the five place value of the Datum Offset to four places. Rounding shall be done to the even number, for example: 1.53455 is rounded to 1.5346. A note shall be made to the effect that the existing Datum Offset was retained in the DCP, or the new Datum Offset was entered with date and GMT time it was entered. When new Datum Offset is entered into the DCP, additional notification is required as listed below under Section 3.5 Movement. For stations that have the ParoScientific pressure sensor(s) as primary sensor(s), the change of accepted orifice offsets

shall be documented on the Site Report with GMT date and time, and additional notification is required as listed below under Section 3.5 Movement.

After documenting the dynamic elevation for the ETG and SPIKE at Great Lakes stations, round to four places and apply these elevations to the "Water Level Transfer" program. Then apply the Hydraulic Corrector utilizing the sign, negative or positive in the program. This elevation is now the hydraulically corrected reference elevation, Zero Electric Tape Gauge (ZETG) and is then rounded to three places and entered in the DCP as Primary Water Level C2. C2 will not be changed unless the elevation differs by greater than $\pm$ 0.003 meters and only then after notifying RDD.

When setting up the encoder offset at Great Lakes stations, the C2 in the Xpert DCP (sensor 14 coefficient 2 in the 9000 DCP) will need to be zeroed (0.000). The encoder gear will then be turned to reference 6.000 M on the display. Then an ETG reading will be obtained and subtracted from the 6.000 M reference. This difference, called the initial C2, is then stored in the Xpert DCP (sensor 14 coefficient 2 in the 9000 DCP). All ETG/Display readings have to be within 0.003 m. If not, the set up procedure must be performed again. NOTE: This procedure can best be accomplished in early morning or late evening when the water is most likely to be calm or by closing off the valve.

The accepted PBM elevation above the Dynamic Height in meters shall be used as the starting elevation on the level abstract at Great Lakes stations. This method results in all bench mark elevations referenced directly to the Dynamic Height.

At coastal sea level stations, the accepted PBM elevation above the SD in meters shall be used as the starting elevation on the level abstract. This method results in all bench mark elevations referenced directly to the SD. "Old" (before sensor swap) and "new" (after sensor swap) AQLP connections, if required, shall be treated as spurs. Regardless of whether the acoustic sensor head is swapped or not, the leveling shall be done only once after the sounding tube has been cleaned and everything is put in place. For stations that have acoustic sensors installed, upon initial inspection of the station, if the installer suspects a movement of the well or that of the AQLP, then leveling shall be done twice, once before disturbing the well or sounding tube for cleaning and then after repairing the well or cleaning the sounding tube. For stations that have pressure sensor(s) installed, upon initial inspection of the station, if the installer suspects a movement of the orifice(s), then leveling shall be done twice, once before disturbing the orifice(s) and then after repositioning/securing of the orifice(s).

3.5. Movement

The movement of an entity, such as (a) AQLP, (b) pressure orifice zero, or (c) bench mark is defined as change in elevation of the entity in excess of 0.0060 m (0.020 foot) as obtained by comparing the current difference in elevation of the entity with PBM, with the previous difference in elevation of the entity with PBM. For acoustic sensors this difference shall be compared to what is stored in the DCP and appropriate action shall be taken as described below. For pressure sensor orifices this difference shall be compared with the accepted orifice offset as listed on the site report (and stored in DMS) because the accepted orifice offset is not stored in

the DCP and appropriate action as described below shall be taken.

The movement shall be noted in the remarks box of the leveling section of the approved site report. If the Datum Offset determined from the latest level run indicates a deviation exceeding 0.0060 meter from the value presently stored in the field unit, and the PBM has remained stable, the new Datum Offset shall be entered into the field unit (no verification levels required). If the PBM is determined to be unstable, and other bench mark differences remain within the 0.0060 m allowable, the Datum Offset in the field unit shall not be changed. The suspected movement of the PBM shall be specifically noted, as instructed above, for further action by RDD. At Great Lakes stations, if the Primary Water Level Coefficient 2 (C2) determined from the latest levels indicates a deviation exceeding 0.003 meter from the value presently stored in the field unit, and the PBM has remained stable, contact RDD within 24 hours and provide them with the leveling abstract and Water Level Transfer.

RDD and supporting FOD field office shall be notified by phone or email immediately when the Datum Offset is changed in the DCP, or the accepted orifice offset has changed more than +/- 0.0060 m. An email, fax copy of the level abstract, and a phone call if possible, must be received by RDD and supporting FOD field office within 24 hours of the change.

SECTION 4.0. GEODETIC DATUMS

A connection to the geodetic datums at a water level station enhances the value of the tidal data, allowing comparison with other data sets. The geodetic network essentially serves as a global reference datum to which all tidal datums can be referenced. The connection to geodetic datums involves the following three ties:

(1) NAVD88 Level Tie
(2) NAD 83 GPS Tie
(3) NAVD88 GPS Tie

4.1. Level Connections

4.1.1. NAVD88 Level Tie

At all water level stations, a valid level tie to at least two Geodetic Bench Marks (GBM) is required on each set of levels, where appropriate marks are available within 1.6 KM (1 mi) leveling distance of the station location. A GBM is defined as a bench mark that exists, is useable, is available in the NGS database, has a Permanent ID (PID), and has a NAVD 88 elevation published on the datasheet. At many NWLON stations, the Primary Bench Mark (PBM) is a GBM. At the majority of NWLON stations, there are two or more tidal bench marks that are also GBM, thus increasing the chance that the geodetic level tie will be valid.

Make a Second-Order, Class I tie for all NWLON stations in the conterminous United States and Caribbean Islands. A Third-Order tie is used for all NWLON stations in Alaska, Hawaii, and Pacific Island areas.

At stations supporting hydro or other special projects, the tie shall be consistent with the accuracy of the levels required for the project.

Information on performing a valid level tie is provided in the Federal Geodetic Control Committee (FGCC) Standards and Specifications for Geodetic Control Networks, listed at the following website:
http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.htm#3.5

Also, *Section 3.4 of "User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987"* provides information regarding how to perform a valid level tie.

The Second-Order, Class I tie is a requirement for digital levels to be accepted into the NGS database. Short level runs to the sensor, PBM, and two marks are excluded from this requirement since they are usually meant to verify sensor stability only. Since a level connection to GBMs with dynamic heights defines the International Great Lakes Datum of 1985 (IGLD 85) datum offset at each station in the Great Lakes, a valid connection to at least two GBMs is required at each site.

A note shall be made in the remarks of the leveling section of the Site Report that a valid tie was achieved or not achieved. If a valid tie is not achieved, an explanation shall be provided and/or recommendations made for making a valid tie in the future.

If the NWLON water level station does not have two or more GBMs within 1.6 km (1 mi) leveling distance of the station location, then the level tie requirement is waived.

4.1.2. Leveling at Continuously Operating Reference Stations (CORS)

For any NGS Continuously Operating Reference System (CORS) reference bench mark that is located within 1.6 km (1 mi) leveling distance of a water level station DCP, a leveling connection shall be made to the tidal bench marks in the water level station network every two years.

Information about NGS CORS stations can be obtained at http://www.ngs.noaa.gov/CORS/.

As of 2007, there are a limited number of water level stations in this category, but NGS and CO-OPS are attempting to secure funding to establish additional co-located sites to support long-term sea level trends monitoring.

4.2. GPS Connections

4.2.1. References

Static GPS observations shall be performed at water level stations in accordance with Reference 6. Rapid static surveys shall be conducted in accordance with the 2 cm standards outlined in Reference 15. These guidelines are written for establishing GPS derived ellipsoid height accuracy standards of 2 cm for all NWLON, PORTS®, survey projects, COASTAL projects, and special project applications.

4.2.2. GPS Observations - Goals and Planning

Precise positioning of NWLON stations in a global geocentric reference framework is needed to support NOS marine safe navigation and height modernization projects, in addition to monitoring vertical crustal motions for absolute sea level and global climate change studies.

CO-OPS shall initiate a program of making periodic GPS observations at water level stations, as resources permit. CO-OPS activities shall be coordinated with NGS activities for best use of available resources.

GPS technology and procedures shall be implemented in the operational plan:

(1) To support the development of a seamless, geocentric reference system for the acquisition, management, and archiving of NOS water level data. This will provide a national and global digital database, which will comply with the minimum geo-spatial metadata standards of the National Spatial Data Infrastructure (NSDI) and connect the NOS water level datums to the NGS NSRS;

(2) To establish transformation functions between NOS chart datum Mean Lower Low Water (MLLW) or Low Water Datum (LWD) in the Great Lakes, and the geocentric reference system to support NOS 3-dimensional hydrographic surveys, the implementation of Electronic Chart Display and Information Systems (ECDIS), and the NOS Vertical Datum transformation (VDatum tool) and tidal datum models. Integration of GPS procedures will support the development of tidally-controlled Digital Elevation Maps and Models for use in programs such as marsh restoration.

(3) To support water level datum transfers by using GPS derived orthometric heights.

(4) To monitor crustal motions (horizontal and vertical) to support global climate change investigations.

The GPS surveys should be scheduled during routine annual maintenance trips to NWLON or PORTS® stations and during the installation of secondary and tertiary water level stations to support the survey projects, U.S. Army Corps of Engineers (USACE) projects, COASTAL project stations, tsunami stations, and special purpose surveys. CO-OPS shall continue to

coordinate the GPS occupation of water level network bench marks with NGS, USACE, and the National Geospatial-Intelligence Agency (NGA), as appropriate.

GPS-derived orthometric heights can be accurately determined and used for water level datum transfers according to the following criteria: (a) use the established guidelines for 3-D precise relative positioning to measure ellipsoid heights; (b) properly connect to several NAVD 88 bench marks; and (c) use the latest high-resolution modeled geoid heights for the area of interest. In many remote locations, the use of GPS-derived orthometric heights for datum transfer will be more efficient (timely) and more cost-effective than the use of conventional differential surveying techniques and may, under certain circumstances, preclude the installation of additional water level stations to establish a datum.

As specified in the Annual Project Instructions, Annual Station Specific Requirements, or in the contract documents, installer shall be required to perform GPS observations at each water level station at specified intervals over time, depending on the rate of sea level rise in that water area of the coast.

As of March 2007, 20 NWLON stations have been identified where annual GPS observations are required because of the sea level rise in those areas. These 20 NWLON stations – 8 in Alaska and 12 in the Gulf of Mexico – will be identified in the annual Project Instructions. The rest of the NWLON stations require GPS observations every five years. These guidelines will be updated as GPS technology improves and the policy or regulations change in the future.

4.2.3. Static Surveys

Static GPS surveys shall be conducted on a minimum of one bench mark at each water level station, according to the priority levels below. Generally, one mark at each station is designated as the GPS mark and observations shall be made to that mark unless otherwise specified in the Station Specific Requirements.

1. National Water Level Observation Network (NWLON) and PORTS® stations.
2. Long term operating secondary water level stations.
3. New tertiary survey, COASTAL stations, and special project stations.
4. Historical subordinate water level stations with an accepted MLLW value on the current official tidal datum epoch

Static GPS surveys shall be conducted at water level stations periodically over time to establish a history of differences between the tidal or water level datums and the ellipsoid. GPS-derived orthometric heights may be determined for selected stations only if a leveling connection is not feasible, i.e. a geodetic level tie as described in Section 4.1 above can not be achieved.

4.2.4. Criteria for Bench Mark Selection for GPS Observations

The GPS Water Level Station Bench Mark (GPSBM) shall be selected based on the following criteria: (a) permanence or stability; (b) historic GPS use; (c) satellite visibility; and (d) safety and convenience.

(a) Permanence or Stability of Bench Marks

NGS has defined the following monumentation quality codes, also called the stability codes, for various bench mark settings.

Stability code A – monuments of the most reliable nature which may be expected to hold their elevations very well; e.g. Class A rod marks, or marks installed on large boulders/rock outcrop.

Stability code B – monuments which probably hold their elevations well; e.g. Class B rod marks, or marks installed on large concrete footings/foundations.

Stability code C – monuments which may hold their elevations but which are commonly subject to surface ground movements; e.g. pavement or concrete monuments.

Stability code D – movements of questionable or unknown reliability.

The station bench mark selected for GPS observations shall be of stability code A or B. GPS observations on the PBM are preferred if the PBM is either stability code A or B, and is suitable for satellite observations. Stability code C and D bench marks shall not be used for GPS observations, unless NGS has previously made GPS observations on those marks.

(b) Historic GPS Use

In many states, CO-OPS has provided NGS with lists of selected marks suitable for GPS observations at water level stations, and NGS has completed observations on these marks. Some tidal marks designated as Federal Base Network (FBN) or Cooperative Base Network (CBN) marks may be of stability code C. Generally once a mark is selected for GPS observations, future GPS observations shall be done on the same mark. If leveling reveals instability of the mark over time, select another mark.

Priority shall be given to a GBM for GPS observations because the GBM already has a NSRS height (NAVD 88). The GBM considered here is one of the 10 tidal or water level bench marks at a NWLON water level station, or one of the 5 bench marks for survey or special projects.

(c) Satellite Visibility

The most desirable bench mark for GPS observations should have 360 degrees clearance around the mark at 10 degrees and greater above the horizon. Newly established marks shall be set in locations that have these clearances, if at all possible. If a station does not have any marks suitable for GPS observations, and it has been selected as needing GPS observations, a new 3-D

rod mark shall be established. This new mark shall be connected to the station bench mark network through conventional geodetic leveling, and then GPS observations shall be made.

All existing station bench marks at operating stations shall be assessed for feasibility of GPS observations, as time and resources permit. A note shall be made, either in the APP field of the electronic leveling HA file or on a copy of the published bench mark sheet, stating the suitability of GPS observations for each mark. The GPS visibility obstruction diagram shall also be completed for each mark observed.

(d) Safety and Convenience

The location of the GPS bench mark should be safe, secure, and convenient. Bench mark locations which allow unattended GPS data collection are desirable as the field crew can multi-task at the same time as collecting the GPS data. The safety of the GPS equipment (vandalism proof) should be considered in the mark selection process.

The bench mark selected for GPS observations should be located on public property rather than on private property, as permissions from private owners may be required in the future to access the bench mark and for collecting the GPS data. The distance from the station DCP should also be convenient.

4.2.5. North American Datum 1983 (NAD 83) GPS Tie

At each NWLON station, GPS observations shall be performed as listed in the Annual Project Instructions, Annual Station Specific Requirements, and contract documents. The frequency of repeated observations on the GPSSBM shall be determined based upon the rate of sea level rise and general stability of bench marks in the local leveling network.

The NGS Online Positioning User Service (OPUS) is now used extensively for quick and convenient processing of the GPS raw data for a variety of applications. The position solution provided by OPUS is considered preliminary data and is not retained by NGS. Further information on using OPUS is provided later in this document.

The expected ellipsoid height accuracy for a 4 hour OPUS solution is 1.8 cm, (at the 67% confidence level), and that is desirable, practical, and achievable with the requirements as specified in Reference 15, NOAA Technical *Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3.*

The length of GPS observation sessions depends upon the length of time the field crew has available for GPS observations, security of the equipment, number of satellites available at a site, number of GPS receivers available for GPS observations, etc.

For all water level stations, collect a minimum of 4 hours of GPS data on the GPSBM. Extra care shall be taken to ensure that the antenna height is precisely recorded, and that the antenna setup is stable. A continuous long session (at least 4 hours long but less than 24 hours) repeated

annually is preferred to two or more shorter sessions (of less than 4 hours each) repeated on the same visit, providing better data for OPUS and more independent observations.

After the data collection session is complete, two independent downloads are required from the GPS receiver to the laptop computer. If one downloaded file gets corrupted, the other file may have good data. Do not make a copy of the downloaded file, as both the files will have the same problem, if there is a problem. Follow the NGS guidelines for naming these files. Submit both copies of the digital GPS data along with the necessary documentation as specified in the Reference 6 *"User's Guide for GPS Observations, Updated March 2007"*.

4.2.6. GPS Data Processing Using OPUS

Field parties shall use OPUS for processing the raw GPS observations. OPUS provides an easily accessible, rapid method for submitting GPS data and receiving an almost instantaneous solution response from NGS via email.

The NGS OPUS web page can be obtained at http://www.ngs.noaa.gov/OPUS/. The following information is found on the OPUS web page but is also presented here for convenience of the reader.

OPUS allows users to submit their GPS data files to NGS, where the data will be processed to determine a position using NGS computers and software. Each data file that is submitted will be processed with respect to three CORS sites. The sites selected may not be the nearest to your site but are selected by distance, number of observations, site stability, etc. The position for your data will be reported back to you via email in both - ITRF and NAD 83 coordinates as well as Universal Transverse Mercator (UTM), U. S. National Grid (USNG) and State Plane Coordinates (SPC) northing and easting.
OPUS is completely automatic and requires only a minimal amount of information from the user, such as:

(a) The email address where you want the results sent
(b) The data file that you want to process (which you may select using the browse feature; raw or RINEX accepted)
(c) The antenna type used to collect this data file (selected from a list of calibrated GPS antennas)
(d) The height of the Antenna Reference Point (ARP) above the monument or mark that you are positioning.

Once this information is complete, you then click the Upload button to send your data to NGS.

Your results will be emailed to you, usually within a few minutes. You may upload multiple data files in a zip archive if you wish. However, be careful, the options that you choose will be applied to all of the data files in that archive (i.e. the same antenna type, ARP height will be used for all of the files in the zip file).

The following are some simple guidelines for analyzing the OPUS solutions.

(a) Make sure the antenna type and the ARP height are correct.
(b) Review the solution statistics:
    (I) A good quality OPUS run should typically use 90% or more of your observations.
    (II) OPUS should have fixed at least 80% of the ambiguities
    (III) The overall RMS should seldom exceed 3 cm.
    (IV) The maximum peak to peak errors should be less than 2 cm for horizontal and 4 cm for vertical (This depends, of course, on the accuracy you are trying to achieve.)

NGS needs to receive orbit data from IGS in order to obtain a solution. If the data is submitted too quickly (before NGS gets the orbit data from IGS), the submitter may need to re-submit the data at a later time. For best results, submit the GPS data to OPUS at least 17 hours after the first midnight (in Greenwich Mean Time) following the time when the observations were recorded. Compare the resultant solution to the last previous solution made at the station, if available, to ensure that you do not have a blunder in the antenna setup. This will be revealed by a noticeable discrepancy in the ellipsoid height. Include a copy of the solution in the station inspection documentation package submitted to RDD/OET, as well as to NGS GPS data sets.

4.2.7. OPUS DB Preliminary information

Pending NGS support, OPUS DB will be released by NGS. This advanced version of OPUS will submit OPUS solutions directly to the NGS database if all required documentation is provided by the submitter. Further guidance will be provided once OPUS DB is released and these Standing Project Instructions will be updated as appropriate. Any data sets submitted to OPUS will be subsequently re-submitted by RDD to OPUS DB to ensure the data is published by NGS.

Height modernization guidelines are here: http://www.ngs.noaa.gov/heightmod/guidelines.shtml

The Opus DB datasheet concept is fully listed at the following NGS web site:
http://www.ngs.noaa.gov/PROJECTS/draft/OPUS/OPUS-DB-concept.htm

The following tables identify the required data elements and optional data elements for OPUS DB respectively.

REQUIRED DATA ELEMENTS (15 each):

ELEMENT	RATIONALE
e-mail	For identification & correspondence.
Filename	Necessary to compute position.
Antenna	Necessary to compute position.
antenna height	Necessary to compute position.
name of submitting agency	Identifies the observer.
permanent identifier (PID)	Identifies the station.
Designation	Identifies the station.
descriptive text	Aids in station recovery.
Rod/pipe depth & units	Describes monumentation quality.
sleeve depth & units	Describes monumentation quality.
setting code & specific setting text	Describes monumentation quality.
photograph (of marker)	Aids in station recovery.

OPTIONAL DATA ELEMENTS (11 each):

ELEMENT	RATIONALE
photographs (of equipment, horizon)	Equipment photos describe antenna height and equipment used. Horizon photos aid in station recovery and could explain visibility or multipath problems.
vertical stability code	Useful for stability assessment.
magnetic property code	Aids in station recovery.
antenna s/n	Useful in identifying equipment-specific problems.
receiver	Useful in identifying equipment-specific problems.
receiver s/n	Useful in identifying equipment-specific problems.
receiver firmware	Useful in identifying firmware-specific problems.
stamping	Aids in station identification.
condition code	Useful for stability assessment.
special application codes	Identifies the station type (tidal station, Public Land Survey corner, etc.)
remarks	Allows user to record observation comments.

This information regarding the Required Data Elements and Optional Data Elements is for reference only and not required at the present time. These requirements will be active once OPUS DB is designated operational by NGS. Out of the 15 Required Data Elements, 13 are applicable to all the marks and the remaining two - rod/pipe depth & units and sleeve depth & units – are applicable only to rod marks.

4.2.8. NAVD88 GPS Tie

The NAVD88 GPS tie involves simultaneous GPS observations at the GWLSBM and one or more GBMs located up to 10 KM (6.26 mi) from the GWLSBM. This "Height Mod" tie is deferred until such time as NGS enables user-friendly bluebooking of campaign data (OPUS projects).

SECTION 5.0. Schedule, Reports, and Deliverables

5.1. Schedule and Reports

Operations schedules are prepared for all water level stations each September for the upcoming fiscal year. Schedules for FOD and contractor operations are combined to produce one composite plan for CO-OPS. Overall accomplishments are compared to the plan on a monthly basis and reported to NOS management.

Contractors shall provide RDD and the supporting FOD field office a proposed annual schedule for accomplishing the indicated work in the station specific annual project instructions, or task orders, at the beginning of the task order with updates on a monthly basis, or as specified in the contract documents. Changes to the schedule must be requested in advance and approved by the Contracting Officer's Representative (COR) or CO-OPS.

Operations related to the indicated work in the station specific annual project instructions, or task orders, shall be discussed in a monthly activities report, or as specified in the contract documents.

5.2. Deliverables - Document Submission and Timelines

The installer is required to submit the documentation to CO-OPS within 15 business days of water level station installation, maintenance, repair, removal, or as specified in the contract documents. The station documentation shall be submitted in digital format only.

All data and documentation submitted to CO-OPS shall be retained by the installer for a period of not less than three years or as stipulated in the contract, whichever is longer.

Standard station documentation package includes the following:

(1) Transmittal letter
(2) Site Report or tide station report
(3) Chartlet
(4) Sensor test worksheet
(5) Sensor elevation drawing
(6) Water level transfer form (Great Lakes stations only)
(7) Barometer Installation Worksheet (Great Lakes stations only)
(8) Bench mark sketch

(9) Bench mark descriptions and “Station To Reach” statement
(10 Photographs of bench marks, station, DCP, equipment, and vicinity in digital and paper format
(11) Levels (raw) (electronic files) and field notes of precise leveling
(12) Abstract of precise leveling
(13) GPS observations, and visibility diagrams, as applicable
(14) Staff to gauge observations, if applicable
(15) Calibration records for sensors, if applicable
(16) Calibration certificates for Invar leveling rods, if applicable
(17) Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable
(18) Other information as appropriate, or as specified in the contract
(19) Water level data download

Generally, for established NWLON stations, the bench mark sketch, chartlet, and "To Reach" statement need only be submitted if those items have been revised during the station maintenance.

When using the electronic/barcode system, the data disk and hard copies of the abstract and bench mark description or recovery notes shall be submitted. At stations where the automated or manual levels are used, Precise Leveling sheets of actual runs (NOAA Form 75-29) and Abstract of Precise Levels (NOAA Form 76-183) shall be completed and submitted.

For submission in electronic format, the station documentation shall be organized by various folders under the main station number folder, and then pertinent information shall be placed in the various folders and submitted on a digital media such as DVD/CD-ROM etc.

Here is an example of submission of the electronic folders for San Francisco tide station:

9414290 San Francisco
/Transmittal letter
/Site Report or tide station report
/Chartlet
/Sensor test worksheet
/Sensor elevation drawing
/Bench mark sketch
/Bench mark descriptions and “Station To Reach” statement
/Photographs of bench marks, station, DCP, equipment, and vicinity in digital and paper format
/Levels (raw) (electronic files) and field notes of precise leveling
/Abstract of precise leveling
/Staff to gauge observations, if applicable
/Calibration records for sensors, if applicable
/Calibration certificates for Invar leveling rods, if applicable
/Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable
/Other information as appropriate, or as specified in the contract
/Water level data download

Submit required GPS data and forms on a separate DVD, for example, GPS submission for San Francisco tide station will be as follows:
9414290 San Francisco
/GPS observations, and visibility diagrams, as applicable

For all work done by NOAA (FOD, NOAA ships, NRT, other NOAA personnel) submit one copy of all the documentation (except GPS submission) in digital format. Submit two copies in digital format of the required GPS submission (data and forms) on a separate DVD.

Submit the completed station package to

Chief, Requirements and Development Division
NOAA/NOS/CO-OPS/RDD
SSMC 4, Station # 6531
1305 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 2897 X 145

For all contract work deliverables, submit two copies of all the documentation (except GPS submission) in digital format. Submit three copies in digital format of the required GPS submission (data and forms) on separate DVD as listed below.

Submit one copy of the completed station package and two copies of GPS submission to

Contracting Officer's Representative
NOAA/NOS/CO-OPS/RDD
SSMC 4, Station # 6544
1305 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 2897 X 129

Submit one copy of the completed station package and one copy of GPS submission to the appropriate supporting FOD field office as listed below:

For East Coast task orders, submit to:
Task XXX Manager, Field Operations Division Atlantic Regional Office
808 Principal Court
Chesapeake, VA 23320
Tel: 757-436-0200

For West Coast task orders, submit to:
Task XXX Manager, Field Operations Division Pacific Regional Office
7600 Sand Point Way, NE
Bin C15700
Seattle, WA 98115
Tel: 206-526-6360