NOS HYDROGRAPHIC SURVEYS SPECIFICATIONS AND DELIVERABLES

May 2008

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

Contents

1 Introduction

These technical specifications detail the requirements for hydrographic surveys to be undertaken either by National Oceanic and Atmospheric Administration (NOAA) field units or by organizations under contract to the Director, Office of Coast Survey (OCS), National Ocean Service (NOS), NOAA, U.S. Department of Commerce.

The specifications described herein are based in part on the International Hydrographic Organization's Standards for Hydrographic Surveys, Special Publication 44, Fourth Edition, April 1998, specifically for Order 1 surveys. Hydrographic surveys classified as Order 1 are intended for harbors, harbor approach channels, recommended tracks, inland navigation channels, coastal areas of high commercial traffic density, and are usually in shallower areas less than 100 meters water depth. Additional details for the specific project areas, including any modifications to the specifications in this manual, will be provided in Hydrographic Survey Project Instructions for NOAA field units or the Statement of Work for contractors.

If a hydrographer has any questions on the interpretation of these Specifications or feels that there may be a "better way" to provide a deliverable, they should contact the COTR or appropriate NOAA Program Office to discuss and clarify the issue. The Specifications will continue to evolve and can only improve with the input of all users.

1.1 Definition

The term "hydrographer" as used through this document, refers to: (a) the chief of party or officer in charge, when the survey is being conducted by NOAA field units, or (b) the contractor where the work is being performed for NOAA under contract.

1.2 Changes from April 2007

Chapter 3 "Hydrographic Position Control"

1. Added reference to section 8.1 for reporting requirements in section 3.1

Chapter 4 "Tides and Water Levels Requirements"

1. Sections under 4.1 General Project Requirements and Scope have had minor clarification changes
2. Section 4.2.3 Station Installation, Operation and Removal has been updated to include additional guidance on installing and maintaing water level stations (designed or installed by contractors) and their various components according to the manufacturer's installation manual, appropriate building codes or as specified by the COTR.

3. Section 4.2.5 Bench Marks and Leveling gives clarification that "At least, geodetic third-order levels (refer to Reference 19, but 2nd order class I levels are preferred) shall be run at short-term subordinate stations operated for less than one-year."

4. Section 4.2.6 Water Level Station Documentation has been revised to state that "The documentation package shall be forwarded to CO-OPS after a) installation of a station,..." instead of "within 10 business days of a) installation of a station,...". Sections under 4.6 Data Submission Requirements have been updated significantly regarding the station documentation package (section 4.6.1) and the Project documentation and data checkoff list (section 4.1). Additionally, section 4.6.3 gives additional guidance regarding redundant DCP data and input records and section 4.6.4 gives naming guidance for hourly height, high and low, monthly means and station datum data files.

5. Section 4.6.5 Tide Reducers and Final Zoning and Final Tide Note has been revised to remove the reiterative verbiage and to include the following regarding documentation forwarded to CO-OPS: "(c) GIS compatible zoning development steps in MapInfo© or ArcGIS© format including geographical presentation of summary data and cophase/corange maps, if appropriate"

6. Section 4.6.6 Submission and Deliverables – Documentation and Time lines has been significantly revised to update the submission requirements and submission example.

Chapter 5 "Depth Sounding"

1. Section 5 Depth Sounding has been updated to include the phrase "Total Propagated Uncertainty (TPU)" instead of the previous "Total Propagated Error (TPE)" and to reference to single beam gridding requirements.

2. Section 5.1.1 Accuracy and Resolution Standards now includes a reference to the new S-44 (5th Edition, February 2008).

3. Section 5.1.1.2 Multibeam Resolution Standards has been shortened so that part of the information in this section has been added to section 5.1.1.3 to lessen some confusion with the Multibeam Resolution Standards and coverage requirements.

4. Section 5.1.1.3 Gridded Data Specifications has been revised to change the practice of creating a grid at the highest resolution possible. HSD has determined that a compromise is necessary to preserve high resolution data for navigation products without needlessly burdening NOAA field units and contractors.

5. Section 5.1.2 Coverage has been significantly altered to help clarify the Object Detection Coverage, Complete Coverage and Set Line Spacing requirements that were once in several different sections of this document. It should also be noted that the old Section 5.1.2.1 and 5.2.2.1 Demonstration of Coverage has been removed - all NOAA field units and contractors can still do this as a quality assurance pratice but the coverage grid is no longer required.

6. Section 5.1.3 Corrections to Echo Soundings has been updated to replace the phrase "Heave, roll, pitch, heading and navigation timing errors (latency) corrections" with "Attitude corrections".

7. Section 5.1.3.2 Draft Corrections and all other sections previously referring to "Settlement and Squat" now refer to "Dynamic Draft".

8. Section 5.1.3.5 Error Budget Analysis for Depths was updated to clarify the reasoning behind giving error ranges and that the required depth accuracy requirements cannot be achieved if the worst error for each sensor shown below is used.

9. Sections 5.1.4.1 Multibeam Sonar Calibration and 5.2.4.1Lidar Calibration have been updated to replace the reference to discussing procedures and results in the Data Reduction section in the Data Acquisition and Processing Report with Section A. Equipment and optional Section B. Quality Control of the project.

10. Section 5.1.4.3 Crosslines has been revised to require a general evaluation of the multibeam crossline to mainscheme agreement.

11. Section 5.1.4.4 Multibeam Sun-Illuminated Digital Terrain Model (DTM) Images has been removed - it is no longer required that NOAA field units and contractors submit two sun-illuminated DTM images. All NOAA field units and contractors can still do this as a quality assurance pratice but this no longer a submission requirement.

12. Verbiage in section 5.2.1 Accuracy and Resolution Standards and 5.2.1.1 Accuracy Standards for lidar has been removed and now simply refers to section 5.1.1 since this information is the same.

Chapter 8 "Deliverables"

1. Section 8.1Field Reports has been updated to clarify the precision of horizontal and vertical reporting requirements.

2. Section 8.1.1 Progress Sketch and Survey Outline has been revised to provide clarification for columns within the statistics spreadsheet.

3. Section 8.1.2 Danger to Navigation has been updated to require a chartlet that portrays the raster chart and the danger features with multibeam and side scan imagery of the danger.

4. Section 8.1.3 has been updated to clarify that Descriptive Report shall be submitted in Microsoft Word and in Adobe PDF (including an approval sheet with digital signature). Also, part C of Vertical and Horizontal Control in Section 8.1.3 Descriptive Report (DR) and section 8.1.4.2 Horizontal and Vertical Control Report have been updated to refer NOAA field units to section 5.2.3.2.3 in the OCS Field Procedures Manual to insure that the Vertical and Horizontal Control Report is only created only in certain instances.

5. Section 8.2.1 S-57 Attribution has been revised to include shoreline encoding information for lidar surveys. Also, the Meta-Objects: M_Qual and M_NSYS have been removed.

6. Section 8.2.2 Cartographic Specifications and Conventions - the horizontal precision reporting requirements have been removed, changed and added to section 8.1 and Generalization of Features section has been revised.

7. Section 8.3 Multibeam and Lidar Sonar Coverage has been removed - there is no longer a requirement to submit a multibeam or lidar swath coverage graphic.

8. Section 8.4 Digital Data Files - For both single beam and multibeam data - digital deliverables are required to be separated into two data types: raw and processed.

9. Sections 8.4.3 Shallow-Water Multibeam and Lidar Data and 8.4.4 Side Scan Sonar Data have been updated to require contractors, that process with Caris, to submit the fieldsheet directory so re-computation can occur, if necessary.

Appendices

1. Updated Descriptive Report Title Sheet in Appendix 3 (Figure C.1)

2 Datums

2.1 Horizontal Datum

All positions will be referenced to the North American Datum of 1983 (NAD 83). This datum must be used throughout a survey project for everything that has a geographic position or for which a position is to be determined. Those documents used for comparisons, such as charts, junctional surveys, and prior surveys, must be referenced or adjusted to NAD 83. In addition, all software used on a survey must contain the correct datum parameters.

The only exception for the NAD83 datum requirement is that the S-57 feature file will be in the WGS84 datum to comply with the international S-57 specifications (see Section 8.2). All data shall be collected in the NAD83 datum and then transformed to the WGS84 datum in the S-57 feature file.

2.2 Sounding Datum

All sounding data will be reduced to Mean Lower Low Water (MLLW). Heights of bridges and overhead cables will be referenced to Mean High Water (MHW).

2.3 Time

Coordinated Universal Time (UTC) will be used for all time records.

3 Hydrographic Position Control

3.1 Horizontal Position Accuracy

The NOS specification for hydrographic positioning is that the total error in position of soundings, at the 95 percent confidence level, will not exceed 5 meters + 5 percent of the depth. This accuracy requirement is independent of survey scale.

For hydrographic surveys using single-beam echosounders, the accuracy of the vessel position can be considered the accuracy of the sounding obtained by that vessel, taking into account transducer offsets. However, for multibeam surveys, due to the oblique sounding pattern, the position of a sounding may be at some distance from the vessel position. The accuracy requirement for the vessel position will depend upon how accurately the sounding is positioned relative to the vessel. That, in turn, will depend upon the characteristics of the multibeam system, depth of water, the accuracy with which heave, roll, pitch, heading, and latency are accounted for and applied, and the reliability with which the speed of sound profile is known. Refer to section 8.1 regarding horizontal reporting requirements.

3.2 Differential Global Positioning System

DGPS is the primary positioning system currently used for hydrographic surveys. DGPS correctors can be obtained either through the U.S. Coast Guard (USCG) Maritime DGPS Service or other differential services provided they meet the accuracy requirement in Section 3.1.

3.2.1 DGPS Specifications

Unless specified otherwise in the Hydrographic Survey Project Instructions or Statement of Work, the following specifications are recommended when DGPS is used as the primary positioning system:

- GPS receiver(s) aboard the vessel will be configured such that satellites below 8 degrees above the horizon will not be used in position computations.
- The age of pseudo-range correctors used in position computation should not exceed 20 seconds; and any horizontal positioning interpolation must not exceed the accuracy requirement in Section 3.1.
- Horizontal Dilution of Precision (HDOP) will be monitored and recorded, and should not exceed 2.5 nominally. Satellite geometry alone is not a sufficient statistic for determining horizontal positioning accuracy. Other variables, including satellite pseudorange residuals can be used in conjunction with HDOP to estimate DGPS horizontal accuracy.
- A minimum of four satellites will be used to compute all positions.
- Horizontal and vertical offsets between the GPS antenna and transducer(s) will be observed and applied in no coarser than 0.1 m increments.

Any deviations from the above specifications shall be clearly documented in the Descriptive Report with an explanation and supporting data to show that the resulting positions meet the accuracy requirement in Section 3.1.

3.2.2 DGPS Site Confirmation

If any non-USCG differential reference stations are used, the hydrographer shall annually conduct a certification to ensure that no multipath or other site specific problems exist. Using a receiver established over a known point, create a plot to compare positions generated (at least one per second for 24 hours) to the known position and prove that the position accuracy requirement of Section 3.1 is met. Include plots in the Horizontal Control Report for each project (see section 8.1.4.2) .

3.2.3 Other GPS Techniques

Real Time Kinematic (RTK) and Post Processed Kinematic (PPK) may be used for positioning during hydrographic surveys. If RTK or PPK techniques are used, the hydrographer must ensure that all positions meet the accuracy requirements of Section 3.1.

Many vessels receive survey positions from a DGPS aided inertial navigation system (e.g. POS MV). A high quality inertial system may be able to maintain accurate positions for several minutes after loss of differential correctors. Also, age of correctors, satellite elevation variables, etc., may not be configurable. When using DGPS aided inertial navigation systems, the DGPS recommended configurations of Section 3.2.1 may not apply. However, whatever positioning system is used, the hydrographer must always ensure that positions meet the accuracy requirements of Section 3.1.

The hydrographer must describe the quality control checks used to ensure positional accuracy was met in the Data Acquisition and Processing Report (DAPR) and/or Descriptive Report (DR).

4 Tides and Water Levels Requirements

4.1 General Project Requirements and Scope

4.1.1 Scope

The requirements and specifications contained in this section cover the water level and vertical datum requirements for operational support of hydrographic surveys and photogrammetric surveys conducted as part of the NOAA Nautical Charting Program. The scope of this support is comprised of the following functional areas:

1. Tide and water level requirements planning
2. Preliminary tidal zoning development
3. Control water level station operation, monitoring, and maintenance
4. Subordinate water level station installation, operation, monitoring, maintenance, and removal
5. Data quality control, processing, and tabulation
6. Tidal datum computation and tidal datum recovery
7. Generation of water level reducers and final tidal zoning
8. Quality control check of contractor submitted data to CO-OPS

For NOAA in-house surveys hydrographic survey, personnel from the NOAA's National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) are responsible for functional areas 1, 2, 3, 5, 6 and 7. NOS hydrographers shall be responsible for functional area 4 above.

For NOAA contract hydrographic surveys, NOS CO-OPS personnel are responsible for functional areas 1, 2, 3 and 8. NOAA contract hydrographers shall be responsible for functional areas 4 through 7 above. NOS CO-OPS will be responsible for operating, maintaining, and processing data from the National Water Level Observation Network (NWLON) control stations.

4.1.2 Objectives

The work performed according to the requirements and specifications of this document is required for NOS major program areas of navigational products and services. The first objective is to provide time series of water level reducers that can be applied to hydrographic soundings so that they can be corrected to chart datum. A second objective is to establish and/or recover tidal datums relative to local benchmarks at each station that can be used for continuing and future hydrographic surveys in the area. A third objective is to provide new information or updated information that can be used to update NOAA tide prediction products and tidal zoning for promote safe navigation applications.

4.1.3 Planning and Preliminary Tidal Zoning

CO-OPS is responsible for all planning of tide requirements for NOS hydrographic surveys. CO-OPS will analyze historical data and tidal characteristics for each project area, specify operational NOS control stations, specify subordinate tide station locations to be installed, and provide the preliminary tidal zoning to be used during survey operations. CO-OPS will provide 6-minute interval tide predictions relative to chart datum for appropriate NOS control stations prior to each survey and will also provide historical published bench mark information available for all historical tide stations specified for reoccupation. If CO-OPS provides a new preliminary tidal zoning scheme, the contractor must use that zoning scheme first for each project, and then, may generate a new scheme if the one provided is not adequate. At the conclusion of the survey, the contractor shall suspend the use of preliminary zoning scheme and develop final zoning scheme using correctors derived from the subordinate stations installed during the survey. Refer to Section 4.5.2 for further details.

4.1.4 NOS Control Stations and Data Quality Monitoring

National Water Level Observation Network

CO-OPS manages the NWLON of approximately 200 (as of October 2007) continuously operating water level observation stations in the U.S. coastal zone, including the Great Lakes. As most of these stations are equipped with satellite radios, near real-time (within about 30 minutes of collection) raw data are made available to all users through the CO-OPS Web homepage at `www.tidesandcurrents.noaa.gov`. Verified products, such as edited 6-minute data, hourly heights, high and low waters, and monthly means are made available over the Web within one to four weeks after data collection. NWLON data and accepted tidal datums are used in hydrographic surveys either to provide tide reducers directly or for control for datum determination at subordinate (short-term) stations. Preliminary and verified data are made available over the Web relative to MLLW datum, station datum, or special water level datum (such as Columbia River datum) as an user option in the interface.

Data Quality Monitoring

CO-OPS has an in-place Continuous Operational Real-Time Monitoring System (CORMS) that provides quality control and system monitoring functions on a 24 hour/day, 7 days/week, all year around basis for CO-OPS monitored gauges. CORMS will monitor the status and performance of all in-house hydro gauges equipped with satellite radios using the NOS satellite message format and that are installed by either CO-OPS, NOAA Ships, Navigational Response Teams (NRT), or CO-OPS IDIQ contractors for NOAA in-house hydro projects only, and once these gauges are listed on the hydro hot list by CO-OPS, as it does for all other NOS water level systems, including all NWLON stations. The CORMS system description can be found in System Development Plan, CORMS. CORMS is a NOS provided support function to the operational field parties and does not relieve the hydrographer of responsibility for performing QC and ensuring proper gauge operation. As stated in Section 4.1.1, for NOAA hydrographic contract surveys, the contractor is responsible for all data monitoring, repairs, and proper functioning of the subordinate gauges.

4.1.5 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 computations and water level reductions shall be referenced to this datum. In non-tidal areas, including the Great Lakes, special low water datums have been defined for specific areas and are used as chart datum in these locations. In some cases where historical sites are re-occupied, site datum shall be zeroed to a pre-established MLLW datum held on a bench mark. In that case, data can be acquired relative to MLLW for immediate application during the survey. At present, in Great Lakes areas, a special Low Water Datum relative to IGLD 85 is the reference datum.

4.1.6 Error Budget Considerations

The water level reducers can be a significant corrector to soundings to reduce them relative to chart datum especially in shallow water areas with relatively high ranges of tide. The errors associated with water level reducers are generally not depth dependent, however. The portion of the error of the water level reducers must be balanced against all other sounding errors to ensure that the total sounding error budget is not exceeded. The allowable contribution of the error for tides and water levels to the total survey error budget falls between 0.20 m and 0.45 m (at the 95% confidence level) depending on the complexity of the tides.

The total error of the tides and water levels can be considered to have component errors of:

1. The measurement error of the gauge/sensor and processing error to refer the measurements to station datum. Gauges/sensors need to be calibrated, and sensor design and data sampling need to include strategies to reduce measurement errors due to waves, currents, temperature, and density effects. The measurements need to be properly referenced to the bench marks and tide staffs, as appropriate and monitored for vertical stability. The measurement error, including the dynamic effects, should not exceed 0.10 m at the 95% confidence level. The processing error also includes interpolation error of the water level at the exact time of the soundings. An estimate for a typical processing error is 0.10 m at the 95% confidence level.

2. The error in computation of tidal datums for the adjustment to an equivalent 19-year National Tidal Datum Epoch (NTDE) periods for short term stations. The shorter the time series, the less accurate the datum, i.e. bigger the error. An inappropriate control station also decreases accuracy. The NTDE does not apply in the Great Lakes, however the accuracy of datum based on shorter time series is analogous. The estimated error of an adjusted tidal datum based on one month of data is 0.08 m for the east and west coasts and 0.11 m for the Gulf coast (at the 95% confidence level).

3. The error in application of tidal zoning. Tidal zoning is the extrapolation and/or interpolation of tidal characteristics from a known shore point(s) to a desired survey area using time differences and range ratios. The greater the extrapolation/interpolation, the greater the uncertainty and error. Estimates for typical errors associated with tidal zoning are 0.20 m at the 95% confidence level. However, errors for this component can easily exceed 0.20 m if tidal characteristics are very complex, or not well-defined, and if there are pronounced differential effects of meteorology on the water levels across the survey area.

Project planning by NOS attempts to minimize and balance these potential sources of errors through the use and specification of accurate reliable water level gauges, and optimization of the mix of zoning required, the number of station locations required, and the length of observations required within practical limits of the survey area and survey duration. The practical limits depend upon the tidal characteristics of the area and suitability of the coastline for the installation and operation of appropriate water level stations.

4.2 Data Collection and Field Work

The hydrographer shall collect continuous and valid data series. Accurate datums cannot be computed for a month of data with a break in the water level measurement series in excess of three days. Even breaks of significantly less than three days duration will not allow for interpolation during times when strong meteorological conditions are present and in areas with little periodic tidal influence. Any break in the water level measurement series affects the accuracy of datum computations. Breaks in data also result in increased error in the tide reducers when interpolation is required to provide data at the time of soundings. At a critical measurement site where the water level measurement data cannot be transmitted or monitored during hydrographic operations, an independent backup sensor or a complete redundant water level collection system shall be installed and operated during the project.

4.2.1 Water Level Station Requirements

Data from NOS National Water Level Observation Network (NWLON) stations will be provided to support hydrographic survey operations where appropriate. Data provided are relative to Chart Datum which is Mean Lower Low Water for the 19-year National Tidal Datum Epoch (NTDE).

The acquisition of water level data from subordinate locations may be required for hydrographic surveys and if so shall be specified by NOS in each individual set of Project Instructions or Statement of Work. These stations shall be used to provide 6-minute time series data, tidal datum references and tidal zoning which all factor into the production of final tide reducers for specific survey areas. Station locations and requirements may be modified after station reconnaissance or as survey operations progress. Any changes shall be made only after consultation between the CO-OPS and the hydrographer (and COTR if contract survey) as moving required stations to new locations may require new seven-digit station identifier numbers and new/historical station and bench mark information.

The duration of continuous data acquisition shall be a 30-day minimum except for zoning stations. Data acquisition shall be from at least 4 hours before the beginning of the hydrographic survey operations to 4 hours after the ending of hydrographic survey operations, and/or shoreline verification in the applicable areas. Stations identified as “30-day” stations are the “main” subordinate stations for datum establishment, providing tide reducers for a given project and for harmonic analysis from which harmonic constants for tide prediction can be derived. At these stations, data must be collected throughout the entire survey period in specified areas for which they are required, and not less than 30 continuous days are required for accurate datum determination. Additionally, supplemental and/or back-up gauges may also be necessary based upon the complexity of the hydrodynamics and/or the severity of environmental conditions of the project area.

In non-tidal areas the correctors for hydrographic soundings are simply water level measurements relative to a specified local low water level datum established for navigational purposes. Laguna Madre and parts of Pamlico Sound are examples of such areas classified as non-tidal which have special low water datums. Some river areas also have special datums due to the effects of seasonal changes on the river, e.g., Columbia River Datum, Hudson River datum, and Mississippi River Low Water are examples of this case. Great Lakes NWLON permanent stations will provide water level data referenced to an established Low Water Datum relative to International Great Lakes Datum of 1985 (IGLD 85).

4.2.2 Water Level Measurement Systems and Data Transmissions

Water Level Sensor and Data Collection Platform

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), or other suitable type that is approved by CO-OPS. The sensor measurement range shall be greater than the expected range of water level. 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 hydrographic surveys are planned. 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.

The Data Collection Platform (DCP) shall acquire and store water level measurements at every 6- minutes. The water level measurements shall consist of an average of at least 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 which comprise the 6-minute measurements shall be computed and stored. The 6-minute centered average water level data is required for compatibility with the NWLON stations, and the standard deviation provides valuable data quality information regarding each measurement. The clock accuracy of a satellite radio system shall be within 5 seconds per month so that channel "stepping" does not occur. Non-satellite radio systems shall have a clock accuracy of within one minute per month. 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.

The NOS is currently using the Aquatrak® self-calibrating air acoustic sensors at the majority of the NWLON stations. (For further information refer to *Next Generation Water level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual*, NOAA/NOS, January 1991 and *User's Guide for 8200 Acoustic Gauges*, NOAA/NOS, Updated August 1998). At stations where the acoustic sensor can not be used due to freezing or the lack of a suitable structure, either a Paro-Scientific intelligent pressure (vented) sensor incorporated into a gas purge system, or a well/float with absolute shaft angle encoder (Great Lakes Stations) are used for water level measurements. (For further information refer to *User's Guide for 8200 Acoustic Gauges*, NOAA/NOS, Updated February 1998).

In each and any case, the water leveling sampling/averaging scheme shall be as described above. For short term subordinate stations which are installed to support NOS hydrographic surveys, the use of air acoustic sensor is preferred over pressure sensor whenever possible. Where the air acoustic sensor can not be installed, NOS uses a vented strain gauge pressure sensor in a bubbler configuration (Refer to *User's Guide for 8200 Acoustic Gauges*, NOAA/NOS, updated February 1998). When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle shall be required (1) at the start, (2) at frequent intervals during deployment, and (3) at the end of a deployment. Frequent gauge/staff comparisons (at least two times per week or minimum eight times per month) during deployment shall be required to assist in assuring measurement stability and minimizing processing type errors. The staff to gauge observations shall be at least three hours long at the beginning and end of deployment and the periodic observations during deployment shall be 1 hour long. The staff-to-gauge comparison criteria are general requirements. When these staff-to-gauge observation frequency or time requirements cannot be met, then refer to section 4.2.4. Staff observations for further information. Along with the averaging procedure described above which works as a digital filter, NOS uses a combination protective well/parallel plate assembly on the acoustic sensor and a parallel plate assembly (with 2" orifice chamber) on the bubbler orifice sensor to minimize systematic measurement errors due to wave effects and current effects, as shown in Figure 4.1.

When pressure sensors are used to collect the water level data, orifice should be mounted on vertical surface such as piling of a wharf so that precise elevation of orifice below a staff stop could be measured with a steel tape, and the elevation of the staff stop can be measured via differential leveling to the nearest benchmark and with the primary bench mark. If the orifice is mounted vertically and its elevation can be determined precisely with reference to the primary bench mark, then staff to gauge readings may not be necessary, and the requirement for staff-to-gauge readings may be waived (e.g. in seawater). If the orifice can not be mounted to a vertical surface i.e. if the elevation of the orifice can not be determined precisely with the primary bench mark, then staff-to-gauge readings are required to relate the water level datums to the bench marks. Refer to additional information about staff and staff observations in section 4.2.4.

Data Transmissions

The Data Transmissions requirements are applicable where CO-OPS is monitoring the gauges as described in Section 4.1.4 above. The ability to monitor water level measurement system performance for near real-time quality assurance is essential to properly support hydrographic survey operations. Therefore, it is required that, where access to the satellite is available, the measurement system shall be equipped with a GOES transmitter to telemeter the data to NOS every three hours or hourly. The data transmissions must use a message format identical to the format as currently implemented in NOS' Next Generation Water Level Measurement Systems (NGWLMS). This is required to assure direct compatibility with the NOS Data Management System (DMS). This data format is detailed in the reference document "NGWLMS GOES MESSAGE FORMATTING" (refer to Section 4.7 for References). Once station and gauge information is configured in DMS and station listed on the Hydro Hot List (HHL), the NOS Continuous Operational Real-Time System (CORMS) will monitor all water level measurement system GOES transmissions to assure they are operating properly, provided that the GOES data transmitted is compatible with NOS format. Data that is not transmitted by GOES, or data transmitted but not in NOS compatible GOES format, or is submitted to CO-OPS on electronic formats currently used such as, CD-ROM, DVD-ROM or such other digital media, must also conform to the format specified in the above document so that data can be loaded properly into DMS software. Refer to Section 4.6.3 for further details about the water level data format specifications.

Close coordination is required between hydrographer and Requirements and Development Division (RDD) of CO-OPS for all hydrographic water level installations with satellite transmission capability. NOS will assist in acquiring assigned platform ID's, time slots, etc. At least three business days prior to the initiation of GOES data transmission in the field, information about the station number, station name, latitude, longitude, platform-ID, transmit time, channel, and serial numbers of sensors, and DCP shall be faxed, phoned, or sent to RDD. Test transmissions conducted on site are outside this requirement. This station and DCP information must be configured in DMS before data transmissions begin so that the data will be accepted in DMS. The documentation required prior to transmission in field is defined in the NGWLMS Site Report, Field Tide Note, or Water Level Station Report, as appropriate. (Refer to Section 4.6 Data Submission Requirements).

4.2.3 Station Installation, Operation and Removal

Hydrographers shall obtain all required permits and permissions for installation of the water level sensor(s), Data Collection Platforms (DCP), bench marks, and utilities, as required. The hydrographer shall be responsible for security and/or protective measures, as required. The hydrographer shall install all components in the manner prescribed by manufacturer, or installation manuals. The hydrographer or contractor shall provide CO-OPS of the position of all tide gauges installed before hydrography begins, including those that were not specified in the Statement of Work or Project Instructions, as appropriate. The positions of bench marks and stations installed or recovered shall be obtained as latitudes and longitudes (degrees, minutes, and tenth of seconds).

Water level station and its various components (tide house, Data Collection Platform, all sensors, bench marks, and pertinent access facilities such as railings, steps, etc., as appropriate), when designed or installed by contractors, shall be installed and maintained as prescribed by manufacturers, installation manuals, appropriate local building codes, or as specified by the Contracting Officer's Technical Representative (COTR), if applicable. Water level station and all installed components shall be structurally sound, secure, and safe to use for NOS, local partners, and general public, as appropriate.

The following paragraphs provide general information regarding requirements for station installation, operations and maintenance, and station removal.

Station Installation

A complete water level measurement gauge installation shall consist of the following:

- The installation of the water level measurement system (water level sensor(s), DCP, and satellite transmitter) and its supporting structure and a tide staff if required.
- The recovery and/or installation of a minimum number of bench marks and a level connection between the bench marks and the water level sensor(s), and tide staff as appropriate.
- The preparation of all documentation and forms.

Operation and Maintenance

When GOES telemetry and NOS satellite message format is used, the hydrographer 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. This monitoring can be performed by accessing the COOPS web page (`http://www.TidesandCurrents.noaa.gov`). The data over this system are typically available for review within three to four hours after collection.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate maintenance forms (see section on water level station documentation below) 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 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; etc.

Removal

A complete removal of the water level measurement gauge shall consist of the following:

- Closing levels - a level connection between the minimum number bench marks and the water level sensor(s) and tide staff as appropriate.
- Removal of the water level measurement system and restoration of the premises, reasonable wear and tear accepted.
- The preparation of all documentation, forms, data, and reports.

4.2.4 Tide Staffs

Staff

The hydrographer shall install a tide staff at a station if the reference measurement point of a sensor (zero of a gauge) cannot be directly leveled to the local bench marks, e.g. orifice is laid over sea floor in case of pressure based bubbler gauges. Even if a pressure gauge can be leveled directly, staff readings are still required for assessment of variations in gauge performance due to density variations in the water column over time. The tide staff shall be mounted independent of the water level sensor so that stability of the staff or sensor is maintained. Staff shall not be mounted to the same pile on which the water level sensor is located. The staff shall be plumb. When two or more staff scales are joined to form a long staff, the hydrographer shall take extra care to ensure the accuracy of the staff throughout its length. The distance between staff zero and the rod stop shall be measured before the staff is installed and after it is removed and the rod stop above staff zero height shall be reported on the documentation forms.

In areas of large tidal range and long sloping beaches (i.e. Cook Inlet and the Gulf of Maine), the installation and maintenance of tide staffs can be extremely difficult and costly. In these cases, the physical installation of a tide staff(s) may be substituted by systematic leveling to the water's edge from the closest bench mark. The bench mark becomes the "staff stop" and the elevation difference to the water's edge becomes the "staff reading".

Staff Observations

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle shall be required (1) at the start of water level data collection, (2) at frequent intervals during deployment, and (3) at the end of a deployment before gauge has been removed. Frequent gauge/staff comparisons during deployment shall be required to assist in assuring measurement stability and minimizing processing type errors. The staff to gauge observations at the start and end of deployment shall be at least each three hours long and the periodic observations during the deployment shall be at least 1 hour long. The staff to gauge observations shall be performed three times per week, during each week of the project, with at least an hour long observations of 6 minute interval for each time. Where staff to gauge observations can not be performed three times a week as required then an explanation is required for the deficiency of number of observations and staff to gauge observations shall be performed at least (a) minimum eight times spread out over each month (e.g. two times per week) and at each time at least 1 hour of observations at 6 minute interval, or (b) minimum of four times spread out over each month (e.g. one time per week) and at each time at least 2 hours of observations at 6 minute interval, whichever is convenient.

The staff-to-gauge differences should remain constant throughout the set of observations and show no increasing or decreasing trends. After the water level data has been collected, the averaged staff-to-gauge shall be applied to water level measurements to relate the data to staff zero. A higher number of independent staff readings decrease the uncertainty in transferring the measurements to station datum and the bench marks. Refer to Figure 4.2 for an example pressure tide gauge record.

If the old staff is found destroyed by elements during the deployment, then a new staff shall be installed for the remainder period of the deployment and a new staff to gauge constant needs to be derived by new sets of staff to gauge observations. Also when a staff or an orifice is replaced or re-established, check levels shall be run to minimum of three bench marks including the PBM. Refer to Section 4.2.5 for leveling frequency and other leveling requirements.

For water level historic stations that are reoccupied, NOS CO-OPS will provide the station datum (SD) information for the station. This information is generally given about the Primary Bench Mark (PBM) above the historic SD. In that case, for pressure sensors that require staff-to-gauge observations, all the water level data shall be placed on the station datum using the following equation:

Water level data on the SD = (Preliminary pressure water level data on an arbitrary datum as collected by the gauge) + (PBM above SD) - (Staff zero below PBM) - (weighted staff-to-gauge constant)

Staff zero below PBM = (Staff stop below PBM) + (Staff zero below Staff stop)

The staff-to-gauge constant shall be derived as a weighted average of all the staff-to-gauge readings done for the project. The staff zero below PBM is obtained generally by (a) leveling from PBM to staff stop and (b) then measuring the staff stop to staff zero elevation with a steel tape and (c) then combining the two (a and b) elevation values. The staff zero below PBM is obtained by averaging the elevations differences during the opening (installation) and closing (removal) leveling runs for short term occupations.

The orifice elevation above station datum is also defined as accepted orifice offset in CO-OPS Data Management System (DMS).

Bubbler Orifice and Parallel Plate Assembly

This bottom assembly is made of red brass, its chemical properties prevent the growth of marine life by the slowly releasing copper oxide on its metal surface. A Swagelok® hose fitting is screwed into the top end cap and is used to discharge the Nitrogen gas. The Nitrogen gas flows through the bottom of the orifice at a rate sufficient to overcome the rate of tidal change and wave height. This opening establishes the reference point for tidal measurements. The parallel plates produce a laminar flow across the orifice to prevent venturi effect. A two inch by eight inch pipe provides the correct volume gas for widest range of surf conditions encountered by most coastal surveys.

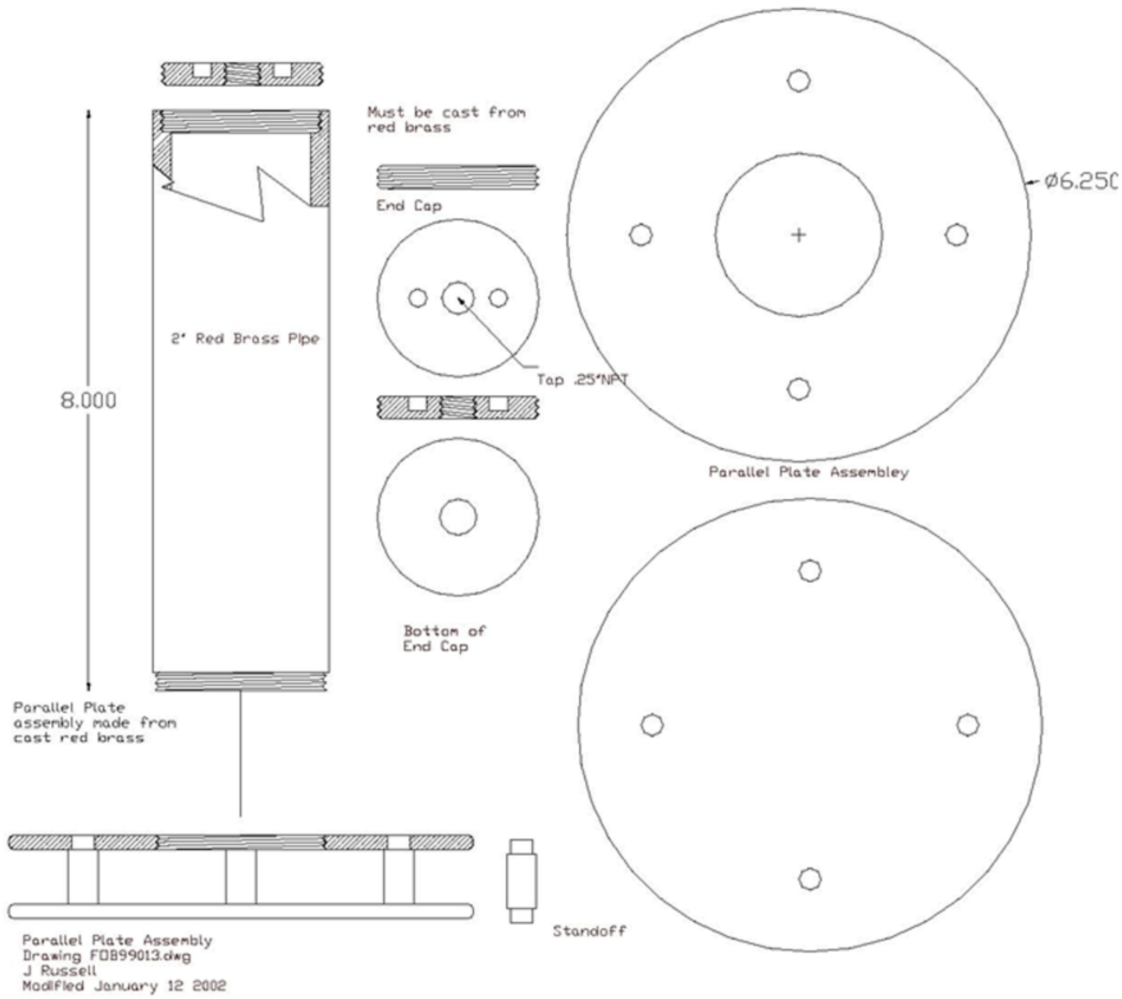

Figure 4.1: Bubbler Orifice Bottom Assembly

PRESSURE TIDE GAUGE RECORD

Station Name:______________________ **Station No. (7 digit #)** ______________________

Date	Time		Staff Reading		Gauge/Staff Difference	Gas Pressure		Wind (Dir/Spd)	Air Temp.	Remarks
(M,D,Y)	Gauge	Correct	High	Low		Cyln	Feed			

Figure 4.2: Example - Pressure Tide Gauge Record

4.2.5 Bench Marks and Leveling

Bench Marks

A bench mark is a fixed physical object or marker (monumentation) set for stability and used as a reference to the vertical and/or horizontal datums. Bench marks in the vicinity of a water level measurement station are used as the reference for the local tidal datums derived from the water level data. The relationship between the bench marks and the water level sensor or tide staff shall be established by differential leveling.

Number and Type of Bench Marks

The number and type of bench marks required depends on the duration of the water level measurements. The *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations*, dated October 1987, specifies the installation and documentation requirements for the bench marks. Each station will have one bench mark designated as the primary bench mark (PBM), which shall be leveled to on every run. The PBM is typically the most stable mark in close proximity to the water level measurement station. The contractor shall select a PBM at sites where the PBM has not already been designated. For historic NOS station reoccupations, CO-OPS will furnish the designation/stamping of the PBM and PBM elevation above station datum, as appropriate and if available.

The most desirable bench mark for GPS observations will have 360 degrees of horizontal clearance around the mark at 10 degrees and greater above the horizon and stability code of A or B. Refer to Section 4.2.10 GPS Observations, and *User's Guide for GPS Observations*, Updated March 2007, for further information.

If the PBM is determined to be unstable, another mark shall be designated as PBM. The date of change and the elevation difference between the old and new PBM shall be documented. NOAA will furnish the individual NOS standard bench mark disks to be installed. Bench mark descriptions shall be written according to *User's Guide for Electronic Levels*, updated January 2003.

Leveling

At least, geodetic third-order levels (refer to Reference 19, but 2nd order class I levels are preferred) shall be run at short-term subordinate stations operated for less than one-year. Requirements for higher order levels will be specified in individual project instructions, as appropriate. Standards and specifications for leveling are found in Standards and Specifications for Geodetic Control Networks and Geodetic Leveling (NOAA Manual NOS NGS 3). Additional field requirements and procedures used by NOS for leveling at tide stations can be found in the User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations. Electronic digital/barcode level systems are preferable. Specifications and standards for digital levels can be found in Standards and Specifications for Geodetic Control Networks and additional field requirements and procedures used by NOS for electronic leveling at water level stations can be found in the User's Guide for Electronic Levels, updated January 2003.

Leveling Frequency

Levels shall be run between the water level sensor(s) or tide staff and the required number of bench marks when the water level measurement station is installed, modified (e.g., water level sensor serviced, staff, or orifice replaced), for time series bracketing purposes, or prior to removal. In any case, levels are required at a maximum interval of six (6) months during the station's operation, and are recommended after severe storms, hurricanes, earthquakes to document stability (see stability discussed below).

Bracketing levels to appropriate number of marks (five for 30-day minimum stations) are required (a) if smooth tides are required 30 days or more prior to the planned removal of a applicable gauge(s), or (b) after 6 months for stations collecting data for long term hydrographic projects.

Stability

If there is an unresolved movement of the water level sensor or tide staff zero relative to the PBM, from one leveling to the next, of greater than 0.006 m, the hydrographer shall verify the apparent movement by re-running the levels between the sensor zero or tide staff to the PBM. This threshold of 0.006 m should not be confused with the closure tolerances used for the order and class of leveling.

4.2.6 Water level Station Documentation

The field team shall maintain a documentation package for each water level measurement station installed for hydrographic projects. The documentation package shall be forwarded to CO-OPS after a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to time frames for submission of documentation in Section 4.6.6.

Generally, all documentation (see Section 4.6 for Data Submission Requirements) shall be forwarded to CO-OPS when a station is installed. For other situations, only information that has changed shall be submitted (e.g., levels and abstract for bracketing or removal levels, NGWLMS Site Report for maintenance and repair or station removal, etc.)

4.2.7 Additional Field Requirements

1. Generally upon completion of the data acquisition for each gauge installed, the data must be sent as a batch for a 30-day minimum station unless the data are transmitted via satellite. For long term station running more than three months, the data shall be sent periodically (monthly) unless the data are transmitted via satellite.

2. All water level data from a gauge shall be downloaded and backed up at least weekly on electronic formats currently used such as CD-ROM or DVD-ROM, whether the gauge data are sent via satellite or not.

3. For new stations that do not have station numbers assigned, once the location of the gauge has been finalized then contact CO-OPS and provide latitude and longitude of the gauge site at least three business days prior to actual installation of the gauge in field. CO-OPS will assign a new station number within three business days and inform the hydrographer.

4. The progress sketch shall show the field sheet, layout, area of hydrography, gauge locations, and other information as appropriate. Verify the location of the gauge as shown on the progress sketch, bench mark and tide station location sketch, field tide note, Xpert Site report, NGWLMS Site Report or Tide station Report.

4.2.8 Geodetic Connections and Datums Relationship

Tidal datums are local vertical datums which may change considerably within a geographical area. A geodetic datum is a fixed plane of reference for vertical control of land elevations. The North American Vertical Datum of 1988 (NAVD 88) is the accepted geodetic reference datum of the National Geodetic Spatial Reference System and is officially supported by the National Geodetic Survey (NGS) through a network of GPS continuously operating reference stations. The relationship of tidal datums to NAVD 88 has many hydrographic, coastal mapping and engineering applications including monitoring sea level change and the deployment of GPS electronic chart display and information systems, etc.

Existing geodetic marks in the vicinity of a subordinate tidal station shall be searched for and recovered. A search routine is available at `http://www.ngs.noaa.gov`. An orthometric level connection and ellipsoidal GPS tie is required at a subordinate tide station which has geodetic bench marks located nearby as stated below for NAVD 88 Level Tie and NAD 83 GPS Tie requirements. NAVD 88 heights for published bench marks are given in Helmert orthometric height units by NGS. The GPS ellipsoid network height accuracies are classified as conforming to 2 cm or 5 cm standards accuracies (Refer to *NOAA Technical Memorandum NOS NGS-58*. At the present time, GPS ellipsoid heights conforming to the 2 cm accuracy standards are required for contract hydrographic surveying projects. Refer to Section 4.2.10 GPS Observations and *User's Guide for Observations, NOAA/NOS*, Updated March 2007.

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. NAVD 88 Level Tie
2. NAD 83 GPS Tie
3. NAVD 88 GPS Tie

4.2.9 NAVD 88 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 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 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 Reference 2 *User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations* 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. Since a level connection to GBMs with dynamic heights defines the IGLD 85 datum offset at each station in the Great Lakes, a valid connection to at least two GBMs is required at each site in the Great Lakes.

A note shall be made in the remarks of the leveling section of the Tide Station 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 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.

4.2.10 GPS Observations

GPS observations are required to obtain elevation ties between the tidal datums and GPS derived datums.

1. References and standards:

   Static GPS observations shall be performed at water level stations in accordance with Reference 8 "User's Guide for GPS Observations", NOAA/NOS Updated March 2007. Reference 20 "NOS NGS 58" provides further details. These guidelines are written for establishing GPS derived ellipsoid height accuracy standards of 2 cm as outlined in NGS-58 document, for all survey projects, and special project applications.

   Static GPS surveys shall be conducted on a minimum of one bench mark at each subordinate water level station installed/occupied for hydrographic or photogrammetric surveys.

   Static GPS surveys shall be conducted at water level stations concurrently with the occupation of NAVD 88 marks, if possible, to accomplish water level datum transfers using GPS-derived orthometric heights.

2. Equipment and accuracies:

   High accuracy static differential GPS surveys require a geodetic quality, dual frequency, full-wavelength GPS receiver with a minimum of 10 channels for tracking GPS satellites.

   A choke ring antenna is preferred, however, any geodetic quality ground plane antenna may be used. More important than antenna type, i.e. choke ring or ground plane, is that the same antennas or identical antennas should be used during the entire observing sessions. (If not, a correction for the difference in antenna phase patterns (modeled phase patterns) must be applied.) This is extremely critical for obtaining precise vertical results. The antenna cable length between the antenna and receiver should be kept to a minimum when possible; 10 meters is the typical antenna cable length. If a longer antenna cable is required, the cable must be fabricated from low loss coaxial cable (RG233 for up to 30 meters and RG214 over 30 meters).

   A fixed height precise GPS antenna tripod is required for this type of a survey. This is a fixed height, 2 meter pole with three adjustable legs, a bull's eye bubble to plumb the antenna, and a magnetic compass to align the antenna to North. These fixed height tripods reduce the chance of introducing an Height of Instrument (HI) "blunder" during the post-processing of the data.

   The manufacturer, model, and complete serial numbers of all receivers and antennas must be noted for each occupation on each station/bench mark observation log sheet as shown in Figure 4.18.

3. Criteria for bench mark selection for GPS observations

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

   - 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 primary bench mark (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. Generally once a mark is selected for GPS observations, future GPS observations shall be done on the same mark.

   - 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 water level station.

   - 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 mark (stability A or B) 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. If electronic leveling equipment is used, then 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.

     GPS visibility obstruction diagram shall also be completed for each mark observed as shown in Figure 4.20.

- 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. Recording of data

   Set the epoch update or recording interval (REC INT) for 15-seconds, which should agree with the recording interval of the reference stations (IGS or CORS) used to post-process the data. For GPS sessions greater than 30 minutes, collect data at 15-second epoch intervals, starting at an even minute. The elevation mask (ELEV MASK) is typically set for 10 degrees for static surveys; low angle satellites can degrade the final solution. Set the minimum number of satellites to four. For static surveying, setting the minimum number of satellites (MIN SV) is not as critical as for kinematic surveying. However, if the number of satellites tracked drops below four, it could be an indication of other problems, such as an antenna or antenna cable connection problem, RF interference, or an obstruction from traffic (vehicle or vessel). The GPS signal from the satellite is not very strong when entering the receiver, so anything that produces further attenuation of the signal can cause the receiver to stop tracking satellites.

5. Position and photograph of the GPS bench mark

   GPS (horizontal) positions (latitude and longitude) of each bench mark installed or recovered shall be listed on the HA files for laser levels, if used, or on the bench mark descriptions sheet for optical leveling, as applicable, at each subordinate water level station occupied for hydrographic or photogrammetric surveys.

   Digital photographs shall be taken of all station bench mark disks in accordance with Reference 23 - Attachment R, Requirements for Digital Photographs of Survey Control, NGS, July 2005". A minimum of three photos shall be taken: close-up of the disk face; chest or waist level view of the 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.

   A digital photo of the stamping of the bench mark occupied must be made as shown in Figure 4.22. If digital photo is not available, then a rubbing of the bench mark must be done as shown in Figure 4.21. A digital photo of the stamping is preferred over rubbing of the mark.

   Photos shall also be taken of station components such as protective wells, staffs, tide house, 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 pressure sensor photo for DCP1 at San Francisco shall be named as 94142901 sensor N1.jpg.

6. Miscellaneous

   Additional GPS suitable marks may be connected during the static survey using rapid static GPS procedures to verify bench mark stability, if time and personnel resources are available. Priority shall be given to connecting to the NSRS, particularly to the North American Vertical Datum of 1988 (NAVD 88) bench marks.

4.2.11 North American Datum (NAD 83) GPS Tie

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 regarding using OPUS is provided in the next section.

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 20, 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 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 *User's Guide for GPS Observations.*

4.2.12 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:

1. The email address where you want the results sent.
2. The data file that you want to process (which you may select using the browse feature; raw or RINEX accepted).

3. The antenna type used to collect this data file (selected from a list of calibrated GPS antennas).
4. 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.

1. Make sure the antenna type and the ARP height are correct.
2. Review the solution statistics:
   (a) A good quality OPUS run should typically use 90% or more of your observations.
   (b) OPUS should have fixed at least 80% of the ambiguities.
   (c) The overall RMS should seldom exceed 3 cm.
   (d) 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, 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 CO-OPS RDD/OET, as well as the GPS data sets.

4.2.13 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 specifications will be updated as appropriate. Any data sets submitted to OPUS and the results will be subsequently re-submitted by CO-OPS' RDD/OET 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:

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	Describe monumentation quality
Photograph (of marker)	Aids in station recovery

Table 1: Required Data Elements (15 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.

Table 2: Optional Data Elements (11 each):

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.

4.2.14 NAVD 88 GPS Tie

The NAVD 88 GPS tie involves simultaneous GPS observations at the GPSBM and one or more GBMs located up to 10 KM (6.26 mi) from the GPSBM. This "Height Mod" tie is deferred until such time as NGS enables user-friendly bluebooking of campaign data (OPUS projects).

4.3 Data Processing and Reduction

4.3.1 Data Quality Control

The required output product used in generation of tide reducers and for tidal datum determination is a continuous time series of 6-minute interval water level data for the desired time period of hydrography and for a specified minimum time period from which to derive tidal datums. CO-OPS will monitor the installed system operation information for all gauges equipped with GOES satellite radios. The 6-minute interval water level data from the water level gauges shall be quality controlled to NOS standards by the contractor for invalid and suspect data as a final review prior to product generation and application. This includes checking for data gaps, data discontinuities, datum shifts, anomalous data points, data points outside of expected tolerances such as expected maximum and minimum values and for anomalous trends in the elevations due to sensor drift or vertical movement of the tide station components and bench marks.

Quality control shall include comparisons with simultaneous data from backup gauges, predicted tides or data from nearby stations, as appropriate. Data editing and gap filling shall use documented mathematically sound algorithms and procedures and an audit trail shall be used to track all changes and edits to observed data. All inferred data shall be appropriately flagged. Water level measurements from each station shall be related to a single, common datum, referred to as Station Datum. Station Datum is an arbitrary datum and should not be confused with a tidal datum such as MLLW. All discontinuities, jumps, or other changes in the gauge record (refer to the specific gauge user's guide) that may be due to vertical movement of any the gauge, staff, or bench marks shall be fully documented. All data shall be recorded on UTC and the units of measurement shall be properly denoted on all hard-copy output and digital files. Refer to Section 4.6 Data Submission Requirements for details.

4.3.2 Data Processing and Tabulation of the Tide

The continuous 6-minute interval water level data are used to generate the standard tabulation output products. These products include the times and heights of the high and low waters, hourly heights, maximum and minimum monthly water levels, and monthly mean values for the desired parameters. Examples of these tabulation products are found in Figure 4.3 and 4.4 for tide stations and Figure 4.5 for Great Lakes stations. The times and heights of the high and low waters shall be derived from appropriate curve-fitting of the 6-minute interval data. For purposes of tabulation of the high and low tides and not non-tidal high frequency noise, successive high and low tides shall not be tabulated unless they are greater than 2.0 hours apart in time and 0.030 meters different in elevation. Hourly heights shall be derived from every 6-minute value observed on the hour. Monthly mean sea level and monthly mean water level shall be computed from the average of the hourly heights over each calendar month of data. Data shall be tabulated relative to a documented consistent station datum such as tide staff zero, arbitrary station datum, MLLW, etc.. over the duration of the data observations. Descriptions of general procedures used in tabulation are also found in the *Tide and Current Glossary, Manual of Tide Observations, and Tidal Datum Planes.*

4.3.3 Computation of Monthly Means

Monthly means are derived on a calendar month basis in accordance with the definitions for the monthly mean parameters as found in the Tide and Current Glossary. Examples of the desired monthly means are found in 4.7. For purposes of monthly mean computation, monthly means shall not be computed if gaps in data are greater than three consecutive days. For partial months of data, tide by tide comparison with the control station data shall be performed.

4.3.4 Data Editing and Gap Filling Specifications

When backup sensor data are not available, data gaps in 6-minute data shall not be filled if the gaps are greater than three consecutive days in length. Data gap filling shall use documented mathematically and scientifically sound algorithms and procedures and an audit trail shall be used to track all gap-fills in observed data. Data gaps of less than 3-hours can be inferred using interpolation and curve-fitting techniques. Data gaps of longer than three hours shall use external data sources such as data from a nearby station. All data derived through gap-filling procedures shall be marked as inferred. Individual hourly heights, high and low waters, and daily means derived from inferred data shall also be designated as inferred.

```
Jan 31 2007 14:09         HIGH/LOW WATER LEVEL DATA       July, 1998
                        National Ocean Service (NOAA)
Station:  9414290                                         T.M.:     0 W
Name:     SAN FRANCISCO, SAN FRANCISCO BAY, CA            Units:    Meters
Type:     Mixed                                           Datum:    STND
Note:     > Higher-High/Lower-Low   [] Inferred Tide      Quality:  Verified

         High             Low                     High             Low
Day   Time  Height     Time  Height       Day   Time  Height     Time  Height
---   ----  ------     ----  ------       ---   ----  ------     ----  ------
 1  >  1.4   3.337      6.8   2.521       16  >  0.6   3.550      6.2   2.343
      12.6   2.996   > 18.5   2.253             12.6   3.187   > 18.1   2.195
 2  >  2.0   3.393      7.8   2.434       17  >  1.4   3.654      7.4   2.205
      13.9   2.950   > 19.4   2.406             14.1   3.096     19.0   2.335
 3  >  2.6   3.458   >  9.1   2.367       18  >  2.2   3.725   >  8.6   2.054
      15.2   2.941     20.1   2.498             15.6   3.132     20.2   2.504
 4  >  3.2   3.524   >  9.7   2.210       19  >  3.1   3.819   >  9.7   1.891
      16.5   2.988     21.1   2.612             16.9   3.188     21.5   2.586
 5  >  4.0   3.584   > 10.3   2.018       20  >  4.1   3.899   > 10.7   1.763
      17.6   3.054     22.0   2.644             18.0   3.267     22.5   2.597
 6  >  4.6   3.656   > 11.1   1.913       21  >  4.9   3.903   > 11.6   1.654
      18.3   3.124     22.7   2.682             18.8   3.309     23.4   2.583
 7  >  5.1   3.711   > 11.8   1.812       22  >  6.0   3.884
      19.1   3.194     23.4   2.697             19.6   3.347   > 12.4   1.587
 8  >  5.8   3.754                        23  >  6.4   3.880      0.2   2.587
      19.7   3.223   > 12.4   1.730             20.3   3.390   > 13.1   1.611
 9  >  6.3   3.789      0.1   2.703       24  >  7.4   3.833      1.1   2.586
      20.4   3.285   > 13.1   1.669             20.9   3.409   > 13.9   1.659
10  >  7.3   3.795      0.9   2.709       25  >  8.1   3.780      1.7   2.562
      21.1   3.306   > 13.7   1.627             21.6   3.445   > 14.5   1.719
11  >  8.0   3.712      1.6   2.614       26  >  8.7   3.668      2.6   2.564
      21.7   3.302   > 14.4   1.579             22.2   3.437   > 14.9   1.826
12  >  8.8   3.639      2.5   2.584       27  >  9.3   3.510      3.2   2.549
      22.3   3.356   > 15.1   1.609           > 22.8   3.416   > 15.6   1.932
13  >  9.3   3.547      3.1   2.530       28    10.1   3.356      4.1   2.538
      23.1   3.419   > 15.6   1.692           > 23.5   3.430   > 16.1   2.042
14    10.1   3.443      4.1   2.522       29    10.9   3.202      5.0   2.495
    > 23.9   3.484   > 16.5   1.800                            > 16.6   2.199
15    11.3   3.282      5.1   2.422       30  >  0.1   3.432      5.9   2.492
                     > 17.0   1.967             12.0   3.099   > 17.3   2.402
                                          31  >  0.8   3.472   >  6.9   2.431
                                                13.1   3.018     18.5   2.513

Highest Tide:            3.903     4.9 Hrs  Jul 21 1998
Lowest  Tide:            1.579    14.4 Hrs  Jul 11 1998

Monthly Means:      MHHW    3.641
                    MHW     3.433     DHQ     0.208
                    MTL     2.832                    GT     1.720     HWI    7.57  Hrs
                    DTL     2.781                    MN     1.203     LWI    0.76  Hrs
                    MSL     2.816
                    MLW     2.230     DLQ     0.309
                    MLLW    1.921
```

Figure 4.3: High and Low Water Data

HOURLY WATER LEVELS

National Ocean Service (NOAA) July 1998

Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA Time Meridian 0 W Tide Type: Mixed

HOUR	Jul 1	Jul 2	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10	Jul 11	Jul 12	Jul 13	Jul 14	Jul 15	Jul 16
00	3.247	3.183	3.119	3.052	2.936	2.837	2.770	2.724	2.717	2.763	2.814	2.960	3.152	3.354	3.481	3.529
01	3.329	3.333	3.319	3.274	3.157	3.066	2.972	2.851	2.762	2.694	2.637	2.723	2.901	3.162	3.365	3.517
02	3.311	3.391	3.449	3.437	3.378	3.293	3.173	3.060	2.913	2.799	2.627	2.602	2.653	2.868	3.123	3.395
03	3.164	3.312	3.463	3.526	3.526	3.504	3.423	3.298	3.171	2.988	2.750	2.618	2.529	2.621	2.792	3.103
04	2.948	3.158	3.338	3.469	3.595	3.629	3.617	3.555	3.420	3.261	2.985	2.755	2.606	2.523	2.523	2.741
05	2.725	2.914	3.091	3.304	3.474	3.628	3.714	3.707	3.652	3.519	3.247	3.012	2.757	2.576	2.423	2.459
06	2.558	2.651	2.811	3.012	3.209	3.430	3.640	3.740	3.782	3.711	3.508	3.252	2.986	2.745	2.472	2.302
07	2.528	2.451	2.531	2.651	2.833	3.112	3.342	3.580	3.746	3.785	3.668	3.485	3.217	2.954	2.619	2.399
08	2.581	2.453	2.387	2.366	2.448	2.653	2.915	3.225	3.496	3.677	3.715	3.628	3.433	3.155	2.804	2.480
09	2.648	2.510	2.375	2.228	2.133	2.243	2.435	2.701	3.060	3.348	3.540	3.626	3.535	3.354	2.997	2.651
10	2.778	2.568	2.400	2.229	2.017	1.994	2.057	2.236	2.477	2.819	3.159	3.410	3.510	3.444	3.185	2.870
11	2.890	2.696	2.494	2.280	2.057	1.909	1.859	1.919	2.081	2.327	2.576	2.970	3.257	3.389	3.283	3.040
12	2.976	2.813	2.643	2.431	2.159	1.972	1.826	1.719	1.774	1.922	2.101	2.422	2.818	3.165	3.248	3.162
13	2.995	2.917	2.750	2.581	2.327	2.124	1.913	1.756	1.674	1.667	1.781	2.000	2.350	2.735	3.051	3.175
14	2.904	2.945	2.897	2.760	2.559	2.338	2.117	1.908	1.744	1.633	1.588	1.706	1.946	2.305	2.737	3.069
15	2.742	2.903	2.922	2.898	2.778	2.611	2.387	2.154	1.944	1.759	1.625	1.612	1.732	1.965	2.365	2.831
16	2.505	2.783	2.909	2.986	2.937	2.862	2.683	2.455	2.260	2.014	1.791	1.690	1.697	1.794	2.053	2.492
17	2.359	2.594	2.814	2.976	3.040	3.034	2.954	2.786	2.585	2.366	2.084	1.911	1.852	1.854	1.971	2.258
18	2.250	2.473	2.649	2.915	3.028	3.137	3.124	3.015	2.936	2.739	2.449	2.242	2.074	1.986	2.020	2.177
19	2.272	2.401	2.550	2.773	2.960	3.099	3.190	3.187	3.141	3.021	2.814	2.618	2.419	2.256	2.193	2.269
20	2.336	2.413	2.484	2.647	2.812	2.990	3.149	3.215	3.271	3.239	3.094	2.975	2.797	2.595	2.462	2.415
21	2.508	2.514	2.527	2.637	2.690	2.843	2.999	3.128	3.251	3.310	3.275	3.220	3.131	2.954	2.781	2.677
22	2.736	2.685	2.631	2.636	2.634	2.709	2.835	2.982	3.130	3.233	3.280	3.369	3.339	3.242	3.104	2.961
23	2.965	2.912	2.814	2.752	2.703	2.700	2.688	2.779	2.916	3.063	3.177	3.322	3.422	3.417	3.336	3.284
Mean	2.761	2.791	2.807	2.826	2.808	2.822	2.824	2.820	2.829	2.819	2.762	2.755	2.755	2.767	2.766	2.802

HOUR	Jul 17	Jul 18	Jul 19	Jul 20	Jul 21	Jul 22	Jul 23	Jul 24	Jul 25	Jul 26	Jul 27	Jul 28	Jul 29	Jul 30	Jul 31	
00	3.514	3.373	3.180	2.993	2.778	2.625	2.586	2.678	2.821	3.048	3.228	3.317	3.411	3.444	3.438	
01	3.654	3.617	3.485	3.264	3.035	2.810	2.649	2.586	2.613	2.749	2.951	3.122	3.270	3.357	3.466	
02	3.620	3.720	3.720	3.573	3.322	3.071	2.848	2.682	2.573	2.590	2.680	2.834	3.030	3.195	3.394	Monthly
03	3.427	3.686	3.818	3.785	3.641	3.379	3.133	2.884	2.694	2.576	2.550	2.625	2.735	2.937	3.148	Max HWL
04	3.111	3.433	3.737	3.907	3.840	3.659	3.444	3.201	2.926	2.761	2.591	2.538	2.547	2.704	2.888	04:54/21
05	2.704	3.048	3.487	3.775	3.898	3.849	3.697	3.460	3.206	2.978	2.759	2.586	2.487	2.523	2.660	3.903
06	2.398	2.607	3.017	3.452	3.745	3.887	3.866	3.717	3.505	3.247	2.976	2.757	2.553	2.486	2.467	
07	2.215	2.254	2.539	2.948	3.376	3.678	3.851	3.828	3.704	3.501	3.210	2.928	2.697	2.545	2.448	
08	2.255	2.073	2.167	2.436	2.810	3.269	3.593	3.770	3.778	3.652	3.390	3.150	2.860	2.659	2.477	Monthly
09	2.319	2.064	1.953	2.018	2.299	2.662	3.083	3.430	3.637	3.659	3.504	3.302	3.031	2.809	2.571	Min LWL
10	2.483	2.155	1.884	1.806	1.896	2.146	2.526	2.942	3.284	3.486	3.479	3.358	3.144	2.948	2.725	14:24/11
11	2.691	2.304	1.993	1.757	1.696	1.794	2.071	2.397	2.758	3.107	3.252	3.294	3.203	3.055	2.856	1.579
12	2.876	2.544	2.195	1.877	1.664	1.603	1.743	1.981	2.282	2.618	2.907	3.090	3.119	3.107	2.975	
13	3.037	2.784	2.453	2.094	1.808	1.637	1.621	1.723	1.924	2.215	2.471	2.741	2.953	3.037	3.031	
14	3.088	2.995	2.738	2.387	2.076	1.816	1.662	1.644	1.740	1.919	2.149	2.402	2.658	2.905	2.975	Monthly
15	3.038	3.104	2.978	2.738	2.434	2.122	1.918	1.797	1.762	1.827	1.956	2.144	2.396	2.676	2.908	Mean
16	2.880	3.119	3.134	3.028	2.790	2.510	2.249	2.056	1.942	1.882	1.950	2.016	2.231	2.493	2.725	MSL
17	2.621	3.011	3.191	3.220	3.078	2.887	2.646	2.422	2.219	2.117	2.061	2.118	2.218	2.398	2.595	2.816
18	2.400	2.812	3.107	3.284	3.266	3.162	3.018	2.791	2.604	2.412	2.302	2.244	2.299	2.432	2.508	
19	2.323	2.600	2.938	3.179	3.300	3.316	3.273	3.162	2.978	2.775	2.615	2.496	2.465	2.490	2.527	
20	2.402	2.513	2.731	3.013	3.210	3.336	3.394	3.345	3.271	3.109	2.939	2.795	2.688	2.663	2.620	
21	2.554	2.550	2.605	2.755	3.012	3.214	3.345	3.401	3.415	3.335	3.215	3.075	2.963	2.884	2.766	
22	2.789	2.698	2.619	2.612	2.735	2.975	3.189	3.316	3.427	3.428	3.369	3.310	3.184	3.109	2.984	
23	3.073	2.920	2.760	2.631	2.613	2.707	2.912	3.118	3.300	3.400	3.407	3.429	3.373	3.308	3.178	
Mean	2.811	2.833	2.851	2.855	2.847	2.838	2.847	2.847	2.848	2.850	2.830	2.820	2.813	2.840	2.847	

[ ] denotes inferred water level values Data Status: Verified

Figure 4.4: Hourly Height Water Level Data for a Tide Station

HOURLY WATER LEVELS

National Ocean Service (NOAA) July 1998

Water Level Heights in meters IGLD (1985)

Station: 9052030 Oswego, Lake Ontario , NY Time Meridian: 75 W Data Type: Great Lakes

HOUR	Jul 1	Jul 2	Jul 3	Jul 4	Jul 5	Jul 6	Jul 7	Jul 8	Jul 9	Jul 10	Jul 11	Jul 12	Jul 13	Jul 14	Jul 15	Jul 16
01	75.21	75.21	75.19	75.18	75.19	75.17	75.15	75.17	75.17	75.20	75.21	75.21	75.20	75.17	75.17	75.17
02	75.25	75.21	75.19	75.19	75.22	75.14	75.17	75.16	75.19	75.19	75.20	75.22	75.18	75.17	75.18	75.16
03	75.26	75.21	75.19	75.17	75.19	75.18	75.18	75.16	75.16	75.19	75.21	75.19	75.18	75.18	75.15	75.17
04	75.25	75.20	75.19	75.20	75.21	75.18	75.17	75.16	75.17	75.20	75.21	75.18	75.17	75.18	75.16	75.16
05	75.25	75.21	75.20	75.19	75.21	75.18	75.17	75.20	75.20	75.18	75.21	75.20	75.19	75.17	75.19	75.16
06	75.25	75.21	75.19	75.20	75.20	75.19	75.17	75.16	75.19	75.20	75.20	75.20	75.17	75.17	75.14	75.15
07	75.25	75.20	75.19	75.19	75.19	75.17	75.18	75.20	75.20	75.19	75.21	75.20	75.18	75.17	75.14	75.17
08	75.24	75.21	75.19	75.21	75.20	75.17	75.17	75.14	75.19	75.20	75.22	75.20	75.19	75.15	75.18	75.15
09	75.24	75.21	75.19	75.20	75.19	75.19	75.16	75.17	75.18	75.18	75.22	75.20	75.19	75.18	75.16	75.14
10	75.24	75.20	75.19	75.18	75.19	75.18	75.16	75.20	75.17	75.20	75.22	75.22	75.18	75.18	75.17	75.16
11	75.23	75.19	75.17	75.18	75.20	75.18	75.15	75.15	75.19	75.20	75.22	75.20	75.19	75.18	75.16	75.15
12	75.22	75.21	75.18	75.18	75.17	75.17	75.17	75.16	75.17	75.19	75.22	75.20	75.18	75.18	75.17	75.16
13	75.22	75.20	75.18	75.19	75.18	75.16	75.16	75.15	75.17	75.18	75.21	75.19	75.19	75.17	75.16	75.16
14	75.23	75.20	75.19	75.21	75.18	75.19	75.14	75.15	75.16	75.18	75.20	75.22	75.17	75.17	75.18	75.17
15	75.22	75.21	75.17	75.19	75.17	75.15	75.14	75.18	75.17	75.19	75.20	75.18	75.18	75.17	75.17	75.17
16	75.21	75.20	75.19	75.18	75.19	75.16	75.18	75.18	75.17	75.19	75.19	75.19	75.17	75.16	75.16	75.16
17	75.21	75.20	75.20	75.21	75.20	75.17	75.17	75.18	75.17	75.19	75.20	75.18	75.17	75.17	75.17	75.15
18	75.22	75.20	75.20	75.21	75.21	75.20	75.18	75.18	75.15	75.17	75.20	75.18	75.16	75.15	75.16	75.16
19	75.21	75.20	75.19	75.21	75.19	75.19	75.18	75.20	75.18	75.22	75.19	75.19	75.17	75.16	75.16	75.17
20	75.20	75.22	75.19	75.25	75.19	75.17	75.18	75.18	75.20	75.22	75.20	75.20	75.16	75.16	75.16	75.13
21	75.20	75.18	75.18	75.15	75.19	75.19	75.15	75.19	75.22	75.18	75.21	75.19	75.18	75.16	75.15	75.17
22	75.21	75.20	75.17	75.17	75.19	75.18	75.19	75.17	75.23	75.20	75.21	75.19	75.18	75.18	75.15	75.13
23	75.20	75.19	75.17	75.24	75.19	75.16	75.18	75.19	75.22	75.22	75.21	75.17	75.18	75.16	75.17	75.13
24	75.21	75.20	75.17	75.20	75.18	75.17	75.17	75.19	75.18	75.21	75.21	75.18	75.18	75.15	75.16	75.15
Mean	75.23	75.20	75.19	75.19	75.19	75.18	75.17	75.17	75.18	75.20	75.21	75.19	75.18	75.17	75.16	75.16

HOUR	Jul 17	Jul 18	Jul 19	Jul 20	Jul 21	Jul 22	Jul 23	Jul 24	Jul 25	Jul 26	Jul 27	Jul 28	Jul 29	Jul 30	Jul 31	
01	75.17	75.17	75.14	75.12	75.13	75.14	75.11	75.16	75.14	75.11	75.09	75.07	75.07	75.10	75.09	
02	75.17	75.18	75.14	75.16	75.12	75.16	75.12	75.16	75.14	75.10	75.08	75.09	75.06	75.11	75.08	
03	75.16	75.19	75.15	75.15	75.11	75.16	75.12	75.15	75.13	75.10	75.08	75.06	75.06	75.10	75.08	Monthly
04	75.17	75.18	75.14	75.14	75.13	75.15	75.10	75.14	75.14	75.10	75.07	75.09	75.02	75.09	75.08	Max HWL
05	75.16	75.18	75.16	75.13	75.14	75.13	75.14	75.16	75.13	75.10	75.06	75.11	75.07	75.08	75.08	03:00/01
06	75.17	75.16	75.15	75.16	75.10	75.17	75.12	75.16	75.12	75.10	75.06	75.07	75.16	75.07	75.08	75.259
07	75.16	75.16	75.17	75.14	75.12	75.13	75.14	75.14	75.13	75.10	75.07	75.06	75.14	75.07	75.07	
08	75.16	75.16	75.14	75.15	75.15	75.12	75.14	75.16	75.13	75.10	75.06	75.08	75.11	75.05	75.07	
09	75.15	75.15	75.11	75.14	75.12	75.20	75.15	75.17	75.13	75.11	75.06	75.06	75.10	75.08	75.07	Monthly
10	75.16	75.15	75.11	75.14	75.11	75.18	75.10	75.15	75.13	75.12	75.08	75.07	75.11	75.07	75.06	Min LWL
11	75.16	75.16	75.13	75.14	75.11	75.16	75.11	75.16	75.12	75.11	75.08	75.06	75.11	75.06	75.07	04:00/29
12	75.16	75.17	75.16	75.14	75.12	75.12	75.13	75.14	75.11	75.11	75.09	75.07	75.12	75.10	75.07	75.021
13	75.16	75.15	75.14	75.14	75.12	75.14	75.13	75.14	75.11	75.10	75.07	75.05	75.08	75.08	75.07	
14	75.16	75.17	75.13	75.15	75.10	75.11	75.14	75.14	75.10	75.11	75.06	75.08	75.08	75.08	75.06	
15	75.17	75.16	75.13	75.13	75.12	75.12	75.12	75.13	75.11	75.09	75.07	75.06	75.07	75.08	75.05	Monthly
16	75.16	75.16	75.13	75.13	75.13	75.14	75.14	75.13	75.12	75.09	75.08	75.05	75.09	75.05	75.06	Mean
17	75.18	75.16	75.13	75.13	75.08	75.11	75.16	75.13	75.10	75.07	75.08	75.07	75.08	75.09	75.06	MSL
18	75.17	75.15	75.14	75.16	75.12	75.13	75.13	75.13	75.10	75.07	75.08	75.06	75.08	75.09	75.06	75.152
19	75.16	75.16	75.13	75.14	75.11	75.11	75.10	75.14	75.10	75.08	75.06	75.05	75.07	75.09	75.06	
20	75.17	75.16	75.16	75.15	75.12	75.13	75.16	75.14	75.11	75.09	75.06	75.07	75.09	75.07	75.06	
21	75.18	75.14	75.11	75.13	75.16	75.12	75.17	75.14	75.11	75.08	75.07	75.05	75.09	75.07	75.04	
22	75.18	75.15	75.14	75.13	75.10	75.15	75.17	75.14	75.11	75.08	75.07	75.06	75.09	75.08	75.06	
23	75.18	75.14	75.14	75.12	75.09	75.14	75.18	75.14	75.11	75.08	75.09	75.05	75.10	75.08	75.05	
24	75.19	75.14	75.11	75.11	75.09	75.12	75.17	75.15	75.11	75.09	75.10	75.08	75.09	75.09	75.06	
Mean	75.17	75.16	75.14	75.14	75.12	75.14	75.14	75.15	75.12	75.10	75.07	75.07	75.09	75.08	75.07	

[ ] denotes inferred water level values Data Status: Verified

Figure 4.5: Hourly Height Water Level Data for a Great Lakes Station

4.4 Computation of Tidal Datums and Water Level Datums

4.4.1 National Tidal Datum Epoch

Tidal datums must be computed relative to a specific 19 year tidal cycle adopted by the National Ocean Service (NOS) called the National Tidal Datum Epoch (NTDE). The present NTDE is the period 1983 through 2001. A primary datum determination is based directly on the average of tide observations over the 19 year Epoch period at NOS permanent long term primary control stations in the National Water Level Observation Network (NWLON). The data from NOS primary stations are used to compute datums at short term subordinate stations by reducing the data from those subordinate stations to equivalent 19 year mean values through the method of comparison of simultaneous observation.

4.4.2 Computational Procedures

The equivalent 19 year tidal datums for subordinate stations are computed for certain phases of the tide using tide-by-tide comparisons or monthly mean comparisons with an appropriate NOS long term control station. Accepted 19 year mean values of mean tide level (MTL), mean range (Mn), diurnal high water inequality (DHQ), diurnal low water inequality (DLQ), diurnal tide level (DTL), and great diurnal range (Gt) are required in the reduction process in which a "short series" of tide observations at any location are compared with simultaneous observations from an NOS control station. Datums are computed by the "standard" method of range ratio comparison generally on the West coast and Pacific Islands where there exists a large diurnal inequality in the low and high waters. The "modified" method of range ratio comparison is generally used on the East coast and Caribbean where small differences exist in the low and high water diurnal inequalities. For stations requiring a datum determination, at least 30 continuous days of tide observations are required for stations where adequate primary datum control exists. For error budget purposes, one month of data results in a datum accuracy of 0.11 m (95% confidence level) for Stations in the Gulf of Mexico and 0.08 m (95% confidence level) for east and West Coast stations. Examples of a tide by tide and a monthly mean simultaneous comparison for datum determination are found in Figures 4.6 and 4.7. Descriptions of the tidal datum computational procedures are found in the *Tide and Current Glossary, Tidal Datum Planes, Manual of Tide Observations, NOAA Special Publication NOS CO-OPS 1Tidal Datums and Their Applications and Computational Techniques for Tidal Datums.*

4.4.3 Tidal Datum Recovery

Whenever tide stations are installed at historical sites, measures shall be taken to "recover" the established tidal datums through leveling which shall be accomplished by referencing the gauge or tide staff zero "0" to more than one existing bench mark (three bench marks are preferred) with a published tidal elevation. Through this process, the published MLLW elevation is transferred by level differences to the "new" gauge or tide staff and compared to the MLLW elevation computed from the new data on the same zero "0". Factors affecting the datum recovery (i.e. differences between old and newly computed datums) include the length of each data series used to compute the datums, the geographical location, the tidal characteristics in the region, the length of time between reoccupations, the sea level trends in the region, and the control station used. Based on all of these factors, the datum recovery can be expected to vary from +/- 0.03 m to +/- 0.08 m. Hence, this process also serves as a very useful quality control procedure. After a successful datum recovery is performed and benchmark stability is established, the historical value of Mean Lower Low Water (MLLW) shall be used as the operational datum reference for data from the gauge during hydrographic survey operations. An example of a published tidal datum sheet for a station for which a datum recovery could be made is found in Figure 4.8.

```
Begin:   Jun 15 2005 00:00          COMPARISON OF SIMULTANEOUS OBSERVATIONS          Tidal Epoch:    1983-2001
End:     Jul 14 2005 23:54                                                          Expected Diff:  0.55 Hrs
Run:     Jan 31 2007 16:30                                                          * Exceeds 2 Standard Dev

(A) Subordinate Station:  9414863  RICHMOND, CHEVRON OIL PIER              Verified   T.M.:  0W   Tide Type:   Mixed
(B) Standard    Station:  9414290  SAN FRANCISCO, SAN FRANCISCO BAY        Verified   T.M.:  0W   Tide Type:   Mixed
```

(A) STATION Time of				(B) STATION Time of				(A) - (B) Time Difference		(A) STATION Height of		(B) STATION Height of		(A) - (B) Height Difference	
2005	HW Hour	Date	LW Hour	Date	HW Hour	Date	LW Hour	HW Hours	LW Hours	HW Meters	LW Meters	HW Meters	LW Meters	HW Meters	LW Meters
Jun 15	2.3 HH	Jun 15	8.4 L	Jun 15	2.0 HH	Jun 15	7.5 L	0.3	0.9	5.091	4.266	3.304	2.546	1.787	1.720
Jun 15	13.6 H	Jun 15	19.7 LL	Jun 15	13.2 H	Jun 15	19.0 LL	0.4	0.7	4.745	3.890	2.970	2.222	1.775	1.668*
Jun 16	3.0 HH	Jun 16	9.3 L	Jun 16	2.5 HH	Jun 16	8.4 L	0.5	0.9	5.193	4.065	3.412	2.362	1.781	1.703
Jun 16	15.0 H	Jun 16	20.5 L	Jun 16	14.6 H	Jun 16	19.7 L	0.4	0.8	4.731	4.070	2.953	2.350	1.778	1.720
Jun 17	3.4 HH	Jun 17	10.0 LL	Jun 17	3.0 HH	Jun 17	9.1 LL	0.4	0.9	5.347	3.861	3.566	2.144	1.781	1.717
Jun 17	16.1 H	Jun 17	21.4 L	Jun 17	15.7 H	Jun 17	20.6 L	0.4	0.8	4.736	4.140	2.960	2.418	1.776	1.722
Jun 18	4.0 HH	Jun 18	10.8 LL	Jun 18	3.5 HH	Jun 18	10.1 LL	0.5	0.7	5.400	3.657	3.612	1.919	1.788	1.738
Jun 18	17.4 H	Jun 18	22.2 L	Jun 18	17.0 H	Jun 18	21.6 L	0.4	0.6	4.793	4.265	3.015	2.539	1.778	1.726
Jun 19	4.5 HH	Jun 19	11.8 LL	Jun 19	4.1 HH	Jun 19	11.1 LL	0.4	0.7	5.528	3.440	3.728	1.714	1.800	1.726
Jun 19	18.6 H	Jun 19	23.0 L	Jun 19	18.1 H	Jun 19	22.4 L	0.5	0.6	4.833	4.365	3.057	2.626	1.776	1.739
Jun 20	5.2 HH	Jun 20	12.6 LL	Jun 20	5.0 HH	Jun 20	11.9 LL	0.2*	0.7	5.603	3.249	3.806	1.503	1.797	1.746
Jun 20	19.5 H	Jun 20	23.8 L	Jun 20	19.1 H	Jun 20	23.2 L	0.4	0.6	4.893	4.452	3.107	2.722	1.786	1.730
Jun 21	5.8 HH	Jun 21	13.4 LL	Jun 21	5.5 HH	Jun 21	12.9 LL	0.3	0.5	5.681	3.127	3.887	1.368	1.794	1.759
Jun 21	20.4 H	Jun 22	0.6 L	Jun 21	20.1 H	Jun 22	0.1 L	0.3	0.5	4.961	4.482	3.167	2.753	1.794	1.729
Jun 22	6.5 HH	Jun 22	14.2 LL	Jun 22	6.2 HH	Jun 22	13.6 LL	0.3	0.6	5.727	3.026	3.933	1.248	1.794	1.778
Jun 22	21.3 H	Jun 23	1.6 L	Jun 22	20.9 H	Jun 23	1.0 L	0.4	0.6	4.984	4.498	3.192	2.766	1.792	1.732
Jun 23	7.6 HH	Jun 23	15.0 LL	Jun 23	7.2 HH	Jun 23	14.4 LL	0.4	0.6	5.736	2.999	3.936	1.230	1.800	1.769
Jun 23	22.1 H	Jun 24	2.5 L	Jun 23	21.7 H	Jun 24	1.9 L	0.4	0.6	5.024	4.476	3.230	2.755	1.794	1.721
Jun 24	8.2 HH	Jun 24	15.9 LL	Jun 24	7.8 HH	Jun 24	15.1 LL	0.4	0.8	5.711	3.054	3.935	1.307	1.776	1.747
Jun 24	22.9 H	Jun 25	3.5 L	Jun 24	22.3 H	Jun 25	2.9 L	0.6	0.6	5.084	4.436	3.309	2.714	1.775	1.722
Jun 25	9.2 HH	Jun 25	16.6 LL	Jun 25	8.8 HH	Jun 25	15.7 LL	0.4	0.9	5.615	3.164	3.839	1.415	1.776	1.749
Jun 25	23.7 H	Jun 26	4.5 L	Jun 25	23.1 H	Jun 26	4.0 L	0.6	0.5	5.165	4.387	3.394	2.678	1.771	1.709
Jun 26	10.3 HH	Jun 26	17.5 LL	Jun 26	9.9 HH	Jun 26	16.6 LL	0.4	0.9	5.453	3.316	3.674	1.577	1.779	1.739
Jun 27	0.4 H	Jun 27	5.7 L	Jun 26	23.7 HH	Jun 27	5.1 L	0.7*	0.6	5.243	4.299	3.477	2.579	1.766*	1.720
Jun 27	11.4 HH	Jun 27	18.1 LL	Jun 27	10.8 H	Jun 27	17.3 LL	0.6	0.8	5.257	3.478	3.467	1.744	1.790	1.734
Jun 28	1.2 HH	Jun 28	6.9 L	Jun 28	0.6 HH	Jun 28	6.4 L	0.6	0.5	5.313	4.167	3.538	2.451	1.775	1.716
Jun 28	12.6 H	Jun 28	18.7 LL	Jun 28	12.1 H	Jun 28	18.1 LL	0.5	0.6	5.007	3.639	3.217	1.921	1.790	1.718
Jun 29	1.9 HH	Jun 29	8.2 L	Jun 29	1.4 HH	Jun 29	7.5 L	0.5	0.7	5.381	3.997	3.591	2.274	1.790	1.723
Jun 29	14.0 H	Jun 29	19.5 LL	Jun 29	13.6 H	Jun 29	18.9 LL	0.4	0.6	4.883	3.908	3.094	2.210	1.789	1.698
Jun 30	2.6 HH	Jun 30	9.3 LL	Jun 30	2.1 HH	Jun 30	8.7 LL	0.5	0.6	5.486	3.850	3.711	2.119	1.775	1.731
Jun 30	15.6 H	Jun 30	20.6 L	Jun 30	15.2 H	Jun 30	20.1 L	0.4	0.5	4.824	4.151	3.047	2.445	1.777	1.706
Jul 1	3.3 HH	Jul 1	10.3 LL	Jul 1	2.9 HH	Jul 1	9.8 LL	0.4	0.5	5.521	3.694	3.741	1.957	1.780	1.737
Jul 1	17.1 H	Jul 1	21.8 L	Jul 1	16.7 H	Jul 1	21.2 L	0.4	0.6	4.867	4.347	3.083	2.625	1.784	1.722
Jul 2	4.2 HH	Jul 2	11.3 LL	Jul 2	3.7 HH	Jul 2	10.7 LL	0.5	0.6	5.554	3.565	3.768	1.816	1.786	1.749
Jul 2	18.4 H	Jul 2	22.7 L	Jul 2	17.9 H	Jul 2	22.2 L	0.5	0.5	4.943	4.500	3.152	2.770	1.791	1.730
Jul 3	4.7 HH	Jul 3	12.2 LL	Jul 3	4.3 HH	Jul 3	11.5 LL	0.4	0.7	5.590	3.464	3.809	1.712	1.781	1.752
Jul 3	19.4 H	Jul 3	23.5 L	Jul 3	18.9 H	Jul 3	23.1 L	0.5	0.4	4.963	4.519	3.180	2.797	1.783	1.722
Jul 4	5.6 HH	Jul 4	12.9 LL	Jul 4	5.1 HH	Jul 4	12.2 LL	0.5	0.7	5.571	3.379	3.782	1.637	1.789	1.742
Jul 4	20.1 H	Jul 5	0.4 L	Jul 4	19.6 H	Jul 4	23.9 L	0.5	0.5	5.016	4.579	3.230	2.853	1.786	1.726
Jul 5	6.0 HH	Jul 5	13.5 LL	Jul 5	5.5 HH	Jul 5	12.7 LL	0.5	0.8	5.540	3.354	3.751	1.598	1.789	1.756
Jul 5	20.9 H	Jul 6	1.2 L	Jul 5	20.3 H	Jul 6	0.6 L	0.6	0.6	5.029	4.598	3.244	2.861	1.785	1.737
Jul 6	6.9 HH	Jul 6	14.1 LL	Jul 6	6.3 HH	Jul 6	13.5 LL	0.6	0.6	5.521	3.354	3.734	1.601	1.787	1.753
Jul 6	21.5 H	Jul 7	1.9 L	Jul 6	20.9 H	Jul 7	1.3 L	0.6	0.6	5.056	4.584	3.272	2.860	1.784	1.724

(a)

Figure 4.6: Tide-By-Tide Comparison

Begin: Jun 15 2005 00:00
End: Jul 14 2005 00:00
Run: Jan 31 2007 16:30

COMPARISON OF SIMULTANEOUS OBSERVATIONS

Tidal Epoch: 1983-2001
Expected Diff: 0.55 Hrs
* Exceeds 2 Standard Dev

(A) Subordinate Station: 9414863 RICHMOND, CHEVRON OIL PIER — Verified — T.M.: 0W — Tide Type: Mixed
(B) Standard Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY — Verified — T.M.: 0W — Tide Type: Mixed

(A) STATION Time of				(B) STATION Time of				(A) - (B) Time Difference		(A) STATION Height of		(B) STATION Height of		(A) - (B) Height Difference	
2005	HW Hour	Date	LW Hour	Date	HW Hour	Date	LW Hour	HW Hours	LW Hours	HW Meters	LW Meters	HW Meters	LW Meters	HW Meters	LW Meters
Jul 7	7.4 HH	Jul 7	14.8 LL	Jul 7	7.2 HH	Jul 7	13.9 LL	0.2*	0.9	5.510	3.380	3.715	1.622	1.795	1.758
Jul 7	22.0 H	Jul 8	2.4 L	Jul 7	21.4 H	Jul 8	1.9 L	0.6	0.5	5.037	4.533	3.248	2.822	1.789	1.711
Jul 8	8.0 HH	Jul 8	15.3 LL	Jul 8	7.6 HH	Jul 8	14.5 LL	0.4	0.8	5.444	3.397	3.660	1.654	1.784	1.743
Jul 8	22.5 H	Jul 9	3.0 L	Jul 8	21.9 H	Jul 9	2.4 L	0.6	0.6	5.016	4.478	3.225	2.775	1.791	1.703
Jul 9	8.7 HH	Jul 9	15.8 LL	Jul 9	8.2 HH	Jul 9	15.1 LL	0.5	0.7	5.375	3.453	3.587	1.719	1.788	1.734
Jul 9	23.1 H	Jul 10	3.7 L	Jul 9	22.5 H	Jul 10	3.2 L	0.6	0.5	5.036	4.462	3.245	2.760	1.791	1.702
Jul 10	9.5 HH	Jul 10	16.2 LL	Jul 10	8.9 HH	Jul 10	15.5 LL	0.6	0.7	5.267	3.541	3.476	1.802	1.791	1.739
Jul 10	23.6 H	Jul 11	4.5 L	Jul 10	23.1 H	Jul 11	4.0 L	0.5	0.5	5.059	4.432	3.260	2.728	1.799	1.704
Jul 11	9.9 HH	Jul 11	16.8 LL	Jul 11	9.5 HH	Jul 11	16.0 LL	0.4	0.8	5.153	3.622	3.365	1.900	1.788	1.722
Jul 12	0.1 H	Jul 12	5.5 L	Jul 11	23.7 H	Jul 12	4.9 L	0.4	0.6	5.110	4.359	3.325	2.651	1.785	1.708
Jul 12	10.8 H	Jul 12	17.2 LL	Jul 12	10.4 H	Jul 12	16.5 LL	0.4	0.7	4.992	3.705	3.211	1.998	1.781	1.707
Jul 13	0.6 HH	Jul 13	6.3 L	Jul 13	0.1 HH	Jul 13	5.8 L	0.5	0.5	5.155	4.294	3.362	2.565	1.793	1.729
Jul 13	11.7 H	Jul 13	17.8 LL	Jul 13	11.3 H	Jul 13	17.1 LL	0.4	0.7	4.875	3.899	3.090	2.204	1.785	1.695

	HW Hours	LW Hours	HHW	HLW	HHW	HLW	HHW	HLW
SUMS			152.709	122.201	102.699	74.045	50.010	48.156
ITEMS			28	28	28	28	28	28
MEANS			5.454	4.364	3.668	2.644	1.786	1.720
STD DEV							0.007	0.011
			LHW	LLW	LHW	LLW	LHW	LLW
SUMS	25.60	36.50	138.919	97.465	88.944	48.861	49.975	48.604
ITEMS	56	56	28	28	28	28	28	28
MEANS	0.46	0.65	4.961	3.481	3.177	1.745	1.785	1.736
STD DEV	0.11	0.13					0.008	0.024

(b)

Figure 4.6: Tide-By-Tide Comparison (continued)

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Begin:  Jun 15 2005 00:00                    COMPARISON OF SIMULTANEOUS OBSERVATIONS                  Tidal Epoch:   1983-2001
End:    Jul 14 2005 00:00                                                                             Expected Diff:  0.55 Hrs
Run:    Jan 31 2007 16:30                                                                             * Exceeds 2 Standard Dev

(A) Subordinate Station:  9414863  RICHMOND, CHEVRON OIL PIER              Verified    T.M.:  0W  Tide Type:        Mixed
(B) Standard    Station:  9414290  SAN FRANCISCO, SAN FRANCISCO BAY        Verified    T.M.:  0W  Tide Type:        Mixed

Mean Difference in HWI:    0.46                                  Mean Difference in LWI:    0.65
Mean HHW Height at (A):    5.454                                 Mean HLW Height at (A):    4.364
Mean LHW Height at (A):    4.961                                 Mean LLW Height at (A):    3.481
DHQ             at (A):    0.246                                 DLQ             at (A):    0.442
Mean HW Height  at (A):    5.208                                 Mean LW Height  at (A):    3.923
MN              at (A):    1.285                                 MTL             at (A):    4.565
GT              at (A):    1.973                                 DTL             at (A):    4.467

Mean HHW Difference:       1.786                                 Mean HLW Difference:       1.720
Mean LHW Difference:       1.785                                 Mean LLW Difference:       1.736
DHQ      Difference:       0.001                                 DLQ      Difference:      -0.008
Mean HW  Difference:       1.785                                 Mean LW  Difference:       1.728
MN       Difference:       0.058                                 MTL      Difference:       1.757
GT       Difference:       0.050                                 DTL      Difference:       1.761
MN       Ratio:            1.047                                 DHQ      Ratio:            1.003
GT       Ratio:            1.026                                 DLQ      Ratio:            0.982
MSL (100.00%)   at (A):    4.548
MSL (100.00%)   at (B):    2.782
MSL      Difference:       1.766

                           HWI    LWI     MTL     MN      MSL     DHQ     DLQ
                          Hours  Hours  Meters  Meters  Meters  Meters  Meters
Accepted  for B:           7.53   0.85   2.792   1.248   2.773   0.186   0.346
Differences and Ratios:    0.46   0.65   1.757   1.047   1.766   1.003   0.982
Corrected for A:           7.99   1.50   4.549   1.307   4.539   0.186   0.340

                                          FINAL/PRELIMINARY DATUMS   Standard Method

                                          MHHW  ---|---   5.388
                                                   |            DHQ   0.186
                                          MHW     -|-     5.202
                                                   |
                                          DTL     -|-     4.472
                                                   |                           GT    1.833
                                          MTL     -|-     4.549
                                                   |                           MN    1.307
                                          MSL     -|-     4.539
                                                   |                                                         Date          ID
                                          MLW     -|-     3.895
                                                   |            DLQ   0.340
                                          MLLW  ---|---   3.555                HWI:  7.99       Comparison  __________  ____

                                          On Staff Of:                         LWI:  1.50       Verified    __________  ____
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(c)

Figure 4.6: Tide-By-Tide Comparison (concluded)

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005)
1983-2001 TIDAL EPOCH

Feb 01, 2007

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER — Product — TM (Ow) — TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY — Product — TM (Ow) — TIDE TYPE (M)

Mon Year		M T L			M S L			H W I			L W I			M N	
	A	B	A - B	A	B	A - B	A	B	A - B	A	B	A - B	A	B	A / B
	METER	METER	METER	METER	METER	METER	HRS	HRS	HRS	HRS	HRS	HRS	METER	METER	RATIO
Jan 2005	4.665	2.900	1.765	4.650	2.876	1.774	7.890	7.450	0.440	1.380	0.750	0.630	1.293	1.212	1.067
Feb 2005	4.639	2.875	1.764	4.626	2.853	1.773	7.970	7.520	0.450	1.430	0.800	0.630	1.315	1.239	1.061
Mar 2005	4.593	2.813	1.780	4.575	2.791	1.784	7.890	7.450	0.440	1.320	0.690	0.630	1.288	1.207	1.067
Apr 2005	4.503	2.740	1.763	4.485	2.713	1.772	7.890	7.500	0.390	1.380	0.720	0.660	1.276	1.199	1.064
May 2005	4.563	2.805	1.758	4.542	2.773	1.769	7.890	7.480	0.410	1.430	0.720	0.710	1.281	1.209	1.060
Jun 2005	4.535	2.780	1.755	4.517	2.750	1.767	7.870	7.450	0.420	1.430	0.710	0.720	1.274	1.210	1.053
Jul 2005	4.607	2.856	1.751	4.590	2.826	1.764	7.950	7.490	0.460	1.460	0.840	0.620	1.284	1.231	1.043
Aug 2005	4.604	2.864	1.740	4.593	2.838	1.755	7.970	7.520	0.450	1.490	0.880	0.610	1.279	1.230	1.040
Sep 2005	4.571	2.838	1.733	4.565	2.819	1.746	7.880	7.460	0.420	1.420	0.830	0.590	1.273	1.225	1.039
Oct 2005		2.809			2.787			7.420			0.810			1.235	
Nov 2005		2.781			2.751			7.440			0.830			1.229	
Dec 2005		2.840			2.805			7.460			0.800			1.245	

Mon Year		D H Q			D L Q			M H W			M L W	
	A	B	A / B	A	B	A / B	A	B	A - B	A	B	A - B
	METER	METER	RATIO	METER	METER	RATIO	METER	METER	METER	METER	METER	METER
Jan 2005	0.227	0.224	1.013	0.401	0.406	0.988	5.312	3.506	1.806	4.019	2.294	1.725
Feb 2005	0.207	0.204	1.015	0.350	0.354	0.989	5.296	3.494	1.802	3.981	2.255	1.726
Mar 2005	0.154	0.152	1.013	0.329	0.324	1.015	5.237	3.417	1.820	3.949	2.210	1.739
Apr 2005	0.156	0.156	1.000	0.388	0.380	1.021	5.141	3.339	1.802	3.865	2.140	1.725
May 2005	0.179	0.179	1.000	0.431	0.427	1.009	5.204	3.409	1.795	3.923	2.200	1.723
Jun 2005	0.246	0.245	1.004	0.439	0.439	1.000	5.172	3.385	1.787	3.898	2.175	1.723
Jul 2005	0.258	0.257	1.004	0.429	0.441	0.973	5.249	3.471	1.778	3.965	2.240	1.725
Aug 2005	0.218	0.216	1.009	0.376	0.393	0.957	5.244	3.479	1.765	3.965	2.249	1.716
Sep 2005	0.161	0.156	1.032	0.305	0.324	0.941	5.207	3.451	1.756	3.934	2.226	1.708
Oct 2005		0.140			0.324			3.427			2.192	
Nov 2005		0.204			0.417			3.395			2.166	
Dec 2005		0.256			0.487			3.462			2.217	

Mon Year		D R L(TL)			G T			M H H W			M L L W	
	A	B	A - B	A	B	A / B	A	B	A - B	A	B	A - B
	METER	METER	RATIO	METER	METER	RATIO	METER	METER	METER	METER	METER	METER
Jan 2005	4.579	2.809	1.770	1.921	1.842	1.043	5.539	3.730	1.809	3.618	1.888	1.730
Feb 2005	4.567	2.800	1.767	1.872	1.797	1.042	5.503	3.698	1.805	3.631	1.901	1.730
Mar 2005	4.505	2.728	1.777	1.771	1.683	1.052	5.391	3.569	1.822	3.620	1.886	1.734
Apr 2005	4.387	2.628	1.759	1.820	1.735	1.049	5.297	3.495	1.802	3.477	1.760	1.717
May 2005	4.438	2.680	1.758	1.891	1.815	1.042	5.383	3.588	1.795	3.492	1.773	1.719
Jun 2005	4.439	2.683	1.756	1.959	1.894	1.034	5.418	3.630	1.788	3.459	1.736	1.723
Jul 2005	4.521	2.764	1.757	1.971	1.929	1.022	5.507	3.728	1.779	3.536	1.799	1.737
Aug 2005	4.526	2.776	1.750	1.873	1.839	1.018	5.462	3.695	1.767	3.589	1.856	1.733
Sep 2005	4.498	2.755	1.743	1.739	1.705	1.020	5.368	3.607	1.761	3.629	1.902	1.727
Oct 2005		2.718			1.699			3.567			1.868	
Nov 2005		2.674			1.850			3.599			1.749	
Dec 2005		2.724			1.988			3.718			1.730	

(a)

Figure 4.7: Monthly Mean Simultaneous Comparison Example

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005) Feb 01, 2007
1983-2001 TIDAL EPOCH

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER Product TM (OW) TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY Product TM (OW) TIDE TYPE (M)

	M T L	M S L	H W I	L W I	M N
	A - B	A - B	A - B	A - B	A / B
	METER	METER	HRS	HRS	RATIO
TOTAL MONTHS	9.000	9.000	9.000	9.000	9.000
SUMS	15.809	15.904	3.880	5.800	9.494
MEANS	1.757	1.767	0.431	0.644	1.055
ACCEPTED FOR B	2.792	2.773	7.535	0.848	1.248
CORRECTED FOR A	4.549	4.540	7.966	1.492	1.317

	D H Q	D L Q	M H W	M L W
	A / B	A / B	A - B	A - B
	RATIO	RATIO	METER	METER
TOTAL MONTHS	9.000	9.000	9.000	9.000
SUMS	9.090	8.893	16.111	15.510
MEANS	1.010	0.988	1.790	1.723
ACCEPTED FOR B	0.186	0.346	3.416	2.168
CORRECTED FOR A	0.188	0.342	5.206	3.891

	D R L(TL)	G T	M H H W	M L L W
	A - B	A / B	A - B	A - B
	METER	RATIO	METER	METER
TOTAL MONTHS	9.000	9.000	9.000	9.000
SUMS	15.837	9.322	16.128	15.550
MEANS	1.760	1.036	1.792	1.728
ACCEPTED FOR B	2.712	1.780	3.602	1.822
CORRECTED FOR A	4.472	1.844	5.394	3.550

METHOD	DATUM		VALUE
MODIFIED RANGE RATIO	MHHW	=	5.394
MODIFIED RANGE RATIO	MLLW	=	3.550
MODIFIED RANGE RATIO	DHQ	=	0.187
MODIFIED RANGE RATIO	DLQ	=	0.340
STANDARD	MHW	=	5.207
STANDARD	MLW	=	3.890
STANDARD	MHHW	=	5.395
STANDARD	MLLW	=	3.548
DIRECT	MN	=	1.315
DIRECT	GT	=	1.844
DIRECT	DHQ	=	0.188
DIRECT	DLQ	=	0.342

TABULATED ______________________

VERIFIED ______________________

FINAL/PRELIMINARY DATUMS

```
MHHW ---|--- 5.395
        |             DHQ  1.88
MHW    -|-   5.207
        |
MTL    -|-   4.549
        |                      GT  1.846
DTL    -|-   4.472
        |                      MN  1.317
MSL    -|-   4.540
        |
MLW    -|-   3.890
        |             DLQ 0.342
MLLW ---|--- 3.548

ON STAFF OF:
```

(b)

Figure 4.7: Monthly Mean Simultaneous Comparison (continued)

COMPARISON OF MONTHLY MEANS (Jan 2005 - Dec 2005)   Feb 01, 2007
1983-2001 TIDAL EPOCH

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER   Product   TM (OW)   TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY   Product   TM (OW)   TIDE TYPE (M)

O U T L I E R   R E P O R T

(MEAN DIFFERENCE EXCEEDS 2 STD. DEV. (MAX/MIN))

	M T L	M S L	H W I	L W I	M N	D H Q	D L Q	M H W	M L W	D T L	G T	M H H W	M L L W	
Std.Dev.	0.009	0.007	0.014	0.034	0.007	0.008	0.016	0.013	0.005	0.007	0.008	0.013	0.004	Std.Dev.
MAX	1.774	1.780	0.459	0.712	1.069	1.025	1.021	1.816	1.734	1.774	1.052	1.818	1.736	MAX
MIN	1.739	1.754	0.404	0.577	1.041	0.995	0.956	1.765	1.713	1.745	1.020	1.766	1.719	MIN
MON YEAR														
Jan 2005														Jan 2005
Feb 2005														Feb 2005
Mar 2005	1.780	1.784						1.820	1.739	1.777	1.052	1.822		Mar 2005
Apr 2005			0.390				1.021						1.717	Apr 2005
May 2005													1.719	May 2005
Jun 2005				0.720										Jun 2005
Jul 2005			0.460										1.737	Jul 2005
Aug 2005					1.040						1.018			Aug 2005
Sep 2005	1.733	1.746			1.039	1.032	0.941	1.756	1.708	1.743		1.761		Sep 2005
Oct 2005														Oct 2005
Nov 2005														Nov 2005
Dec 2005														Dec 2005

(c)

Figure 4.7: Monthly Mean Simultaneous Comparison (concluded)

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Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

To reach the tidal bench marks, proceed west along U.S. Highway 101 in the direction of the Golden Gate Bridge, then NW along Crissey Field Avenue (before the bridge) to the Golden Gate National Park (Presidio). The bench marks are located mostly along the coast in the vicinity. The tide gauge is located on the NE side of the National Parks Service wharf.

T I D A L B E N C H M A R K S

PRIMARY BENCH MARK STAMPING: 180 1936
DESIGNATION: 941 4290 TIDAL 180

MONUMENTATION: Tidal Station disk VM#: 967
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0702
SETTING CLASSIFICATION: Concrete sea wall

The primary bench mark is a disk set in the top of a 1 m (3 ft) high concrete seawall in Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, 15 m (50 ft) east of the NE corner of the Sanctuaries building, 6.10 m (20.0 ft) south of the south side of the garage building, and 1.07 m (3.5 ft) north of an angle in wall.

BENCH MARK STAMPING: BM 174 1925
DESIGNATION: 941 4290 TIDAL 174
ALIAS: TIDAL 174

MONUMENTATION: Tidal Station disk VM#: 971
AGENCY: US Coast and Geodetic Survey (USC&GS) PID: HT0697
SETTING CLASSIFICATION: Concrete monument

The bench mark is a disk set in a concrete post flush with the ground inside a circle of bricks in the pavement, 38.10 m (125.0 ft) west of the extended west edge of Engineer's Dock where it crosses Marine Drive, at the center of "Y" between Marine Drive and the road leading SE to Fort Winfield Scott, 12.95 m (42.5 ft) SW of the fire hydrant, and 8.69 m (28.5 ft) south of the south edge of an iron manhole cover.

(a)

Figure 4.8: Published Bench Mark Sheet

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National Ocean Service

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Station ID:	9414290	PUBLICATION DATE:	04/21/2003
Name:	SAN FRANCISCO CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: BM 176 1925
DESIGNATION: 941 4290 TIDAL 176
ALIAS: TIDAL 176

MONUMENTATION:	Tidal Station disk	VM#:	972
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0705
SETTING CLASSIFICATION:	Concrete step		

The bench mark is a disk set in the west end of the lowest concrete step at the main entrance to the porch of the building at No. 651 Mason Street, 29.87 m (98.0 ft) SE of the intersection of Crissey Field Avenue and Mason Street, 15.24 m (50.0 ft) south of the centerline of Mason Street, and 0.21 m (0.7 ft) above sidewalk.

BENCH MARK STAMPING: 181 1945
DESIGNATION: 941 4290 TIDAL 181
ALIAS: TIDAL 181

MONUMENTATION:	Tidal Station disk	VM#:	973
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0701
SETTING CLASSIFICATION:	Sea wall		

The bench mark is a disk set in NW corner of a sea wall at the Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, 62 m (204 ft) west of the inshore end of the pier, 45.87 m (150.5 ft) NW of a flag pole, 21.64 m (71.0 ft) NE of the north corner of Building S.F. 19.4 (paint shop and storage building), and 1.22 m (4.0 ft) above ground.

(b)

Figure 4.8: Published Bench Mark Sheet (continued)

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Station ID:	9414290	PUBLICATION DATE:	04/21/2003
Name:	SAN FRANCISCO CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: NO 2 1948
DESIGNATION: CLARK RM 2
ALIAS: 941 4290 TIDAL 183

MONUMENTATION:	Triangulation Station disk	VM#:	975
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0700
SETTING CLASSIFICATION:	Sea wall		

The bench mark is a disk set flush in the top of a sea wall west of the public fishing pier, 11.43 m (37.5 ft) west of the west edge of the pier, 8.08 m (26.5 ft) NE of the NE corner of corrugated iron building No. 985, and about 0.91 m (3.0 ft) above ground.

BENCH MARK STAMPING: CLARK 1948
DESIGNATION: CLARK
ALIAS: 941 4290 TIDAL 185

MONUMENTATION:	Triangulation Station disk	VM#:	976
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0698
SETTING CLASSIFICATION:	Concrete sea wall		

The bench mark is a disk set in the top of a concrete sea wall west of the public fishing pier, about 549 m (1800 ft) NW of the Gulf of Farallons National Marine Sanctuary headquarters in Golden Gate National Park, 24.23 m (79.5 ft) west of the west edge of the pier, 6.86 m (22.5 ft) NE of the NW corner of corrugated iron building No. 985, 3.05 m (10.0 ft) west of the NW corner of a stucco paint locker building, and 1.07 m (3.5 ft) above ground.

(c)

Figure 4.8: Published Bench Mark Sheet (continued)

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National Ocean Service

Station ID:	9414290	PUBLICATION DATE:	04/21/2003
Name:	SAN FRANCISCO CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: 4290 K 1976
DESIGNATION: 941 4290 K TIDAL

MONUMENTATION:	Tidal Station disk	VM#:	978
AGENCY:	National Ocean Service (NOS)	PID:	HT2255
SETTING CLASSIFICATION:	Bedrock		

The bench mark is a disk set vertically in bedrock on the south side of Marine Drive, 24 m (79 ft) SSW of the SE corner of the National Park Service building # T989, 14.69 m (48.2 ft) NW of bench mark BM 174 1925, and 2.44 m (8.0 ft) south of the road curb.

BENCH MARK STAMPING: 4290 L 1976
DESIGNATION: 941 4290 L TIDAL

MONUMENTATION:	Tidal Station disk	VM#:	979
AGENCY:	National Ocean Survey (NOS)	PID:	HT2253
SETTING CLASSIFICATION:	Bedrock		

The bench mark is a disk set in bedrock on the south side of Marine Drive, 114 m (375 ft) west of the National Park Service building # T989, 15.70 m (51.5 ft) SE of the eastern-most concrete and steel safety chain stanchion on the seawall, 7.77 m (25.5 ft) from the centerline of Marine Drive, and 1.22 m (4 ft) above street level.

(d)

Figure 4.8: Published Bench Mark Sheet (continued)

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National Ocean Service

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Station ID:	9414290	PUBLICATION DATE:	04/21/2003
Name:	SAN FRANCISCO CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: 4290 M 1982
DESIGNATION: 941 4290 M TIDAL

MONUMENTATION:	Tidal Station disk	VM#:	980
AGENCY:	National Ocean Survey (NOS)	PID:	HT3538
SETTING CLASSIFICATION:	Concrete foundation		

The bench mark is a disk set flush in concrete foundation in front of Stilwell Hall (building # 650) on Mason Street, 27.34 m (89.7 ft) south of the centerline of Mason street, 10.30 m (33.8 ft) east of the NE corner of the west wing of the Stilwell Hall, 6.07 m (19.9 ft) west of the west edge of the sidewalk leading to the entrance of Stilwell Hall, 0.30 m (1.0 ft) SE of the NW corner of the foundation, and 0.12 m (0.4 ft) above ground level.

BENCH MARK STAMPING: BM 175 1925
DESIGNATION: 941 4290 TIDAL 175
ALIAS: TIDAL 175

MONUMENTATION:	Tidal Station disk	VM#:	1829
AGENCY:	US Coast and Geodetic Survey (USC&GS)	PID:	HT0696
SETTING CLASSIFICATION:	Sea wall		

The bench mark is a disk set in top surface of the sea wall, near the National Park Service building at the intersection of the pavement and the seawall, 65.23 m (214.0 ft) NE of bench mark 4290 L 1976, 58.67 m (192.5 ft) west from the NW corner of the National Park Service building, 28.90 m (94.8 ft) WNW of the northern-most post of pedestrian gate, 6.86 m (22.5 ft) north of the centerline of Marine Drive, and 0.73 m (2.4 ft) south from the north edge of the sea wall.

(e)

Figure 4.8: Published Bench Mark Sheet (continued)

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Station ID:	9414290	PUBLICATION DATE:	04/21/2003
Name:	SAN FRANCISCO CALIFORNIA		
NOAA Chart:	18649	Latitude:	37° 48.4' N
USGS Quad:	SAN FRANCISCO NORTH	Longitude:	122° 27.9' W

T I D A L   B E N C H   M A R K S

BENCH MARK STAMPING: 4290 N 1995
DESIGNATION: 941 4290 N

MONUMENTATION:	Tidal Station disk	VM#:	15436
AGENCY:	National Ocean Service (NOS)	PID:	AE5209
SETTING CLASSIFICATION:	Concrete sea wall		

The bench mark is a disk set in a concrete seawall in Golden Gate National Park at the Gulf of Farallons National Marine Sanctuary headquarters, near an inshore end of a walkway leading to a pier, 13.70 m (44.9 ft) north of bottom of stairs leading to the Sanctuary building, 3.96 m (13.0 ft) east of a step in seawall, and 3.20 m (10.5 ft) west of the center of the walkway.

(f)

Figure 4.8: Published Bench Mark Sheet (continued)

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National Ocean Service

Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

T I D A L D A T U M S

Tidal datums at SAN FRANCISCO based on:

LENGTH OF SERIES:	19 Years
TIME PERIOD:	January 1983 - December 2001
TIDAL EPOCH:	1983-2001
CONTROL TIDE STATION:	

Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:

HIGHEST OBSERVED WATER LEVEL (01/27/1983)	= 2.640
MEAN HIGHER HIGH WATER (MHHW)	= 1.780
MEAN HIGH WATER (MHW)	= 1.595
MEAN TIDE LEVEL (MTL)	= 0.970
MEAN SEA LEVEL (MSL)	= 0.951
MEAN LOW WATER (MLW)	= 0.346
MEAN LOWER LOW WATER (MLLW)	= 0.000
NORTH AMERICAN VERTICAL DATUM-1988 (NAVD)	= -0.018
LOWEST OBSERVED WATER LEVEL (12/17/1933)	= -0.877

Bench Mark Elevation Information In METERS above:

Stamping or Designation	MLLW	MHW
180 1936	3.972	2.378
BM 174 1925	5.013	3.418
BM 176 1925	4.814	3.219
181 1945	3.987	2.392
NO 2 1948	4.221	2.626
CLARK 1948	4.233	2.639
4290 K 1976	5.828	4.234
4290 L 1976	6.620	5.025
4290 M 1982	3.705	2.111
BM 175 1925	4.160	2.566
4290 N 1995	3.646	2.051

(g)

Figure 4.8: Published Bench Mark Sheet (continued)

Station ID: 9414290 PUBLICATION DATE: 04/21/2003
Name: SAN FRANCISCO
CALIFORNIA
NOAA Chart: 18649 Latitude: 37° 48.4' N
USGS Quad: SAN FRANCISCO NORTH Longitude: 122° 27.9' W

D E F I N I T I O N S

Mean Sea Level (MSL) is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD 88).

NGVD 29 is a fixed datum adopted as a national standard geodetic reference for heights but is now considered superseded. NGVD 29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level on some early issues of Geological Survey Topographic Quads. NGVD 29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long term tide stations as fixed. Numerous local and wide-spread adjustments have been made since establishment in 1929. Bench mark elevations relative to NGVD 29 are available from the National Geodetic Survey (NGS) data base via the World Wide Web at http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=HT0702&EPOCH=1983-2001.

NAVD 88 is a fixed datum derived from a simultaneous, least squares, minimum constraint adjustment of Canadian/Mexican/United States leveling observations. Local mean sea level observed at Father Point/Rimouski, Canada was held fixed as the single initial constraint. NAVD 88 replaces NGVD 29 as the national standard geodetic reference for heights. Bench mark elevations relative to NAVD 88 are available from NGS through the World Wide Web at http://www.ngs.noaa.gov/cgi-bin/ngs_opsd.prl?PID=HT0702&EPOCH=1983-2001.

NGVD 29 and NAVD 88 are fixed geodetic datums whose elevation relationships to local MSL and other tidal datums may not be consistent from one location to another.

The Vertical Mark Number (VM#) and PID# shown on the bench mark sheet are unique identifiers for bench marks in the tidal and geodetic databases, respectively. Each bench mark in either database has a single, unique VM# and/or PID# assigned. Where both VM# and PID# are indicated, both tidal and geodetic elevations are available for the bench mark listed.

The NAVD 88 elevation is shown on the Elevations of Tidal Datums Table Referred to MLLW only when two or more of the bench marks listed have NAVD 88 elevations. The NAVD 88 elevation relationship shown in the table is derived from an average of several bench mark elevations relative to tide station datum. As a result of this averaging, NAVD 88 bench mark elevations computed indirectly from the tidal datums elevation table may differ slightly from NAVD 88 elevations listed for each bench mark in the NGS database.

(h)

Figure 4.8: Published Bench Mark Sheet (concluded)

4.4.4 Quality Control

It is essential for tidal datum quality control to have data processing and leveling procedures carried out to the fullest extent. Caution must also be used in computing tidal datums in riverine systems or in regions of unknown tidal regimes. Tide-by-tide comparisons between subordinate and control station data will often detect anomalous differences which should be investigated for possible gauge malfunction or sensor movement. Datums shall be established from more than one bench mark. Differences in elevations between bench marks based on new leveling must agree with previously established differences from the published bench mark sheets. Any changes in the elevation differences must be reconciled before using in any datum recovery procedure. Datum accuracy at a subordinate station depends on various factors, but availability and choice of an adequate control station of similar tidal characteristics, similar daily mean sea level and seasonal mean sea level variations, and similar sea level trends are the most important. The length of series will also determine accuracy. The longer the series, the more accurate the datum and the greater quality control and confidence gained from analyzing numerous monthly mean differences between the subordinate and control station. At reoccupied historical stations for which datum recoveries are made, updated datums shall be computed from the new time series and compared with the historical datums as the survey progresses.

4.5 Final Zoning and Tide Reducers

Data relative to MLLW from subordinate stations or from NWLON stations, as appropriate, shall be applied to reduce sounding data to chart datum, either directly or indirectly through a correction technique referred to as tidal zoning. Whether corrected or direct, time series data relative to MLLW or other applicable LWD applied to reference hydrographic soundings to chart datum are referred to as “tide reducers” or “water level reducers”.

4.5.1 Water Level Station Summaries

Data are reduced to mean values and subsequently adjusted to National Tidal Datum Epoch (NTDE) values for tidal datums and characteristic tidal attributes as prescribed in Section 4.4 and 4.5. “Summary files” shall be created for each subordinate tide station occupied for the survey. These summary data facilitate the development of corange and cophase lines and final zoning schemes. They also provide input into the NOS tidal datum bench mark publication process which supports navigation, boundary and shoreline determination, coastal engineering and management. NTDE values for Greenwich high and low water intervals, mean and diurnal ranges and high and low water inequalities shall be tabulated in these summary files which also contain the datums, the time and length of the series and NOS control station which was used to compute 19-year equivalent NTDE values. NTDE datums shall be tabulated in the summary file relative to a documented consistent station datum such as tide staff zero or arbitrary station datum. The elevation of the primary bench mark shall be provided in this summary relative to the same zero or station datum. Latitude and longitude positions shall also be provided. An example of a summary file is provided in Figure 4.9.

Summary file data from new station occupations and NOS provided summaries from historical occupation and control stations within the survey area shall be used as input data to the tidal zoning process.

4.5.2 Construction of Final Tidal Zoning Schemes

As tidal characteristics vary spatially, data from deployed water level gauges may not be representative of water levels across a survey area. Tidal zoning shall be implemented to facilitate the provision of time series water level data relative to chart datum for any point within the survey area such that prescribed accuracy requirements are maintained for the water level measurement component of the hydrographic survey. NOS currently utilizes the "discrete tidal zoning" method for operations, where survey areas are broken up into a scheme of zones bounding areas of common tidal characteristics. The minimum requirement is for a new zone for every 0.06 m change in mean range of tide and every 0.3 hour progression in time of tide (Greenwich high and low water intervals). Phase and amplitude corrections for appropriate tide station data shall be assigned to each zone.

As part of the process, tidal characteristics shall be accessed using geographic spatial placement of summary data in a commercial GIS compatible format to assess spatial variations in tidal characteristics. Corange and cophase maps shall be generated to provide the base for development of zoning schemes. Preliminary zoning, which is based on available historical tide station data and estuarine and global tide models, is referenced to an applicable predictions reference station for utilization during field work. For final processing, preliminary zoning shall be superseded by "final zoning" which is a refinement based on new data collected at subordinate stations during the survey. With the final zoning scheme, correctors for each zone shall be derived from a subordinate station specifically installed for the survey rather than the reference station used with preliminary zoning. For contract surveys, the contractor shall develop and utilize a zoning scheme to the specifications mentioned above such that water level reducers are within required accuracy across the entire survey area. Zoning errors shall be minimized such that when combined with errors from actual water level measurement at the gauge and errors in reduction to chart datum, the total error of the tide reducers is within specified tolerances. The final zoning scheme and all data utilized in its development shall be documented and submitted. Examples of zoning files and graphics are provided in Figures 4.10, 4.11, 4.12, 4.13, and 4.15 .

4.5.3 Tide Reducer Files and Final Tide Note

Verified time series data collected at appropriate subordinate stations are referenced to the NTDE Mean Lower Low Water (Chart Datum) through datum computation procedures outlined in Section 4.4. Time series data collected in six-minute intervals and reduced to chart datum as specified, both from subordinate gauges operated by the contractor and from NWLON stations where appropriate, shall be used either directly or corrected through use of a zoning scheme as determined appropriate by the contractor such that tide reducers are within specified tolerances. A Final Tide Note shall be submitted for each hydrographic sheet with information as to what final tidal zoning should be applied to which stations to obtain the final tide reducers. An example Final Tide Note and final tidal zoning graphic is found in Figure 4.15.

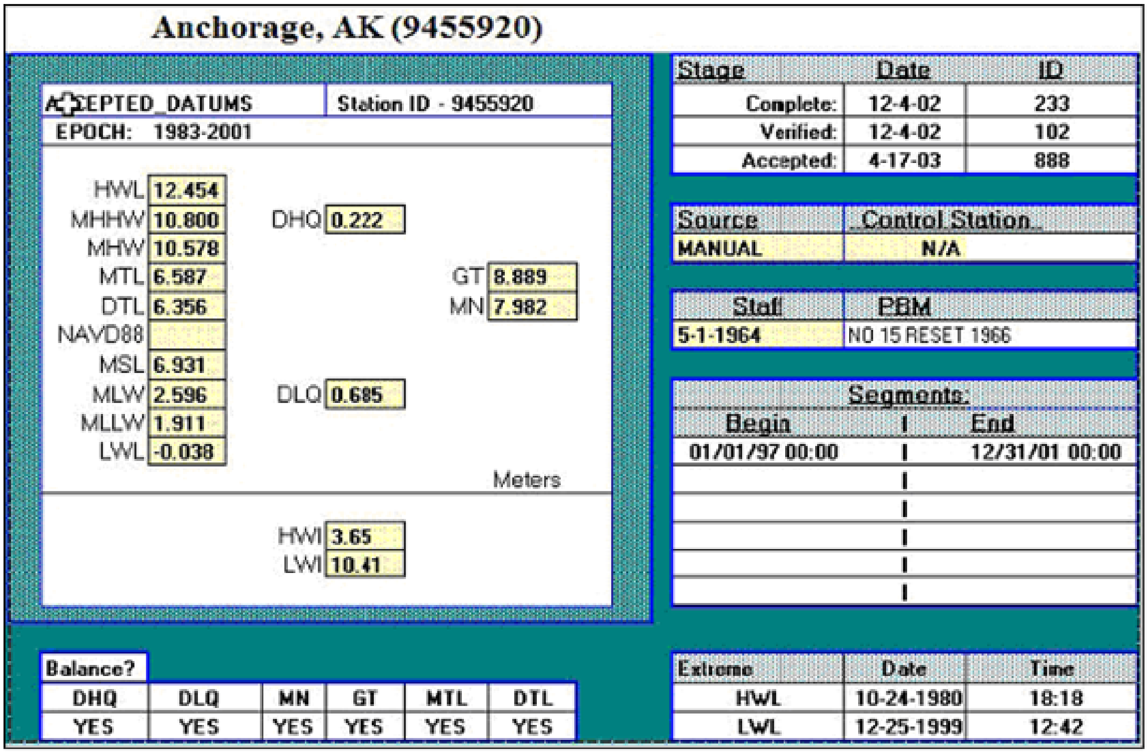


Figure 4.9: Tide Station Summary

STATION	NAME	ST	HWI	LWI	TCHHWI	TCLLWI	MN	DHQ	DLQ	GT	EPOCH	SERIES	HA_SERIES	COMP_STAT	COMMENTS	LATITUDE	LONGITUDE
9455176	BURNT ISLAND, JURNALAIN ARM	AK	3.67	10.25	N/A	N/A	28.0	0.8	2.4	31.2		4H/L,1912	N/A	Fire Island		60.950000000	-149.983333333
9455182	CAIRN POINT, KNIK HARBOR	AK	3.69	10.35	N/A	N/A	26.97	0.76	2.38	30.11		224H/L,1916	N/A	Anchorage staff		61.233333333	-149.916666667
9455697	SISTERS ROCK, COOK INLET	AK	0.31	6.85	N/A	N/A	16.31	0.85	2.02	19.18	41-59	34H/32L,Jul-Aug79	N/A	Seldovia		60.301666667-	-151.455000000
9455711	CAPE KASILOF, COOK INLET	AK	0.43	6.80	N/A	N/A	17.66	0.60	2.08	20.34	41-59	60H/L,Jun-Aug74	N/A	Seldovia		60.336666667	-151.380000000
9455715	KASILOF, KASILOF RIVER	AK			N/A	N/A						36H,Jul80	N/A		High waters only	60.358333333	-151.276666667
9455722	KALGIN ISLAND (WEST)	AK	0.36	6.71	N/A	N/A	15.63	0.71	1.90	18.24	41-59	126H/127L,Jun-Aug74	N/A	Seldovia	mean of 2 series	60.453333333	-151.956666667
9455728	LIGHT POINT, KALGIN ISLAND	AK	0.70	7.13	N/A	N/A	15.95	0.70	2.00	18.65		58H/L,Jul-Aug75	N/A	Nikiski		60.486666667	-151.835000000
9455735	CHINULNA POINT, COOK INLET	AK	0.68	7.22	N/A	N/A	17.89	0.74	2.02	20.65	60-78	1Mo,Jun85	N/A	Seldovia	3 series	60.503333333	-151.283333333
9455737	KENAI RIVER	AK	0.80		N/A	N/A		0.67			41-59	24Dy,Jul-Aug74	N/A	Nikiski	high waters only	60.521666667	-151.206666667
9455741	DRIFT RIVER	AK	0.69	7.04	N/A	N/A	15.58	0.68	1.93	18.19		64H/L,Jul-Aug74	N/A	Seldovia	superceded	60.555000000	-152.133333333
9455742	KENAI	AK	0.76	7.75	N/A	N/A	14.49	0.73	1.64	19.86	41-59	2Mo,Jun-Jul76	N/A	Seldovia		60.545000000	-151.218333333
9455760	NIKISKI	AK	1.22	7.60	N/A	N/A	17.69	0.70	2.08	20.47	60-78	5Yr,1972-75&77	N/A	Seldovia		60.683333333	-151.396666667
9455768	WEST FORELAND	AK	1.53	7.56	N/A	N/A	13.30	0.68	2.23	18.21	60-78	1Mo,Jul76	N/A	Seldovia		60.713333333	-151.710000000
9455769	NIKISHKA, 1ST EAST FURGUNA	AK	1.43	8.03	N/A	N/A	18.05	0.49	2.11	20.65		9H/L,1909	N/A	Seldovia		60.733333333	-151.333333333
9455771	PLATFORM DILLON,T-39,COOK INLET	AK	1.48	7.70	N/A	N/A	17.28						N/A		CHART 16660	60.736666667	-151.513333333
9455772	NIKISHKA #2, COOK INLET	AK	1.59	8.22	N/A	N/A	17.33	0.65	2.21	20.19	41-59	4Mo,Jul-Oct71	N/A	Seldovia		60.743333333	-151.308333333
9455779	SHELL PLATFORM, GIDDLE GROUND	AK	1.68	8.06	N/A	N/A	16.4					1Mo,1968	N/A		Chart 16660	60.795000000	-151.495000000
9455781	JUMBO ROCK, BOULDER POINT	AK	1.83	8.48	N/A	N/A	18.02	0.68	2.08	20.76	41-59	15H/L,Sep76	N/A	Nikiski		60.797000000	-151.170000000
9455782	DOLLY VARDEN PLATFORM,COOK INLET	AK	1.68	8.14	N/A	N/A	16.22	0.68	2.11	19.01		1Mo,Dec71	N/A	Anchorage		60.808333333	-151.636666667
9455783	TRADING BAY, COOK INLET	AK	1.47	7.88	N/A	N/A	16.5	0.8	2.20	19.50		22H,12L,1910	N/A	Seldovi/1st Red.		60.801666667	-151.776666667
9455787	GRAY CLIFFE	AK	1.95	8.56	N/A	N/A	19.47	0.79	2.08	22.32	41-59	2Mo,Jul-Aug77	N/A	Anchorage		60.833333333	-150.971666667
9455799	MIDDLE RIVER, COOK INLET	AK			N/A	N/A							N/A			60.911666667	-151.616666667
9455809	T-37 PLATFORM (OPR 469)	AK			N/A	N/A	16.82	0.63	2.15	19.60	60-78	24H/L,Jul75	N/A	Nikiski		60.928333333	-151.530000000
9455824	MOOSE POINT	AK	2.73	9.23	N/A	N/A	20.6	0.8	2.3	23.7		4H/L,1910	N/A	Chinulna Pt.		60.953300000	-150.731600000
9455826	MOOSE POINT T33 (OPR 469)	AK			N/A	N/A							N/A			60.975000000	-150.606666667
9455828	T-29 CHICALOON BAY,TURNAGAIN ARM	AK			N/A	N/A							N/A			60.966666667	-149.850000000
9455845	T-36 PLATFORM, OFF GRANITE POINT	AK	2.25	8.68	N/A	N/A	16.73	0.65	2.08	19.46		62h/l,Jul-Aug1975	N/A	Nikiski		61.000000000	-151.330000000
9455846	T-29 RAINBOW (OPR-469)	AK	3.59	11.28	N/A	N/A	27.51	0.59	1.56	29.66		20H/L,Jul1975	N/A	Anchorage		61.000000000	-149.640000000
9455856	TYONEK, COOK INLET	AK	2.32	8.77	N/A	N/A	17.5	0.8	2.3	20.6		4H/L,1910	N/A	Chinulna Pt.		61.020000000	-151.316666667
9455866	T-39 POINT POSSESSION (OPR-469)	AK	3.00	9.68	N/A	N/A	23.19	0.66	2.20	26.05	41-59	1Mo,Jul1975	N/A	Anchorage		61.036666667	-150.413000000
9455869	NORTH FORELAND	AK	2.71	9.03	N/A	N/A	17.88	0.61	2.08	20.57	41-59	107H/L,Jun-Aug1975	N/A	Nikiski	GP changed 5/5/98	61.048300000	-151.158300000
9455885	PHILLIPS PLATFORM	AK	2.79	9.21	N/A	N/A	19.20	0.64	2.19	13.04	60-78	1Mo,Jul1975	N/A	Anchorage	not verified	61.076700000	-150.951666667
9455909	THREE MILE CREEK, COOK INLET	AK	2.68	9.16	N/A	N/A	19.2	0.8	2.3	22.3		7H/8L,1919	N/A	Chinulna Pt.		61.143333333	-151.075000000
9455911	FIRE ISLAND (WEST SIDE)	AK			N/A	N/A	24.6	0.7	2.2	27.5		22H/21L,May1941	N/A			61.156666667	-150.240000000
9455912	FIRE ISLAND	AK	3.27	10.00	N/A	N/A	24.01	0.65	2.08	26.74	60-78	108H/107LMay-Jun1962	N/A	Anchorage		61.173333333	-150.213333333
9455915	PT. WORONZOF	AK	3.41	10.15	N/A	N/A	24.43	0.68	2.12	27.23	60-78	2Mo,Jul-Aug1971	N/A	Anchorage		61.196666667	-150.030000000
9455920	ANCHORAGE, KNIK ARM, COOK INLET	AK	3.72	10.42	N/A	N/A	26.25	0.71	2.28	29.24	60-78	8Yr,1984-91	N/A	Seldovia		61.238333333	-149.888333333
9455921	ANCHORAGE (ADR)	AK			N/A	N/A							N/A			61.238333333	-149.888333333
9456043	HARRIET POINT	AK	0.50	6.72	N/A	N/A	14.19	0.70	1.95	16.84	41-59	100H/99L,Jun-Jul1974	N/A	Seldovia		60.403333333	-152.255000000
9456094	REDOUBT PT	AK	0.33	6.50	N/A	N/A	14.01	0.44	1.95	16.40	41-59	1Mo,Jul75	N/A	Nikiski		60.301666667	-152.385000000

Figure 4.10: GIS Summary Data File

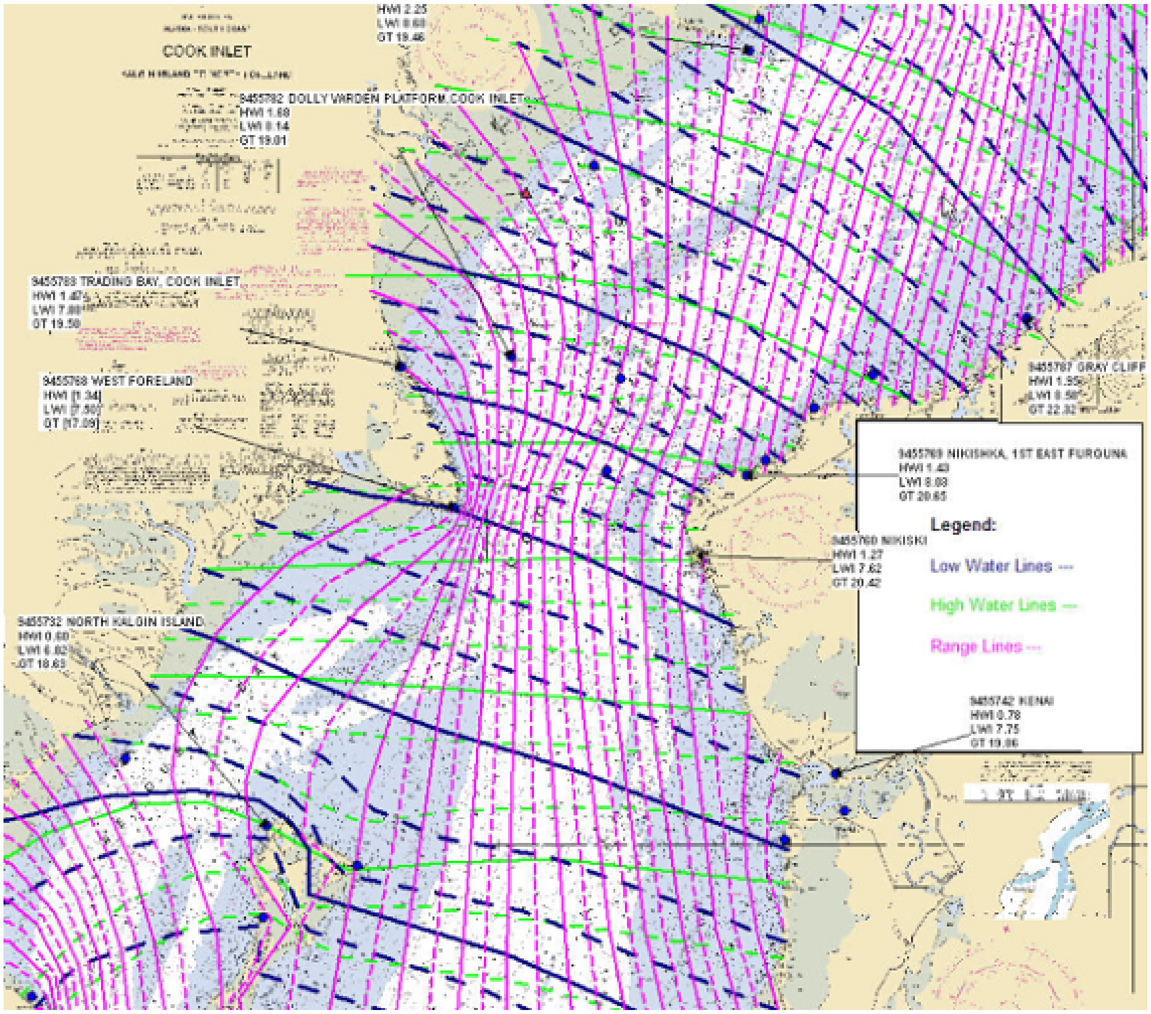


Figure 4.11: Corange Line of Greenwich, High and Low Water Intervals (in hours)

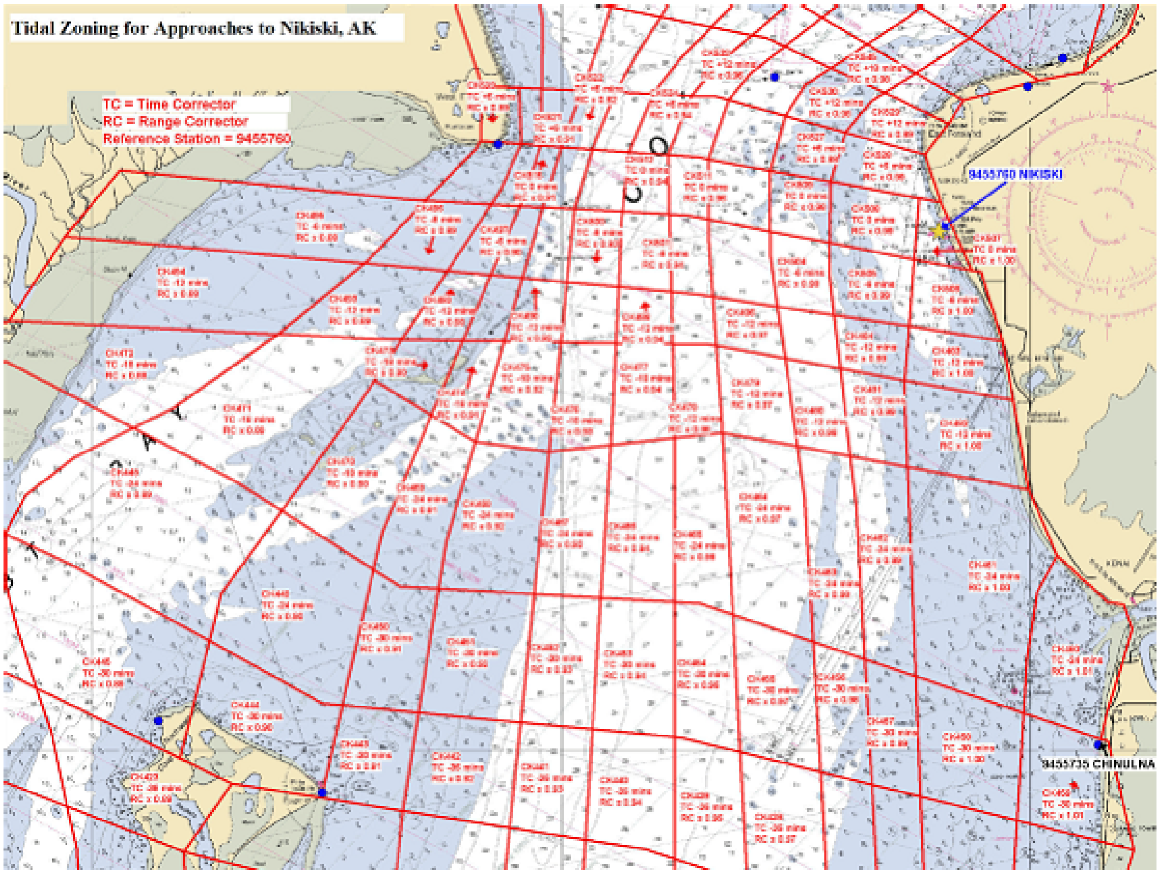


Figure 4.12: Tidal Zoning for Approaches to Nikiski, Alaska

STATION	DATE/TIME utc	WL VALUE on MLLW meters	WL SIGMA meters	inferred	flat	quality control flags: rofc	temp
9414290	10/1/98 0:00	1.373	0.042	0	0	0	0
9414290	10/1/98 0:06	1.390	0.043	0	0	0	0
9414290	10/1/98 0:12	1.403	0.036	0	0	0	0
9414290	10/1/98 0:18	1.424	0.039	0	0	0	0
9414290	10/1/98 0:24	1.426	0.033	0	0	0	0
9414290	10/1/98 0:30	1.436	0.034	0	0	0	0
9414290	10/1/98 0:36	1.458	0.032	0	0	0	0
9414290	10/1/98 0:42	1.489	0.035	0	0	0	0
9414290	10/1/98 0:48	1.507	0.032	0	0	0	0
9414290	10/1/98 0:54	1.520	0.038	0	0	0	0
9414290	10/1/98 1:00	1.533	0.042	0	0	0	0
9414290	10/1/98 1:06	1.537	0.029	0	0	0	0
9414290	10/1/98 1:12	1.541	0.033	0	0	0	0
9414290	10/1/98 1:18	1.548	0.032	0	0	0	0
9414290	10/1/98 1:24	1.572	0.033	0	0	0	0
9414290	10/1/98 1:30	1.596	0.037	0	0	0	0
9414290	10/1/98 1:36	1.609	0.039	0	0	0	0
9414290	10/1/98 1:42	1.624	0.036	0	0	0	0
9414290	10/1/98 1:48	1.639	0.040	0	0	0	0
9414290	10/1/98 1:54	1.638	0.036	0	0	0	0
9414290	10/1/98 2:00	1.649	0.032	0	0	0	0
9414290	10/1/98 2:06	1.658	0.036	0	0	0	0
9414290	10/1/98 2:12	1.659	0.033	0	0	0	0
9414290	10/1/98 2:18	1.660	0.041	0	0	0	0
9414290	10/1/98 2:24	1.671	0.029	0	0	0	0
9414290	10/1/98 2:30	1.669	0.039	0	0	0	0
.	.	.	.				
.	.	.	.				
.	.	.	.				
.	.	.	.				
9414290	11/30/98 23:00	0.350	0.120	0	0	0	0
9414290	11/30/98 23:06	0.342	0.124	0	0	0	0
9414290	11/30/98 23:12	0.343	0.090	0	0	0	0
9414290	11/30/98 23:18	0.359	0.106	0	0	0	0
9414290	11/30/98 23:24	0.389	0.079	0	0	0	0
9414290	11/30/98 23:30	0.412	0.087	0	0	0	0
9414290	11/30/98 23:36	0.446	0.128	0	0	0	0
9414290	11/30/98 23:42	0.459	0.102	0	0	0	0
9414290	11/30/98 23:48	0.399	0.089	0	0	0	0
9414290	11/30/98 23:54	0.463	0.136	0	0	0	0

Figure 4.13: Example Tide Reducer File from NOAA Acoustic System

4.6 Data Submission Requirements

Data submission requirements for water level measurement stations are comprised of both supporting documents for the installation, maintenance, and removal of stations, and the formatted digital water level data collected by the water level measurement system required for NOS quality control and ingestion into the NOS data base management system. In addition, documentation for processing and tabulation of the data, tidal datum computation, and final tidal zoning are required.

Data submission requirements for GPS project consists of project reports, station (bench mark) description or recovery notes, observation log sheets, station visibility diagrams, photographs or rubbings of station marks, raw GPS data, RINEX GPS data, and other info as pertinent.

4.6.1 Station Documentation

The documentation package shall be forwarded to CO-OPS after a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to Section 4.6.6 for time frames for documentation submission requirements and Figure 4.14, Water Level Station Documentation Checkoff List. The station documentation generally includes, but is not limited to the following:

1. Transmittal letter (PDF format).
2. Field Tide Note (PDF format), if applicable.
3. Calibration test documentation from an independent source other than the manufacturer for each sensor used to collect water level or ancillary data. (PDF format).
4. E-Site Report, Water Level Station Xpert Site Report, or Tide Station Report (NOAA Form 77-12), or equivalent. (E-Site report application is in web based electronic format, Water Level Station Xpert Site Report or Tide Station report in Microsoft Excel format). Contractor created Site Reports are acceptable as long as the reports provide same required information.
5. Google Chartlet, or NOAA Chartlet with chart number or map name and scale shown including standard NOS title block (JPEG and PDF format).
6. U.S. Geological Survey quadrangle map (7.5 minutes map) indicating the exact location of the station, with map name and scale shown (JPEG and PDF format).
7. Sensor test worksheet (JPEG and PDF format) (applicable for acoustic gauges).
8. Sensor elevation drawing (JPEG and PDF format) showing sea floor, pier elevation, and sensor elevation if sensor is mounted vertically.
9. Water level transfer form (applicable for Great Lakes stations only, in JPEG and PDF format).
10. Large-scale bench mark location sketch of the station site showing the relative location of the water level gauge, staff (if any), bench marks, and major reference objects found in the bench mark descriptions. The bench mark sketch shall include an arrow indicating north direction, a title block, and latitude and longitude (derived from handheld GPS) of the gauge (JPEG and PDF format).
11. New or updated description of how to reach the station from a major geographical landmark (in Microsoft Word and PDF format). (Refer to User's Guide for Writing Bench Mark Descriptions, NOAA/NOS, Updated January 2003).

12. Bench mark descriptions with handheld GPS coordinates (in Microsoft Word and JPEG format) (Refer to User's Guide for Writing Bench Mark Descriptions, NOAA/NOS, Updated January 2003).

13. Digital photographs of bench mark disk faces, setting, bench mark locations from two different (perpendicular) cardinal directions, station, DCP, equipment, underwater components, and vicinity (JPEG and PDF format). As a minimum, photographs shall show a view of the water level measurement system as installed, including sensors and DCP; a front view of the staff (if any); multiple views of the surroundings and other views necessary to document the location; and photographs of each bench mark, including a location view and a close-up view showing the bench mark disk (face) stamping. Bench mark photo file names start with mark designation followed by either "face" or "location" and direction of view, with jpg extension (e.g. 8661070 B location south.jpg). All other station component photo file names start with station number and view name (e.g. 8661070 tide station view south).

14. Level records (raw levels) including level equipment information (electronic files) and field notes of precise leveling, if applicable.

15. Level abstract (electronic file for optical and barcode levels).

16. Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor "zero" measurement point is referenced to the bench marks.

17. Calibration certificates for Invar leveling rods, if applicable (in PDF format).

18. Staff to gauge observations, if applicable (in Microsoft Excel and PDF format).

19. Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable (in PDF format).

20. Other information as appropriate, or as specified in the contract (in PDF format).

21. Water level data download.

22. GPS Project report, GPS observations in raw and RINEX format, GPS observations log sheets, antenna height measurements, visibility diagrams, OPUS results, as required GPS documentation, if applicable, (all in various electronic format). The GPS documentation requirements are described in detail in the next Section 4.6.2.

4.6.2 GPS Project Documentation

The following information in addition to the results obtained from OPUS shall be submitted to CO-OPS at the end of the project (see the time frames for submission of GPS data later in Section 4.6.6) so that proper information can be forwarded to NGS for blue-booking purposes.

This documentation is important because most of the information is used to submit the GPS data to NGS. In addition to the log, data must comply with the "Data Submission to NGS Section" of NGS-58 and the "Input Formats and Specifications of the National Geodetic Survey (NGS) Data Base" to become part of the NSRS.

GPS data collected by contractors or NOAA Ships for hydrographic survey support, or special projects shall be processed by the parties, and final data product - Receiver Independent Exchange Format (RINEX) data and appropriate forms - shall be submitted to CO-OPS which will be forwarded to NGS, as per the contracts, project instructions, Statement of Work, or as appropriate.

GPS forms in PDF format can be found at the following NGS Federal Base Network web site: `http://www.ngs.noaa.gov/PROJECTS/FBN/index.htm`

Refer to Figure 4.16 through Figure 4.22 for GPS projects submission checklist and sample package contents.

- Project report (Refer to Figure 4.16): One project report per GPS project is required.
- Station (bench mark) description or recovery notes (Refer to Figure 4.17): One per bench mark, for which GPS observations are submitted, is required.
- Observation log sheets (Refer to Figure 4.18 and Figure 4.19): One per each GPS observation session is required.
- Station/bench mark visibility diagrams (Refer to Figure 4.20): One per each bench mark, for which GPS observations are submitted, is required.
- Photographs or rubbings of station (bench) marks (Refer to Figure 4.22 and Figure 4.21): One per each bench mark, for which GPS observations are submitted, is required.
- Raw GPS data
- RINEX GPS data
- OPUS results

I. **For Each Water Level Station:**

PROJECT DOCUMENTATION AND DATA CHECKOFF LIST

Project Number: ______________ **Locality:** ______________________

Station Number: ______________ **Station Name:** __________________

A. Field Tide Note (Required only for Hydrographic /Photogrammetry Surveys)

	1. Verify station latitude and longitude with handheld GPS.
	2. Verify work dates.

B. Site Report (required for both installation and removal)

	1. All applicable information complete, especially serial numbers of DCP/sensors and dates of installation/removal of DCP/sensors and levels
	2. Verify latitude and longitude of the station (ensure that this is the same as on the field tide note for Hydro/Photo surveys). Provide latitude and longitude in d/m/s.x format as determined by handheld GPS for the primary sensor.
	3.. Note UTC time and date the datum offset and sensor offset entered or changed in the DCP
	4. Provide metadata for ancillary sensors, if installed and as required
	5. Provide notes on results of diving inspection, and cleaning of underwater components.
	6. Provide status of valid tie to NAVD 88 geodetic marks, if applicable, in level section remarks area.
	7. Provide notes of excessive movement of water level sensor or bench marks in level section remarks area.

C. Chart Section

	1. Ensure that station location is clearly depicted with circle and station number.
	2. Standard title block includes : station number, station name, lat/long as d/m/s.x,, NOAA chart number, edition, date, and scale, USGS quad name all in caps.
	3. Provide a digital copy of the chart section in jpg format

D. Bench Mark/Station Location Sketch

	1. Ensure Gage/staff and bench marks are shown, and local body of water is labeled.
	2. Ensure Standard Title block includes: station number and station name, field unit, date of revision
	3. Ensure North arrow depicted.
	4. Include hard copy sketch and GIS digital format on diskette.
	5. Ensure All active (recovered and not recovered) bench marks are identified by designations
	6. Ensure bench marks that are confirmed as destroyed are removed from the sketch.
	7. Provide a digital copy of the sketch saved in jpg format.

(a)

Figure 4.14: Project Documentation and Data Checkoff List

E. **Digital Photographs**

	1. Provide digital photographs of gauge, staff, surrounding area, wells and brackets, DCP. Provide tide gauge photos from two perpendicular directions.
	2. Station component file name starts with station number followed by the specific component view, with jpg extension (e.g. 86610170 well.jpg)
	3. Provide several shots of met towers and sensors from different directions (e.g. 8661070 met tower looking SW.jpg)
	4. Provide digital bench mark photos – close up of disk face, without GPS handheld in view, and setting view, two photos from different directions (90 degrees apart, if possible) showing general location for all new marks. File names start with mark designation followed by either "face" or "location" and direction of view, with jpg extension (e.g. 866 1070 B location south.jpg)

F. **Bench Mark Descriptions/Recovery Notes**

	1. Stampings for new and recovered marks verified.
	2. Descriptions for new marks provided in NOS format (MS Word).
	3. Recovery notes provided for all historical marks. RAD/xxx noted for all marks recovered as described, where xxx is party chief, or contractor initial.
	4. Provide handheld GPS position in d/m/s.x format at the end of the text description.
	5. For electronic levels, make sure HA files codes are completed accurately
	6. For electronic levels, text description begins with a statement on how to reach the mark, followed by the description in NOS format
	7. For electronic levels, provide handheld GPS position in d/m/s format at the end of the text in HA file since HA file does not accept decimal seconds s.x

G. **Levels**

	1. Ensure all information written in ink.
	2. Cover information complete; station name, number, instrument and rod type, serial numbers, date, personnel.
	3. Note type of levels: installation, bracketing and closing.
	4. Staff information complete (if applicable).
	5. Collimation check shown.
	6. Note that bench mark descriptions are submitted on separate sheets.
	7. Headers on all applicable pages complete.
	8. For multi year projects, or for NWLON, all marks must be connected every two years
	9. Levels include marks specially noted in station specific requirements of the project instructions
	10. Explanation provided for any marks not leveled during this level run.
	11. Provide sectional and overall closure tolerances and ascertain they are within allowable limits.
	12. Compute level abstract starting with PBM accepted elevation and ending with primary sensor elevation
	13. Check for valid tie to NAVD 88, as applicable.

(b)

Figure 4.14: Project Documentation and Data Checkoff List (continued)

	14. For electronic levels, provide original IN file in separate folder if modified IN file is provided.
	15. For electronic levels, all file dates must be chronologically consistent, i.e. the HA and INX files can not have dates more recent than the ABS file
	16. For electronic levels, provide Invar rod calibration certificates for the first time digital leveling
	17. For electronic levels, error flags are not allowed on sectional distances of the ABS file

H. <u>Datum Offset Computation Worksheet</u>

	1. Submit for stations that have Vitel or Sutron DCP with Aquatrak sensor.

I. <u>Data Submitted on Diskettes or CD-ROM or DVD</u>

	1. Label diskettes with contractor name and list of files on each diskettes.
	2. Data files should be named in the following format: xxxxxxx1.w1.dat, where xxxxxxx = seven digit station number and 1 is the DCP designation. For multiple files from the same station, change the extension, i.e., xxxxxxx1.w1.da1, da2, etc.
	3. Check the begin and end dates of data submitted with dates of hydrographic surveying operations, or project duration for special projects.
	4. Check data continuity.

J. <u>Transmittal Letter</u>

	1. Transmittal letter attached with current contractor address, phone number and email.

K. <u>All Documentation Enclosed in Tide Level Envelope (NOAA Form 75-29A)</u>

	1. Leave "sheets" box blank, complete other information in title boxes.
	2. Verified complete by contractor and Include date.

II. <u>For the Project:</u>

A. <u>Files</u>

	1. Contractor created station summary files for subordinate stations
	2. Documentation of tidal zoning development steps; including methodology of tidal reducer computation and geographical presentation
	3. GIS compatible digital final zoning files (Mapinfo© or ArcGIS© format)
	4. Final Tide Reducer Files for each H-Sheet

B. Final Tide Notes

	1. Final Tide Note for each H-Sheet

(c)

Figure 4.14: Project Documentation and Data Checkoff List (continued)

C. Transmittal Letter

	1. Transmittal letter attached with current contractor address, phone number and email.

D. All Documentation Enclosed in Tide Level Envelope (NOAA Form 75-29A)

	1. Leave "sheets" box blank, complete other information in title boxes.
	2. Verified complete by contractor and Include date.

(d)

Figure 4.14: Project Documentation and Data Checkoff List (concluded)

FINAL TIDE NOTE and FINAL TIDE ZONING CHART

DATE: December 22, 1999

HYDROGRAPHIC BRANCH: Pacific
HYDROGRAPHIC PROJECT: OPR-342-RA-99
HYDROGRAPHIC SHEET: H-10910

LOCALITY: 6 NM Northwest of Cape Kasilof, AK

TIME PERIOD: July 22 - August 20, 1999

TIDE STATION USED: 945-5711 Cape Kasilof, AK
Lat. 60° 20.2'N Lon. 151° 22.8'W
PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters
HEIGHT OF HIGH WATER ABOVE PLANE OF REFERENCE: 5.850 meters

REMARKS: RECOMMENDED ZONING
Use zone(s) identified as: CK394, CK395, CK399, CK400, CK401,
CK407, CK408, CK409, CK434, CK435, CK441, CK442, CK443, CK467, CK468, CK469, CK470, CK477, CK480, CK481, CK482, CK483, CK493 & CK494.

Refer to attachments for zoning information.

Note 1: Provided time series data are tabulated in metric units (Meters), relative to MLLW and on Greenwich Mean Time.

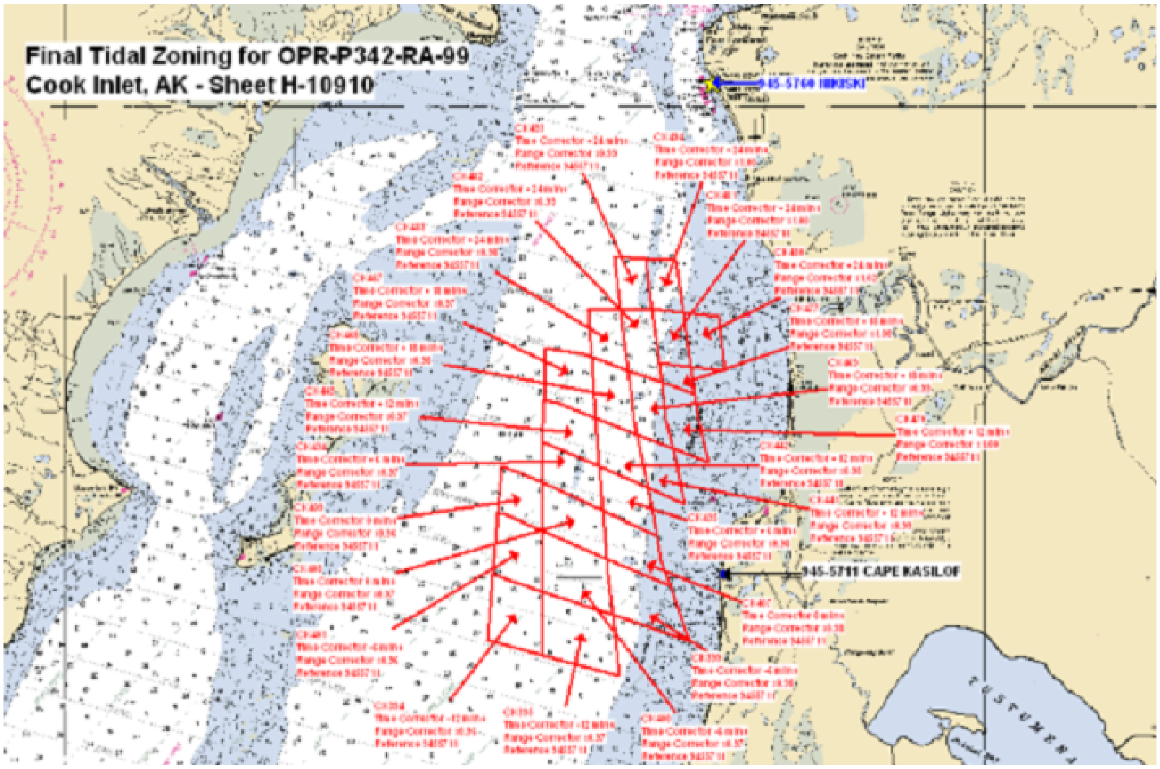
Note 2: Nikiski, AK served as datum control for subordinate tide stations and for tidal zoning in this hydrographic survey. Accepted datums for this station have been updated recently and have changed significantly from previous values.

The current National Tidal Datum Epoch (NTDE) used to compute tidal datums at tide stations is the 1960-78 NTDE. Traditionally, NTDEs have been adjusted when significant changes in mean sea level (MSL) trends were found through analyses amongst the National Water Level Observation Network (NWLON) stations. Epochs are updated to ensure that tidal datums are the most accurate and practical for navigation, surveying and engineering applications and reflect the existing local sea level conditions. For instance, analyses of sea level trends show that a new NTDE is necessary and efforts are underway to update the 1960-1978 NTDE to a more recent 19-year time period.

Note: This example of Field Tide Note and Final Tidal Zoning Chart was written in December 1999, at that time NTDE was 1960-1978, now the new NTDE is 1983-2001.

(a)

Figure 4.15: Final Tide Note and Final Tidal Zoning Chart



(b)

Figure 4.15: Final Tide Note and Final Tidal Zoning Chart (continued)

However, analyses also show that there are several geographic areas whose sea level trends are strongly anomalous from the average trends found across the NWLON and thus, must be treated differently. One of these areas is in Cook Inlet, Alaska. Nikiski has shown a significant relative sea level change due to continued vertical land movement after the 1964 earthquake. NOS has adopted a procedure for computing accepted tidal datums for this anomalous region by using an MSL value calculated from the last several years of data rather than the 19-year NTDE. The accepted range of tide is still based on the 19-year NTDE and, when applied to the updated MSL, will result in updated values for Mean High Water (MHW) and Mean Lower Low Water (MLLW) derived through standard datum calculation procedures. For Nikiski, the MSL value was computed from the period of 1994-1998. This resulted in a lowering of the MLLW datums relative to land by approximately 1.0 ft at Nikiski compared to the previous MLLW elevations used in surveys prior to January 1, 1998. Subordinate tide stations in the area used for hydrographic surveys and controlled by Nikiski will be affected similarly. Accepted datums have been computed and may be accessed on the Internet through the URL specification `http://www.tidesandcurrents.noaa.gov`.

PROJECT SUBMISSION CHECKLIST

GPS PROJECTS

Project Title: ____

Submitting Agency: ____

Observing Agency: ____

Receiver Type: ____

Antenna Type: ____

PACKAGE CONTENTS

( ) Project Report
( ) Station Description or Recovery notes
( ) Observations Logs Sheets
Data which must be filled out: Station Designation, Date (UTC), General Location, Day of Year, Project Name, Session ID, Observation Session Times, Agency Full Name, Operator Full Name, Phone Number, GPS Receiver, GPS Antenna, Antenna Height, Data File Name
( ) Station Visibility Diagrams
( ) Photographs or Rubbings of Station Marks
( ) Raw GPS data
( ) RINEX GPS Data - See below
( ) OPUS results
( ) Other

DATA REFORMATTING
Convert the raw GPS data to RINEX2 format with your manufacturer's software. The software should require you to enter the raw data filename, the output filenames, your name, the observer's name and agency, and the antenna type used.

The NGS-standard data filenames are as follows:

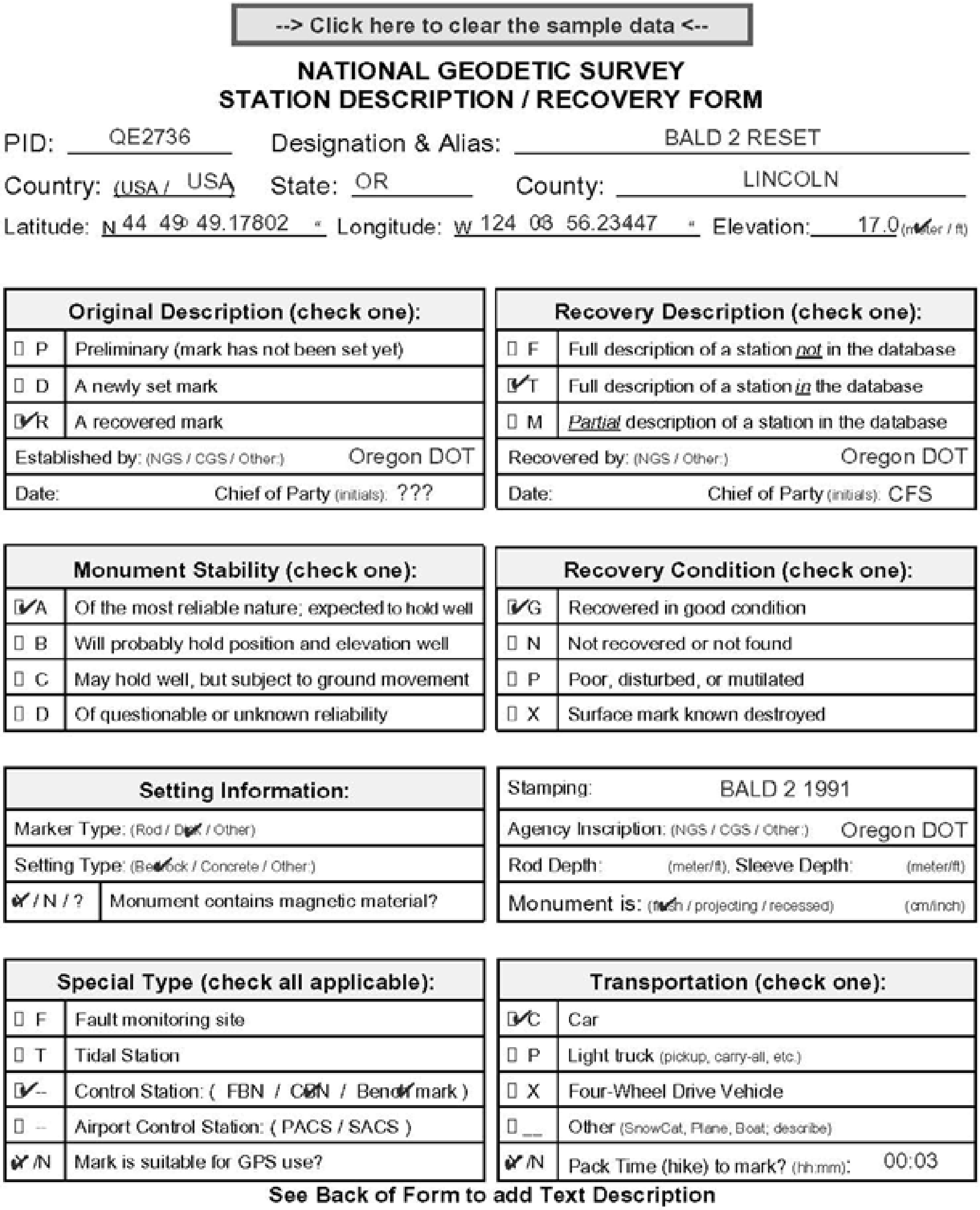
Raw GPS input files: aaaaddds.xxx
Where: aaaa = alphanumeric 4-character station identifier, ddd = day of year, s = session, yy = year of observations, and xxx is the receiver-dependent file extension (e.g., .DAT, .EPH, .ION, .MES, etc.)

RINEX2 Navigation File: aaaaddds.yyn
RINEX2 Observation File: aaaaddds.yyo

For example, RINEX2 filenames from station BALD 2 on session A of 12/31/98 are ALD365A.98o and BALD365A.98n

Copy the raw GPS data files and the converted RINEX2 data files onto separate 3.5-inch electronic formats currently in use such as a CD ROM.

Figure 4.16: Project Submission Checklist



--> Click here to clear the sample data <--

NATIONAL GEODETIC SURVEY
STATION DESCRIPTION / RECOVERY FORM

PID: QE2736 Designation & Alias: BALD 2 RESET

Country: (USA / USA) State: OR County: LINCOLN

Latitude: N 44 49 49.17802 Longitude: W 124 08 56.23447 Elevation: 17.0 (meter / ft)

Original Description (check one):	
☐ P	Preliminary (mark has not been set yet)
☐ D	A newly set mark
☑ R	A recovered mark
Established by: (NGS / CGS / Other:) Oregon DOT	
Date: Chief of Party (initials): ???	

Recovery Description (check one):	
☐ F	Full description of a station *not* in the database
☑ T	Full description of a station *in* the database
☐ M	*Partial* description of a station in the database
Recovered by: (NGS / Other:) Oregon DOT	
Date: Chief of Party (initials): CFS	

Monument Stability (check one):	
☑ A	Of the most reliable nature; expected to hold well
☐ B	Will probably hold position and elevation well
☐ C	May hold well, but subject to ground movement
☐ D	Of questionable or unknown reliability

Recovery Condition (check one):	
☑ G	Recovered in good condition
☐ N	Not recovered or not found
☐ P	Poor, disturbed, or mutilated
☐ X	Surface mark known destroyed

Setting Information:	
Marker Type: (Rod / Disk / Other)	
Setting Type: (Bedrock / Concrete / Other:)	
Y / N / ?	Monument contains magnetic material?

Stamping:	BALD 2 1991
Agency Inscription: (NGS / CGS / Other:)	Oregon DOT
Rod Depth: (meter/ft), Sleeve Depth: (meter/ft)	
Monument is: (flush / projecting / recessed) (cm/inch)	

Special Type (check all applicable):	
☐ F	Fault monitoring site
☐ T	Tidal Station
☑ --	Control Station: (FBN / CBN / Benchmark)
☐ --	Airport Control Station: (PACS / SACS)
Y /N	Mark is suitable for GPS use?

Transportation (check one):	
☑ C	Car
☐ P	Light truck (pickup, carry-all, etc.)
☐ X	Four-Wheel Drive Vehicle
☐ __	Other (SnowCat, Plane, Boat; describe)
Y /N	Pack Time (hike) to mark? (hh:mm): 00:03

See Back of Form to add Text Description

(a)

Figure 4.17: Station Descriptive - Recovery Form

General Station Location: The station is located in about 10 km south from Lincoln Bay, 13 km north from Depoe Bay, and at the US101 Boiler Bay wayside rest area.

(Describe general location; include airline distances to three towns or mapped features.)

Ownership: The station is on the property of Oregon State Department of Parks and Recreation.

(name, address, phone of landowner)

To Reach Narrative: To reach the station from the intersection of US routes 5 and 101 in Depoe Bay, go north on US 101 for 1 km to the south entrance of the Boiler Bay wayside. Bear left on entrance road for 0.4 km to the parking area on the left. Pack northwest inside fence for about 90 meters to end of fence and the station on the right.

(Leg-by-leg distances and directions from major road intersection to mark)

Monument Description and Measurements: The station is set into drill hole in bedrock, 7.6 m south from the north fence corner, 8.8 m east from the west fence corner, and 3.6 m southeast from the northwest end of the outcrop.

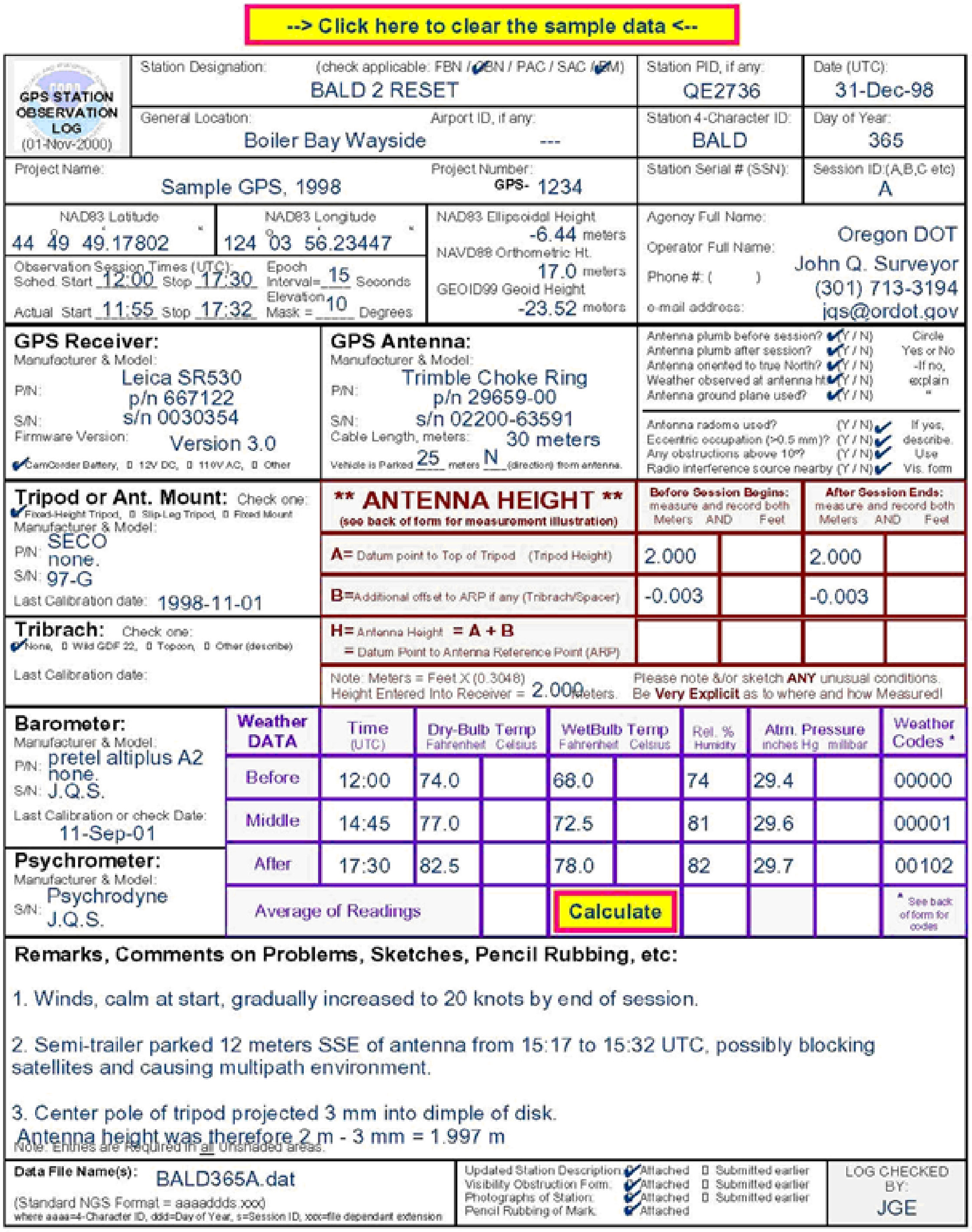
(Add at least three measurements to permanent, identifiable, nearby objects; and a description of the monument size, shape, height, etc.)

NOTE: - Include a pencil rubbing, sketch, or photographs of mark.

Described by: John Q. Surveyor Phone: (301)713-3194 e-mail: jqs@ordot.gov

(b)

Figure 4.17: Station Descriptive - Recovery Form (continued)



--> Click here to clear the sample data <--

GPS STATION OBSERVATION LOG (01-Nov-2000)

Station Designation: (check applicable: FBN / CBN / PAC / SAC / PM) BALD 2 RESET		Station PID, if any: QE2736	Date (UTC): 31-Dec-98
General Location: Boiler Bay Wayside	Airport ID, if any: ---	Station 4-Character ID: BALD	Day of Year: 365
Project Name: Sample GPS, 1998	Project Number: GPS- 1234	Station Serial # (SSN):	Session ID:(A,B,C etc) A

NAD83 Latitude: 44° 49' 49.17802"
NAD83 Longitude: 124° 03' 56.23447"
NAD83 Ellipsoidal Height: -6.44 meters
NAVD88 Orthometric Ht.: 17.0 meters
GEOID99 Geoid Height: -23.52 meters

Observation Session Times (UTC): Sched. Start 12:00 Stop 17:30; Actual Start 11:55 Stop 17:32
Epoch Interval= 15 Seconds
Elevation Mask = 10 Degrees

Agency Full Name: Oregon DOT
Operator Full Name: John Q. Surveyor
Phone #: (301) 713-3194
e-mail address: jqs@ordot.gov

GPS Receiver:
Manufacturer & Model: Leica SR530
P/N: p/n 667122
S/N: s/n 0030354
Firmware Version: Version 3.0
✔ CamCorder Battery, ☐ 12V DC, ☐ 110V AC, ☐ Other

GPS Antenna:
Manufacturer & Model: Trimble Choke Ring
P/N: p/n 29659-00
S/N: s/n 02200-63591
Cable Length, meters: 30 meters
Vehicle is Parked 25 meters N (direction) from antenna.

Antenna plumb before session? ✔Y / N
Antenna plumb after session? ✔Y / N
Antenna oriented to true North? ✔Y / N
Weather observed at antenna ht? ✔Y / N
Antenna ground plane used? ✔Y / N
(Circle Yes or No -If no, explain)

Antenna radome used? (Y / N)✔
Eccentric occupation (>0.5 mm)? (Y / N)✔
Any obstructions above 10°? (Y / N)✔
Radio interference source nearby (Y / N)✔
(If yes, describe. Use Vis. form)

Tripod or Ant. Mount: Check one: ✔ Fixed-Height Tripod, ☐ Slip-Leg Tripod, ☐ Fixed Mount
Manufacturer & Model: SECO
P/N: none.
S/N: 97-G
Last Calibration date: 1998-11-01

Tribrach: Check one: ✔ None, ☐ Wild GDF 22, ☐ Topcon, ☐ Other (describe)
Last Calibration date:

** ANTENNA HEIGHT ** (see back of form for measurement illustration)	Before Session Begins: Meters	Feet	After Session Ends: Meters	Feet
A= Datum point to Top of Tripod (Tripod Height)	2.000		2.000	
B=Additional offset to ARP if any (Tribrach/Spacer)	-0.003		-0.003	
H= Antenna Height = A + B = Datum Point to Antenna Reference Point (ARP)				

Note: Meters = Feet X (0.3048)
Height Entered Into Receiver = 2.000 Meters.
Please note &/or sketch **ANY** unusual conditions. Be **Very Explicit** as to where and how Measured!

Barometer:
Manufacturer & Model: pretel altiplus A2
P/N: none.
S/N: J.Q.S.
Last Calibration or check Date: 11-Sep-01

Psychrometer:
Manufacturer & Model: Psychrodyne
S/N: J.Q.S.

Weather DATA	Time (UTC)	Dry-Bulb Temp Fahrenheit	Celsius	WetBulb Temp Fahrenheit	Celsius	Rel. % Humidity	Atm. Pressure inches Hg	millibar	Weather Codes *
Before	12:00	74.0		68.0		74	29.4		00000
Middle	14:45	77.0		72.5		81	29.6		00001
After	17:30	82.5		78.0		82	29.7		00102
Average of Readings				Calculate					* See back of form for codes

Remarks, Comments on Problems, Sketches, Pencil Rubbing, etc:

1. Winds, calm at start, gradually increased to 20 knots by end of session.

2. Semi-trailer parked 12 meters SSE of antenna from 15:17 to 15:32 UTC, possibly blocking satellites and causing multipath environment.

3. Center pole of tripod projected 3 mm into dimple of disk.
Antenna height was therefore 2 m - 3 mm = 1.997 m

Note: Entries are Required in all Unshaded areas.

Data File Name(s): BALD365A.dat
(Standard NGS Format = aaaadddsxxx)
where aaaa=4-Character ID, ddd=Day of Year, s=Session ID, xxx=file dependant extension

Updated Station Description: ✔Attached ☐ Submitted earlier
Visibility Obstruction Form: ✔Attached ☐ Submitted earlier
Photographs of Station: ✔Attached ☐ Submitted earlier
Pencil Rubbing of Mark: ✔Attached

LOG CHECKED BY: JGE

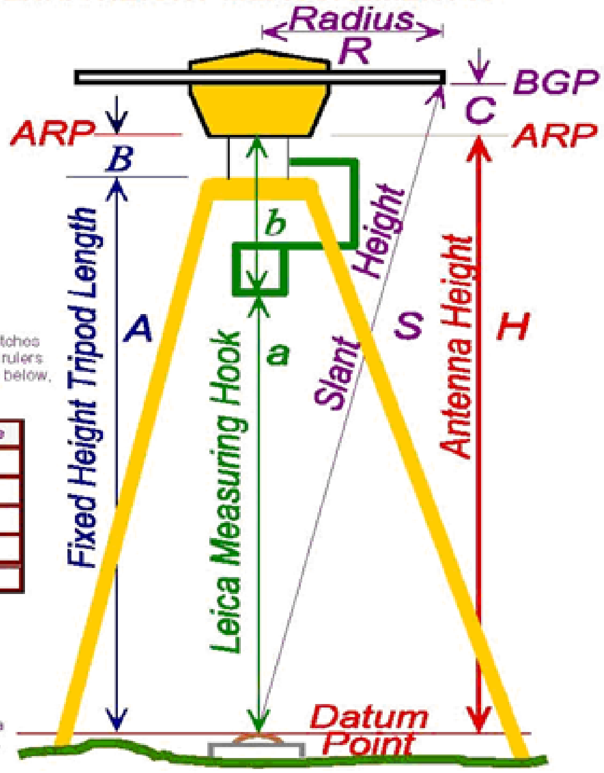
Figure 4.18: GPS Station Observation Log

ILLUSTRATION FOR ANTENNA HEIGHT MEASUREMENTS:

I. Instructions for Fixed-Height Tripods:

Measure & record the fixed-height tripod length **(A)** and other offsets, if any, between the tripod and the Antenna Reference Point (ARP) **(B)**

$$Antenna.Height = H = A + B$$



II. Instructions for Slip-Leg Tripods:

1. Measure the Slant Height (S)

Measure the slope distance from the mark to at least three notches on the Bottom of Ground Plane (BGP) using two independent rulers (e.g., metric and imperial). Record measurements in the table below, and compute the average.

Measure S	Notch #_	Notch #_	Notch #_	Average
Before, cm	223.40	223.30	223.30	
Before, inch	87.95	87.94	87.93	
After, cm	223.40	223.40	223.30	
After, inch	87.97	87.96	87.95	
Note: cm= inch x (2.54)	Overall average, cm			

S = ________________ cm

2. Record the Antenna Radius (R) and the Antenna Constant (C)

The antenna radius (R) is the horizontal distance from the center of the antenna to the measurement notch. The antenna constant (C) is the vertical distance from the ARP to the BGP. Consult your antenna users manual for exact measurements.

R = 19.05 cm

C = 3.50 cm

3. Compute Antenna Height (H)

Use the following Pythagorean equation:

$$Antenna.Height = H = ((\sqrt{S^2 - R^2}) - C)$$

III. Instructions for using the Leica Brand Measuring Hook:

Follow the Leica operating instructions, being sure to reduce the height to the Antenna Reference Point (ARP), NOT the L1 Phase Center.

$$Antenna.Height = H = a + b$$

Table of Weather Codes -- for entry into Weather Data Table on front of form:					
CODE	PROBLEM	VISIBILITY	TEMPERATURE	CLOUD COVER	WIND
0	NO PROBLEMS encountered	GOOD More than 15 miles	NORMAL 32° F to 80°F	CLEAR Below 20%	CALM Under 5mph (8km/h)
1	PROBLEMS encountered	FAIR 7 to 15 miles	HOT Over 80°F (27 C)	CLOUDY 20% to 70%	MODERATE 5 to 15 mph
2	-- NOT USED --	POOR Less than 7 miles	COLD Below 32° F (0 C)	OVERCAST Over 70%	STRONG over15mph (24km/h)
Examples: Code 00000 = Code 12121 =	0 - No problems, 1 - Problems,	0 - good visibility, 2 - poor visibility,	0 - normal temperature, 1 - hot temperature,	0 - clear sky, 2 - overcast,	0 - calm wind 1 - moderate wind

Figure 4.19: GPS Antenna Height Measurements

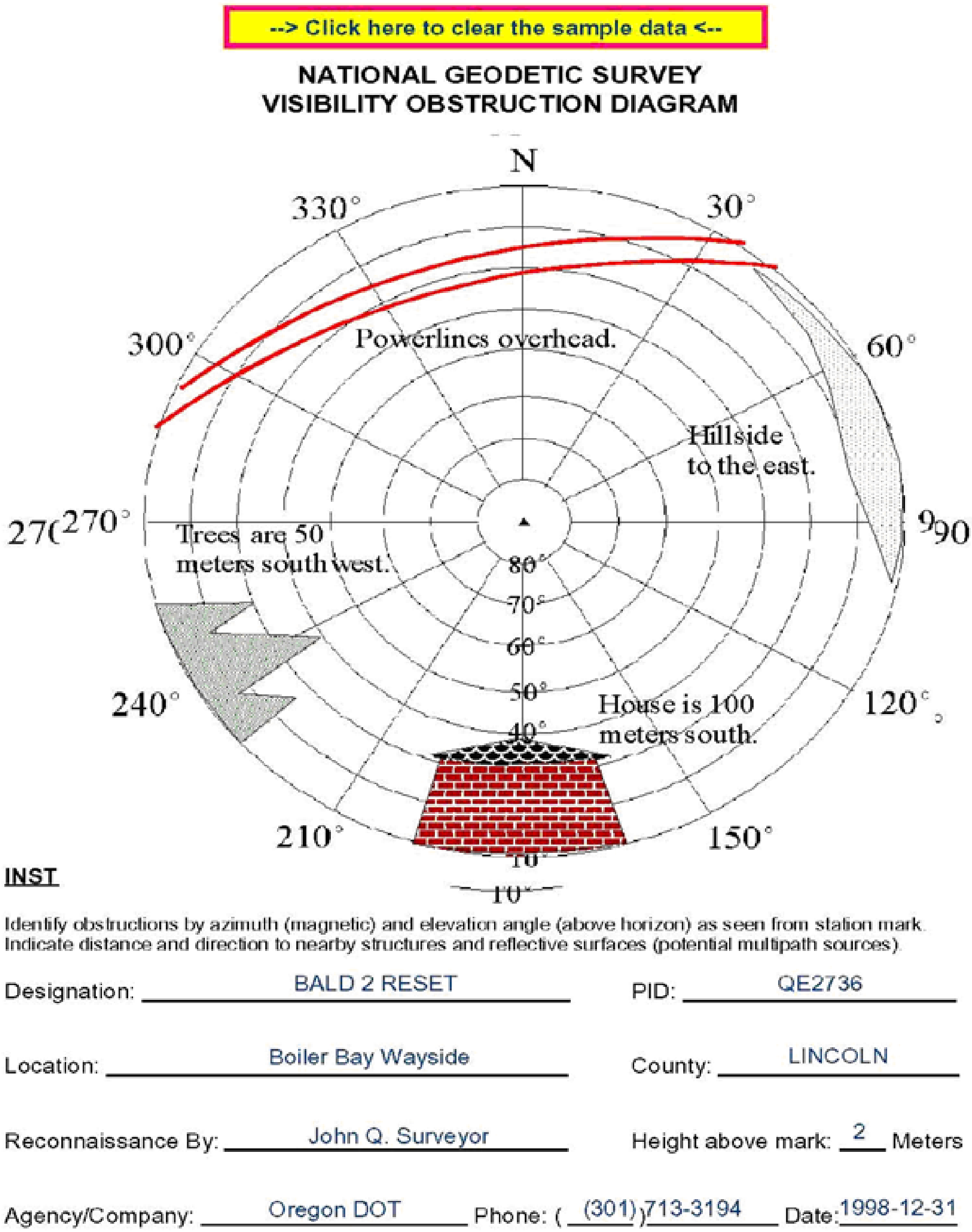
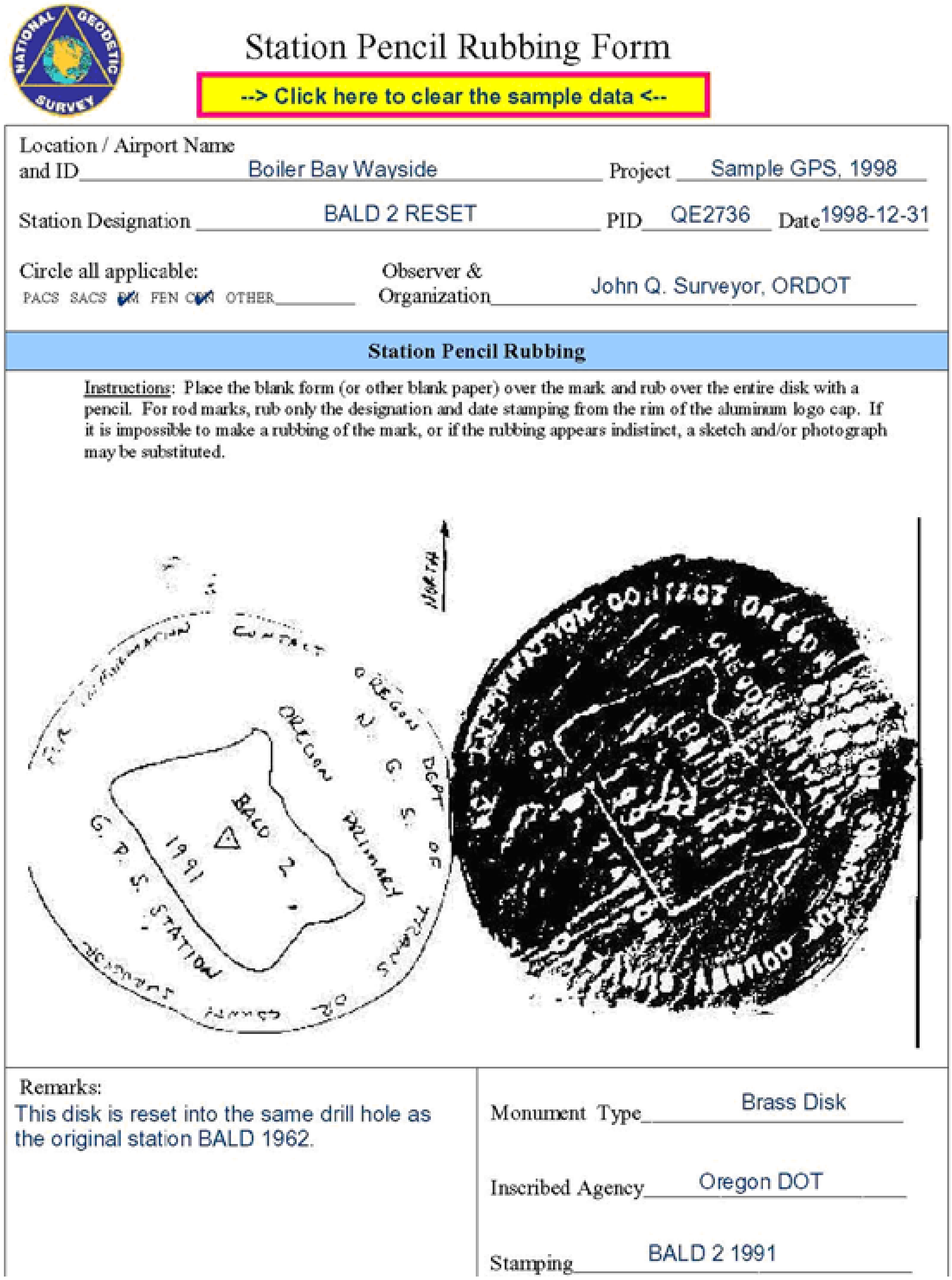


Figure 4.20: GPS Visibility Obstruction Diagram



Station Pencil Rubbing Form

--> Click here to clear the sample data <--

Location / Airport Name and ID Boiler Bay Wayside   Project Sample GPS, 1998

Station Designation BALD 2 RESET   PID QE2736   Date 1998-12-31

Circle all applicable: PACS SACS BM FEN CORS OTHER____   Observer & Organization John Q. Surveyor, ORDOT

Station Pencil Rubbing

Instructions: Place the blank form (or other blank paper) over the mark and rub over the entire disk with a pencil. For rod marks, rub only the designation and date stamping from the rim of the aluminum logo cap. If it is impossible to make a rubbing of the mark, or if the rubbing appears indistinct, a sketch and/or photograph may be substituted.

Remarks:
This disk is reset into the same drill hole as the original station BALD 1962.

Monument Type Brass Disk

Inscribed Agency Oregon DOT

Stamping BALD 2 1991

Figure 4.21: Station Pencil Rubbing Form

Figure 4.22: Digital Photo of Stamping of Bench Mark

4.6.3 Water Level Data

The final observed water level measurements shall be reported as heights in meters to three decimal places (i.e. 0.001 m). All heights shall be referenced to station datum and shall be referenced to UTC. The final tide reducer time series data shall be referenced to MLLW and shall be referenced to UTC. The contractor shall provide the water level data in the format specified below from the water level gauges installed.

The original raw water level data and also the correctors used to convert the data to chart datum shall be retained until notified in writing or at least two years after the survey is completed. All algorithms and conversions used to provide correctors shall be fully supported by the calibrations, maintenance documentation, leveling records, and sound engineering/oceanographic practices. Sensors for measurements used to convert data (e.g. pressure to heights) shall be calibrated and maintained for the entire water level collection period.

All digital water level and ancillary data shall be transmitted to CO-OPS in a format dependent on the DCP configuration. If GOES satellite is used, the data shall be transmitted and received using the NOS compressed pseudo binary format (see NGWLMS GOES Message Formatting, Libraro, 1/2003). These satellite messages are then decoded by NOS DMS upon receipt from NESDIS before further processing and review by CORMS can be completed. If satellite transmission configurations cannot be installed, the data shall be manually downloaded from the DCP and submitted to NOS, as shown in the format below, in a digital format, on CD-ROM, or by email as an ASCII data attachment. It may be prudent to submit data at more frequent intervals under specific circumstances.

Data download files shall be named in the following format: xxxxxxxy.w1.DAT, where xxxxxxx is the seven digit station number, y is the DCP number (usually 1), w1 is the product code for 6-minute data, and DAT is the extension (Use T = 2,3...if more than one file is from the same station and DCP). This is the format needed when the data is loaded into DMS. Also each water level data file (XXX.BWL or XXX.ACO) shall have only 3 months of data. If the water level station was operational for more than three months, please submit multiple xxxxxxxy.DAT files, each file with only three months of data.

Multiple DCP may have been used to collect 6-minute water level data for a particular site, and backup or redundant DCP data may be used to fill the gap in the primary DCP data,. but, water level data shall be submitted for single DCP (numbered as 1). All the water level data shall be on station datum.

Each input record (including the final record) ends with a carriage return and excludes any extraneous characters such as trailing blank spaces for all types of water level data (6-minute water level data, hourly height, high/low, monthly means, and station datum).

The 6-minute interval data (acoustic sensor and pressure sensor examples follow) shall have the following format for CO-OPS database to accept.

Acoustic Sensor Data (XXX.ACO format)

Column 1- 7 Station ID (7 digits, assigned in the project instructions)

Column 8- 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)

Column 9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)

Column 20-20 Blank

Column 21-22 Hours in 24 hour format (i.e. 00, 01, ..., 23)

Column 23-23 : (colon)

Column 24-25 Minutes (00,06,12, ..., 54)

Column 26-32 Data value in millimeters, right justified, (e.g. 1138)

Column 33-38 Sigma (standard deviation in millimeters in integer format)

Column 39-44 Outlier (integer format)

Column 45-50 Temperature 1 (tenth of degrees C in integer format)

Column 51-56 Temperature 2 (tenth of degrees C in integer format)

Column 57-58 Sensor type (A1 for acoustic type)

Column 59-60 blank

Column 61-61 Data Source (S for Satellite, D for Diskette)

Sample data:

```
85169901AUG 17 2007 05:00 1138 23 0 308 297A1 D

85169901AUG 17 2007 05:06 1126 26 0 308 298A1 D

85169901AUG 17 2007 05:12 1107 26 1 309 298A1 D
```

Pressure Sensor or Generic Data (XXX.BWL format)

Column 1- 7 Station ID (7 digits, assigned in the project instructions)

Column 8- 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)

Column 9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)

Column 20-20 Blank

Column 21-22 Hours in 24 hour format (i.e. 00, 01, ..., 23)

Column 23-23 : (colon)

Column 24-25 Minutes (00-54)

Column 26-32 Data value in millimeters, right justified, (e.g. 1138)

Column 33-38 Sigma (standard deviation in millimeters in integer format)

Column 39-44 Outlier (integer format)

Column 45-50 Sensor temperature (tenth of degrees C in integer format)

Column 51-52 Sensor type (Z1 for generic or pressure)

Column 53-53 blank

Column 54-54 Data Source (S for Satellite, D for Diskette)

Sample data:

```
85169901AUG 17 2007 05:00 1138 23 0 308Z1 D

85169901AUG 17 2007 05:06 1126 26 0 308Z1 D

85169901AUG 17 2007 05:12 1107 26 1 309Z1 D
```

Note: pressure data must be accompanied by documented staff observations as listed in Section 4.2.2 and 4.2.4, if applicable.

4.6.4 Tabulations and Tidal Datums

For contract surveys, the contract hydrographer shall provide digital and hard copies of tabulations of staff/gauge differences, hourly heights, high and low waters, monthly means, and water level datums for the entire time series of observations from each water level station. Along with the final contractor computed tidal datums, the contractor shall provide copies of the tide-by-tide and/or monthly mean simultaneous comparison sheets from which the final tidal datums were determined. Audit trails of data edits and gap-filling shall be summarized and provided also.

The digital tabulation files for hourly heights, high and low waters, monthly means, and station datum shall have the following formats:

Each input record (including the final record) ends with a carriage return and excludes any extraneous characters such as trailing blank spaces for all types of water level data (6-minute water level data, hourly height, high/low, monthly means, and station datum).

Hourly Height data Format:

Column 1- 7 Station ID (7 digits, assigned in the project instructions)

Column 8- 8 Blank

Column 9-16 Date (YYYYMMDD format, e.g. 20070120)

Column 17-17 Blank

Column 18-19 Hours (2 digits 00-23, use leading zeros)

Column 20-20 : (colon)

Column 21-22 Minutes (2 digits 00-54, use leading zeros)

Column 23-23 Blank

Column 24-30 Water level value in meters (F7.3 format, e.g. 123.456)

Sample data:

```
9414290 20040101 00:00 123.456
```

Hourly height data file shall be named in the following format:xxxxxxx.w2.DAT, where xxxxxxx is the seven digit station number, w2 is the product code for the hourly heights data, and DAT is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

High/Low Data Format:

Column 1- 7 Station ID (7 digits, assigned in the project instructions)

Column 8- 8 Blank

Column 9-16 Date (YYYYMMDD format, e.g. 20070120)

Column 17-17 Blank

Column 18-19 Hours (2 digits 00-23, use leading zeros)

Column 20-20 : (colon)

Column 21-22 Minutes (2 digits 00-54, use leading zeros)

Column 23-23 Blank

Column 24-30 Water level value in meters (F7.3 format, e.g. 123.456)

Column 31-31 Blank

Column 32-33 Water level high/low type (H, L, HH, or LL)

Sample data:

```
9414290 20040101 00:00 123.456 HH
```

Definition of Acronym:

H: Higher low water level value

L: Lower high water level value

HH: Higher high water level value

LL: Lower low water level value

High and low data file shall be named in the following format: xxxxxxx.w3.DAT, where xxxxxxx is the seven digit station number, w3 is the product code for the high/low data, and DAT is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

Monthly Mean Data Format:

Column 1- 7 Station ID (7 digits, assigned in the project instructions)

Column 8- 8 Blank

Column 9- 12 Year (YYYY format, e.g. 2007)

Column 13- 13 Blank

Column 14- 15 Month (in 2 digits 01-12, use leading zeros)

Column 16- 16 Blank

Column 17- 23 MHHW in meters (F7.3 format, e.g. 123.456)

Column 24- 24 Blank

Column 25- 31 MHW in meters (F7.3 format, e.g. 123.456)

Column 32- 32 Blank

Column 33- 39 DTL in meters (F7.3 format, e.g. 123.456)

Column 40- 40 Blank

Column 41- 47 MTL in meters (F7.3 format, e.g. 123.456)

Column 48- 48 Blank

Column 49- 55 MSL in meters (F7.3 format, e.g. 123.456)

Column 56- 56 Blank

Column 57- 63 MLW in meters (F7.3 format, e.g. 123.456)

Column 64- 64 Blank

Column 65- 71 MLLW in meters (F7.3 format, e.g. 123.456)

Column 72- 72 Blank

Column 73- 79 GT in meters (F7.3 format, e.g. 123.456)

Column 80- 80 Blank

Column 81- 87 MN in meters (F7.3 format, e.g. 123.456)

Column 88- 88 Blank

Column 89- 95 DHQ in meters (F7.3 format, e.g. 123.456)

Column 96- 96 Blank

Column 97-103 DLQ in meters (F7.3 format, e.g. 123.456)

Column 104-104 Blank

Column 105-111 Maximum Water Level in meters (F7.3 format, e.g. 123.456)

Column 112-112 Blank

Column 113-120 Maximum Water Level Date (in YYYYMMDD format, last occurrence)

Column 121-121 Blank

Column 122-123 Maximum Water Level Hour (2 digits 00-23, use leading zeros)

Column 124-124 : (colon)

Column 125-126 Maximum Water Level Minute (2 digits 00-54, use leading zeros)

Column 127-127 Blank

Column 128-128 Maximum Water Level occurrences (1 digit)

Column 129-129 Blank

Column 130-136 Minimum Water Level in meters (F7.3 format, e.g. 123.456)

Column 137-137 Blank

Column 138-145 Minimum Water Level Date (in YYYYMMDD format, last occurrence)

Column 146-146 Blank

Column 147-148 Minimum Water Level Hour (2 digits 00-23, use leading zeros)

Column 149-149 : (colon)

Column 150-151 Minimum Water Level Minute (2 digits 00-54, use leading zeros)

Column 152-152 Blank

Column 153-153 Minimum Water Level occurrences (1 digit)

Sample data (with column ruler):

```
         0         0         0         0         0         0         0         0
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
9414290 2004 01 123.456 123.456 123.456 123.456 123.456 123.456 123.456 123.456

         0         1         1         1         1         1         1
         9         0         1         2         3         4         5
12345678901234567890123456789012345678901234567890123456789012345678901234567890123
123.456 123.456 123.456 123.456 20040101 00:00 1 123.456 20040101 00:00 1
```

Definition of Acronym:

MHHW	Mean Higher High Water
MHW	Mean High Water
DTL	Diurnal Tide Level
MTL	Mean Tide Level
MSL	Mean Sea Level
MLW	Mean Lower Water
MLLW	Mean Lower Low Water
GT	Great Diurnal Tide Range
MN	Mean Range of Tide
DHQ	Diurnal High Water Inequality
DLQ	Diurnal Low Water Inequality
MAX_WL	Maximum Water Level during the Month measurement period
MAX_DATE	Date of Maximum Water Level
MAX_HOUR	Hour of Maximum Water Level
MAX_MIN	Minute of Maximum Water Level
MAX_OCCUR	Number of occurrences during the month the Water Level meets the MAX_WL
MIN_WL	Minimum Water Level during the Month measurement period
MIN_DATE	Date of Minimum Water Level
MIN_HOUR	Hour of Minimum Water Level
MIN_MIN	Minute of Minimum Water Level
MIN_OCCUR	Number of occurrences during the month the Water Level meets the MIN_WL

Monthly Means data file shall be named in the following format: xxxxxxx.w5.DAT, where xxxxxxx is the seven digit station number, w5 is the product code for the monthly means data, and DAT is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

Station Datum Data Format:

Column 1- 7 Station ID (7 digits, assigned in the project instructions)

Column 8- 16 Blank

Column 17- 23 MHHW in meters (F7.3 format, e.g. 123.456)

Column 24- 24 Blank

Column 25- 31 MHW in meters (F7.3 format, e.g. 123.456)

Column 32- 32 Blank

Column 33- 39 DTL in meters (F7.3 format, e.g. 123.456)

Column 40- 40 Blank

Column 41- 47 MTL in meters (F7.3 format, e.g. 123.456)

Column 48- 48 Blank

Column 49- 55 MSL in meters (F7.3 format, e.g. 123.456)

Column 56- 56 Blank

Column 57- 63 MLW in meters (F7.3 format, e.g. 123.456)

Column 64- 64 Blank

Column 65- 71 MLLW in meters (F7.3 format, e.g. 123.456)

Column 72- 72 Blank

Column 73- 79 GT in meters (F7.3 format, e.g. 123.456)

Column 80- 80 Blank

Column 81- 87 MN in meters (F7.3 format, e.g. 123.456)

Column 88- 88 Blank

Column 89- 95 DHQ in meters (F7.3 format, e.g. 123.456)

Column 96- 96 Blank

Column 97-103 DLQ in meters (F7.3 format, e.g. 123.456)

Column 104-104 Blank

Column 105-111 Maximum Water Level in meters (F7.3 format, e.g. 123.456)

Column 112-112 Blank

Column 113-120 Maximum Water Level Date (in YYYYMMDD format, last occurrence)

Column 121-121 Blank

Column 122-123 Maximum Water Level Hour (2 digits 00-23, use leading zeros)

Column 124-124 : (colon)

Column 125-126 Maximum Water Level Minute (2 digits 00-54, use leading zeros)

Column 127-127 Blank

Column 128-128 Maximum Water Level occurrences (1 digit)

Column 129-129 Blank

Column 130-136 Minimum Water Level in meters (F7.3 format, e.g. 123.456)

Column 137-137 Blank

Column 138-145 Minimum Water Level Date (in YYYYMMDD format, last occurrence)

Column 146-146 Blank

Column 147-148 Minimum Water Level Hour (2 digits 00-23, use leading zeros)

Column 149-149 : (colon)

Column 150-151 Minimum Water Level Minute (2 digits 00-54, use leading zeros)

Column 152-152 Blank

Column 153-153 Minimum Water Level occurrences (1 digit)

Sample data (with column ruler):

```
         0         0         0         0         0         0         0         0
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
9414290         123.456 123.456 123.456 123.456 123.456 123.456 123.456 123.456

         0         1         1         1         1         1         1
         9         0         1         2         3         4         5
12345678901234567890123456789012345678901234567890123456789012345678901234567890123
123.456 123.456 123.456 123.456 20040101 00:00 1 123.456 20040101 00:00 1
```

Definition of Acronyms for Station Datum data are same as that for the Monthly Mean data.

Station datum data file shall be named in the following format: xxxxxxx.w7.DAT, where xxxxxxx is the seven digit station number, w7 is the product code for the station datum data, and DAT is the extension. This is the format needed when the data is loaded into CO-OPS DMS database.

If the Greenwich High Water Interval (HWI) and Greenwich Low Water Interval (LWI) are available, then contractor shall provide that information in F5.2 format and that file shall be named as xxxxxxx.GWI.txt, where xxxxxxx is the seven digit station number.

4.6.5 Tide Reducers and Final Zoning and Final Tide Note

The final zoning scheme shall be fully supported by documentation of data and methodology which comprised the final zoning model. The contractor must provide final tidal zoning scheme digitally in the MAPINFO, ARCVIEW, or CARIS compatible format. Final tidal zoning scheme in AUTOCAD format is not acceptable.

Final tide reducers shall be submitted in the specified format.

All documentation listed below shall be forwarded to CO-OPS:

- Contractor created summary files.
- Documentation of NOS summary files utilized for final zoning
- GIS compatible zoning development steps in MapInfo©, ArcGIS© or CARIS© format including geographical presentation of summary data and cophase/corange maps, if appropriate
- GIS compatible digital final zoning files
- Final tide reducer data files
- Final Tide Note

The final zoning scheme shall be fully supported by documentation of data and methodology which derived the final zoning model.

4.6.6 Submission and Deliverables – Documentation and Time lines

The check list in Figures 4.14 shall be used to check and verify the documentation that is required for submission. All documentation, water level data, processed data including hourly height, high/low data, monthly means data, and station datums data, GPS forms and data including OPUS results, zoning and other reports (as listed above in Section 4.6.5) as required, shall be forwarded within 15 business days of the removal of the stations/gauges.

Submit a transmittal letter to the appropriate Contracting Officer's Technical Representative (COTR) listing what is forwarded to CO-OPS. Submit a duplicate transmittal letter, all data and documentation to CO-OPS POC, as listed below.

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

All data and documentation shall be submitted in digital format. Please refer to Section 4.6.1, 4.6.2, 4.6.3, 4.6.4, and 4.6.5 for details about various data and documentation.

Standard station documentation package includes the following:

1. Transmittal letter
2. Field Tide note, if applicable
3. Calibration records for sensors, if applicable

4. E-Site Report, Xpert Site Report, or tide station report
5. Chartlet
6. USGS Quad map (7.5 minutes quadrangle maps)
7. Sensor test worksheet
8. Sensor elevation drawing
9. Water level transfer form (Great Lakes stations only)
10. Bench mark sketch
11. "Station To Reach" statement
12. Bench mark descriptions
13. Photographs of bench marks, station, DCP, equipment, and vicinity in digital and paper format
14. Levels (raw) (electronic files) and field notes of precise leveling
15. Abstract of precise leveling
16. Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor "zero" measurement point is referenced to the bench marks.
17. Calibration certificates for Invar leveling rods, if applicable
18. Staff to gauge observations, if applicable
19. Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable
20. Other information as appropriate, or as specified in the contract
21. Water level data, 6-minute data, all tabulated data, such as hourly heights, high and low, monthly means, and station datum data in the specified format. (refer to Section 4.6.3 and 4.6.4)
22. GPS data and documentation, as applicable
23. Contractor created summary files, final zoning, final tide reducer data, final tide note, and cophase/corange maps if appropriate, etc.

Generally, for established water level 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. For optical levels, submit the raw levels and the leveling abstract.

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 FY 08 Installation

/Transmittal letter

/Field Tide Note

/Calibration records for sensors, if applicable

/Site Report or tide station report

/Chartlet and USGS Quad maps

/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

/Datum offset computation worksheet or Staff/Gauge difference work sheet (elevation of sensor zero measurement point referenced to bench marks)

/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 (6-minute, hourly heights, high/low, monthly means, station datum)

/GPS data and documentation

/Final tidal zoning, final tide reducers, final tide note, summary files, cophase/corange maps

Submit only required GPS deliverables (data and documentation) on a separate DVD/CD-ROM, so that CO-OPS can forward that information to NGS. for example, GPS submission for San Francisco tide station will be as follows:

9414290 San Francisco

/GPS data and documentation, as applicable

Submit one copy of all the documentation, water level data, including GPS data and documentation, final tidal zoning, final tidal reducers, final tide note, etc., in digital format. Submit one copy in digital format of the only required GPS deliverables (GPS documentation and data including OPUS results) on a separate CD-ROM/DVD for transfer to NGS.

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

Submit at the same time an original transmittal letter to the COTR, listing what was forwarded to CO-OPS.

4.7 Guidelines and References

References for the water level measurement and leveling requirements issued by the NOS Center of Operational Oceanographic Products and Services (CO-OPS) and the National Geodetic Survey (NGS) are listed below.

Some of these documents are available on CO-OPS web site at `http://www.CO-OPS.nos.noaa.gov`.

1. Next Generation Water Level Measurement System (NGWLMS) Site Design, P reparation, and Installation Manual, NOAA/NOS, January 1991.
2. User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, NOAA/NOS, dated October 1987.
3. User's Guide for Writing Bench Marks Descriptions, NOAA/NOS, Updated January 2003.
4. User's Guide for Electronics Levels, NOAA/NOS, updated January 2003.
5. User's Guide for 8200 Bubbler Gauges, NOAA/NOS, updated February 1998.
6. User's Guide for 8200 Acoustic Gauges, NOAA/NOS, updated August 1998.
7. User's Guide for 8210 Bubbler Gauges, NOAA/NOS, updated February 2001.
8. User's Guide for GPS Observations, NOAA/NOS, updated March 2007.
9. Tidal Datums and Their Applications, Special Publication No. CO-OPS 1, NOAA/NOS, June 2000.
10. Manual of Tide Observations, U.S. Department of Commerce, Publication 30-1, Reprinted 1965.
11. Tidal Datum Planes, U.S. Department of Commerce, Special Publication No.135, Marmer 1951.
12. Tide and Current Glossary, U.S. Department of Commerce, NOAA, NOS, October 1989.

13. Standing Project Instructions: Great Lakes Water Levels, June 1978.

14. NOAA Technical Report NOS 64 "Variability of Tidal Datums and Accuracy in Determining Datums from Short Series of Observations", Swanson, 1974.

15. Data Quality Assurance Guidelines for Marine Environmental Programs, Robert J. Farland, Office of Ocean Engineering, NOAA, March, 1980.

16. System Development Plan, CORMS: Continuous Operational Real-Time Monitoring System, NOAA Technical Report NOS OES 014, U.S. Department of Commerce, NOAA, NOS February, 1997.

17. NGWLMS GOES MESSAGE FORMATTING, Phil Libraro, 1/2003.

18. Computational Techniques for Tidal Datums, NOAA Technical Report NOS CO-OPS 2, U.S. Department of Commerce, NOAA, NOS, DRAFT December 1998.

19. Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, September 1984.

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

21. Geodetic Leveling, NOAA Manual NOS NGS 3, U.S. Department of Commerce, NOAA, National Ocean Survey, August, 1981.

22. NOAA Special Publication NOS CO-OPS 1Tidal Datums and Their Applications, February 2001.

23. "Attachment R, Requirements for Digital Photographs of Survey Control, NGS, July 2005"

24. Xpert Operations and Maintenance Manual, October 2006.

5 Depth Sounding

Depths shall be recorded in meters, with a precision of at least centimeters. This precision shall be maintained throughout the processing pipeline and be maintained in the digital data.

Depths reported in the Descriptive Report (DR), other reports or correspondence should be rounded to the nearest centimeter and have the associated Total Propagated Uncertainty (TPU) (or Total Propagated Error (TPE) as it is often referred to) of the depth listed to the nearest centimeter.

Certain projects may require the use of single beam echosounder data. Gridding requirements for single beam data are included in section 5.1.1.3

5.1 Multibeam and Other Echosounders

Many SOWs or Hydrographic Project Instructions require the use of multibeam echosounders for NOS Hydrographic Surveys however there are occasions where there may be a requirement for single beam or in the future Phase Differencing Bathymetric Systems. Therefore, NOS Specifications, listed in section 5.1 and all its subsections, will refer to multibeam echosounders unless otherwise specified.

5.1.1 Accuracy and Resolution Standards

As mentioned in Section 1, the NOS Specifications are partly based on the IHO Standards for Hydrographic Surveys as outlined in Special Publication 44 (S-44). IHO S-44 specifications are suggested minimum standards that member states may choose to follow. The IHO minimum standards for accuracy are used in the NOS Specifications as a convenient point of reference. When the NOS Specifications refer to an IHO Order, it is usually in terms of the final accuracy of a measurement. No other claim for "meeting" an IHO Order survey is implied.

In the future, NOS Specifications will only define the requirements for grid accuracy and grid resolution, subjects not covered in the current version of S-44 (5th Edition, February 2008). As an interim step, sounding accuracy is still defined in the NOS Specifications, in addition to grid requirements.

5.1.1.1 Accuracy Standards NOS standards for the accuracy of measured depths in hydrographic surveys apply to the systematic measurement of general water depths and to the least depths determined over wrecks and obstructions. By extension, they also apply to the elevations of rocks or other features which uncover at low water and to the measurement of overhead clearances. These standards apply regardless of the method of determination; whether by single beam echosounder, multibeam echosounder, lead line or diver investigation.

The total sounding error in a measured depth at the 95 percent confidence level, after systematic and system specific errors have been removed, shall not exceed:

$$\pm\sqrt{a^2 + (b \star d)^2}$$

where in depths less than 100 meters, a = 0.5 meters and represents the sum of all constant errors, (b * d) represents the sum of all depth dependent errors, b = 0.013 and is a factor of depth dependent error, and d is depth (in meters) (IHO S-44, Order 1).

In depths greater than 100 meters, a =1.0, b=0.023, d=depth (IHO S-44, Order 2).

The maximum allowable error in measured depth includes all inaccuracies due to residual systematic and system specific instrument errors; the speed of sound in water; static vessel draft; dynamic vessel draft; heave, roll, and pitch; and any other sources of error in the actual measurement process, including the errors associated with water level (tide) variations (both tidal measurement and zoning errors).

5.1.1.2 Multibeam Resolution Standards The ability to detect objects is a function of the beam width, beam foot print on the seafloor, bottom detection algorithms, and the spacing of soundings on the seafloor, both across track and along track. The feature detection capabilities of the multibeam equipment shall be consistent with the coverage requirements in section 5.1.2. Along track coverage is also dependent on the sounding ping rate and the speed of the survey vessel. To ensure proper along track coverage, the hydrographer shall ensure that vessel speed is adjusted so that no less than 3.2 beam footprints, center-to-center, fall within 3 m, or a distance equal to 10 percent of the depth, whichever is greater, in the along track direction.

5.1.1.3 Gridded Data Specifications In the Navigation Surface approach, survey data are archived as a certified digital terrain model rather than as a set of verified soundings. While the elevation model may be archived at the highest resolution supported by the sounding data, HSD has determined that the highest resolution possible is rarely needed for navigation products. A compromise grid resolution between the highest resolution possible and a resolution required for navigation products has the advantage of preserving high-resolution data for posterity without needlessly burdening NOAA field units and contractors. The end product of creating a nautical chart is then created from scale-appropriate generalizations of the Navigation Surface elevation model.The Navigation Surface requires that each sounding have a horizontal and vertical uncertainty. To do this effectively, an error model is needed for all systems supplying measurements to compute the sounding; including not only the multibeam echosounder, but the GPS sensors, the heave, pitch, and roll sensors, the sound speed measuring devices, tide gauges, draft measurements, dynamic draft, and anything else that contributes to the calculation of a sounding. Once this comprehensive error model is assembled, then all the inherent errors in each measurement can be propagated from the measurement platform to each individual sounding. Only when each sounding has an associated Total Propagated Uncertainty (TPU), can we combine the soundings into a Navigation Surface with each node having a depth and uncertainty attribute.

Currently, the open source Bathymetric Attributed Grid (BAG) standard format does not include support for multi-resolution grids. The BAG format was developed to create an open source exchange format for gridded data. The Open Navigation Surface Working Group (ONSWG) was formed to develop the format. ONSWG is comprised of government and private sector groups. The primary goals of the ONSWG are to define an open, platform independent, grid database file format suitable for access, archival, and interchange of Navigation Surface results, and to develop an open source software access library to operate on this format. For more information see `http://www.opennavsurf.org`. The CARIS Bathymetry with Associated Statistical Error (BASE) surface has multi-resolution functionality; however, it is not presently approved for NOAA surveys. Therefore, the survey area will typically be required to be subdivided into several grids of varying resolution dependent on depth.

The hydrographer may adjust these values based on the bathymetry of the survey area, the type of multibeam sonar used and other factors. However, adjacent grids shall always overlap in depth to ensure no gaps in coverage exist at the transition from one depth grid to another.

The hydrographer shall also consider the size of objects that they are attempting to detect. Typically, a grid must have twice the resolution of the object (i.e. a 1 meter grid would be required to properly depict a 2 meter cube).

The hydrographer has the responsibility to review the surface and ensure that it truly reflects the conditions in the survey area. No algorithm will ever perfectly model the seafloor. Especially in the case of small diameter objects (pilings, small rocks, etc.), depending on the resolution of the gridded surface, it is unlikely that the surface will capture the absolute least depth on all features. An experienced hydrographer, therefore, must review the data and occasionally select "designated" soundings which override the gridded surface and force the model to recognize the shoal sounding.

Designated Soundings In depths less than 30 meters, a designated sounding should be selected when the difference between the gridded surface and reliable shoaler sounding(s) are more than one-half the allowable IHO error budget for the depth, for navigationally significant features/areas. For instance, a rock on a steep slope should not be selected if the hydrographer determines it is a navigationally significant feature based on the vessel traffic in the area.

In depths greater than 30 meters, a designated sounding should be selected when the difference between the gridded surface and reliable shoaler sounding(s) are more than the allowable IHO error budget for the depth.

Additional designated soundings may be selected by the hydrographer as deemed necessary.

Conversely, if noisy data, or 'fliers' are incorporated into the gridded solution, the surface may be shoaler than the true seafloor. In such cases the spurious soundings will need to be rejected and the surface recomputed. Therefore, if noisy data causes the surface to be shoaler than expected by an amount greater than the IHO error budget for depth, then the noisy data shall be rejected and the surface recomputed.

If an excessive number of designated soundings need to be selected, the hydrographer may need to reassess the grid resolution of the surface. If the data supports a higher resolution grid, the resultant surface may model the seafloor more accurately and result in fewer designated soundings being required. In some cases, often in rocky nearshore areas, the least depths of many features in a relatively small area may fail to be preserved, even by very high resolution BASE surfaces. In these instances the hydrographer shall designate the least depths on the shoalest features. See section 8.1.2 for guidance on delineating and characterizing this rocky seabed area.

Uncertainty By definition each node of the grid includes not only a depth value, but other attributes including "uncertainty". The uncertainty value for the grid shall be the greater of the standard deviation and the a priori uncertainty at each node. The hydrographer shall include a discussion in the DAPR on how the uncertainty was computed on each individual sounding and how the uncertainty was computed on the grid, with a justification for that methodology.

The hydrographer shall examine the finalized grids and explain in the DR any areas of unusually high uncertainty.

5.1.2 Coverage

In general, there are three classifications of multibeam coverage: Object Detection Coverage, Complete Coverage and Set Line Spacing. The survey coverage technique will be specified in the Statement of Work. Field operations shall be conducted such that the accuracy requirements in Section

5.1.1 are met for the entire multibeam coverage area and the multibeam is operated as stated in section 5.1.1.2.

In some cases a hybrid coverage technique may be used, such as, 100% side scan with Complete Multibeam Coverage. The requirements for any assigned hybrid coverage will be described in the Statement of Work or Project Instructions. If single beam and multibeam are specified in the Hydrographic Survey Project Instructions or Statement of Work and they both fall in a common area, then a separate single beam surface is required.

These requirements shall be followed by contractors unless stated otherwise in the SOW or an exemption is approved by the COTR. NOAA field units shall refer to the Project Instructions for specifics. Any deviations from the requirements shall be discussed in the Descriptive Report and NOAA field units shall notify HSD Operations.

The experienced hydrographer should use discretion when using the following gridding requirements described in sections 5.1.2.1, 5.1.2.2, and 5.1.2.3. If the required resolution of the grid for an area does not seem appropriate, the hydrographer should notify HSD or the appropriate COTR to discuss exceptions to the gridding specifications and recommend alternate gridding resolutions. The discussion should occur early in the data acquisition phase of the project, in case the exception is not agreed upon. For instance, a very narrow high resolution grid along shore in a "steep and deep" fjord serves no purpose. Also, object detection coverage gridding specifications may not be necessary areas where object detection requirements are met by side scan sonar or other technologies (and where objects found have an accurate least depth determined with an appropriate echosounder).

5.1.2.1 Object Detection Coverage

- Detect and include in the grid bathymetry all features measuring at least 1m x 1m x 1m in waters up to 20 meter deep, and a cube measuring 5% of the depth in waters 20m and deeper.
- Grid resolution shall be 0.5m in waters less than 20m deep, and approximately 5% of the water depth in waters 20m and deeper.
- The maximum propagation distance of soundings to node shall be one grid resolution or approximately 4% of depth, whichever is greater.
- At least 95% of all nodes on the surface shall be populated.
- For depths up to 30m no holiday spanning more than 3 nodes; for depths deeper than 30m,hydrographer's discretion shall be used, notwithstanding any violation of other coverage requirements.
- No holidays over tops of potentially significant features.
- An example of grid-resolution thresholds as a function of depth range:

Depth Range (m)	**Resolution (m)**
0 – 23	0.5
20-30	1
27-52	2
46-115	4
103-350	8
350+	16

5.1.2.2 Complete Multibeam Coverage

- Detect and include in the grid bathymetry from all features measuring 2m x 2m horizontally, and 2m vertically in waters less than 20m deep
- Detect features 10% of depth horizontally and approximately 5% vertically in waters above 20m.
- Grid resolution shall nominally be 1m in waters less than 20m deep, and approximately 5% of the water depth in waters 20m and deeper. Coarser resolutions may be warranted in certain areas due to bottom topography ("steep and deep"), or if side scan data is also collected, or other project specific reasons. However, there is rarely a circumstance where the depths encountered are deep enough to warrant the use of grid resolutions greater than 10m. The coarsest resolution shall be 8m for areas with depths up to 350m and a 16m resolution for areas with depths greater than 350m.
- Maximum propagation distance of soundings to node shall be one grid resolution or approximately 20% of depth, whichever is greater.
- At least 95% of all nodes on the surface shall be populated.
- No holiday spanning more than 3 nodes in waters less than 30m; for depths deeper than 30m, hydrographer's discretion shall be used, notwithstanding any violation of other coverage requirements.
- No holidays over tops of potentially significant features.
- All significant shoals or features found in waters less than 30m deep shall be developed to Object Detection standards or designate soundings from nadir beam developments.
- An example of grid-resolution thresholds as a function of depth range

Depth Range (m)	Resolution (m)
0-23	1
20-52	2
46-115	4
103-350	8
350+	16

5.1.2.3 Set Line Spacing The hydrographer shall conduct multibeam and single beam operations at the line spacing specified in the Hydrographic Survey Project Instructions or Statement of Work. For example, set line spacing may be employed in the following scenarios: (1) when acquiring multibeam data concurrently with side scan sonar operations (sometimes referred to as "skunk-stripe" coverage, where the side scan swath is wider than the multibeam swath) and 2) when acquiring single beam data in areas that are too shallow or efficient multibeam operations, or otherwise too risky of an area to use multibeam equipment.

- For multibeam operations the requirements are the same within the swath, as for Complete Coverage above. Note: that in a "skunk striping" scenario (see above) elements of object detection area also in operation, due to side scan sonar data coverage and any associated contact scanning requirments.

- For single beam operations the resolution of the single beam grid should be at least between 2m to 5m and be multiples of any overlapping multibeam grids set such that the geometry is in alignment.
- Splits between set line spacing shall be acquired for both multibeam and single beam hydrography to adequately define shoals and to verify currently-charted soundings that are shoaler than any adjacent limits of echosounder coverage.

5.1.3 Corrections to Echo Soundings

To meet the accuracy and resolution standards for measured depths specified in Section 5.1.1, and to create a BAG that includes an accurate uncertainty layer, the hydrographer should conduct an error analysis of their survey systems.

Precise measurements are fundamental to the field of hydrography. Synchronization of multiple sensors with the sonar system is essential for meaningful spatial analysis of the data. All measurements, however careful and scientific, are subject to some uncertainties. Error analysis is the study and evaluation of these uncertainties with the purpose of estimating the extent of the uncertainties and when necessary, reducing them.

Uncertainty-based processing has fundamentally altered bathymetric data processing and product creation. The validity and usefulness of the results are directly correlated to the accuracy of the individual estimates that compose the error model. The error model for CARIS contains uncertainties associated with the sensor and sonar, physical offsets, latency, draft, loading, sound speed and tide and tidal zoning (NOAA field units may refer to section 4.2.3.6 of the OCS Field Procedures Manual for more information). Non-CARIS users must build a similar model of all the correctors to the depth measurement and the associated uncertainties.

In recognition of the possibility that some discrepancies in sounding may not be detected until the final processing phase of the survey, the determination and application of corrections to echo soundings must be accomplished and documented in a systematic manner. In addition, it is preferable that all corrections be applied in such a way that the on-line values may be removed and replaced with a revised set of correctors during office processing. Corrections to echo soundings are divided into five categories, and listed below in the sequence in which they are applied:

Instrument error corrections account for sources of error related to the sounding equipment itself.

Draft corrections shall be added to the observed soundings to account for the depth of the echosounder transducer below the water surface.

Dynamic draft corrections shall be applied to soundings to correct the vertical displacement of the transducer, relative to its position at rest, when a vessel is underway.

Speed of sound corrections shall be applied to soundings to compensate for the fact that echosounders may only display depths based on an assumed sound speed profile while the true speed may vary in time and space.

Attitude corrections shall be applied to multibeam soundings to correct the effect of vessel motion caused by waves and swells (heave, roll, pitch) and the error in the vessel's heading

5.1.3.1 Instrument Error Corrections In modern digital sounding instruments, instrument errors are generally small and of a fixed magnitude independent of the observed depth. Proper set up and adjustment of digital sounding equipment using internal checks and echo simulators will often eliminate instrument error entirely. However, to ensure the proper operation of echosounders, "confidence checks" shall be conducted periodically.

For single beam echosounders, a comparison should be made at least once per week with depths from bar checks, lead lines, or other single beam echosounders.

For multibeam echosounders, comparisons should be made at least once per week between the nadir (vertical) beam of the multibeam and a single beam system or lead line. On surveys where multiple vessels collect data that overlaps with each other to allow comparison of depths, the frequency of formal confidence checks can be reduced to once per survey. In addition, frequent checks should be made between the overlap of mainscheme and crosslines collected on different days. These comparisons should be made frequently during data collection to find errors promptly, and not saved until final data processing after the field party has left the working grounds.

Comparisons should be conducted during calm sea conditions, preferably in areas with a relatively flat sandy bottom. Any differences should be investigated, and if, after analysis, a corrector is necessary, it should be applied with an explanation of the cause of the difference explained in the Descriptive Report (DR) section B.2, Quality Control.

5.1.3.2 Draft Corrections The corrections for draft account for the depth of the transducer reference point below the surface of the water. Draft corrections comprise a value for the draft of the vessel at rest, sometimes known as static draft, and settlement corrections which compensate for the variation in draft that occurs when the vessel is making way. The sum of the static draft and the settlement and squat correctors is known as the dynamic draft. Draft is transducer-specific. When more than one transducer is fixed to a vessel, the hydrographer must exercise care to apply the proper draft correction for each transducer. In addition to the draft values, to complete the vessels' error model, the hydrographer must determine the uncertainty associated with all draft values.

Static Draft The static draft, as an echo-sounding correction, refers to the depth of the transducer reference point below surface of the water when the vessel is not making way through the water. The required frequency of static draft measurements depends upon the range of variation in the vessel draft and the depths of water to be surveyed. For depths of 30 m or less, the static draft shall be observed and recorded to at least the nearest 0.1 m. Measurements are required with sufficient frequency to meet this criterion. When sounding in waters deeper than 30 m, the static draft shall be observed and recorded to at least the nearest 0.2 m.

Draft values for small vessels such as survey launches should be determined for the range of loading conditions anticipated during survey operations (maximum and minimum). Draft values for larger vessels must be observed and entered into the record before departing from and upon returning to port. In both cases, the draft should be determined by averaging the max/min or beginning/ending values if the differences do not exceed ± 0.2 m. Otherwise, the applicable draft should be determined in at least 0.1 m increments. If significant changes to a vessel's draft (greater than ± 0.1 m) occur, draft values shall be modified and applied accordingly.

Loading and static draft uncertainties typically represent a small percentage of the total error budget. However, the accuracy of the error model and the results of BAG surface processing are dependent on knowledge of all the uncertainty values that compose the model.

Dynamic Draft Transducers are generally displaced vertically, relative to their positions at rest, when a vessel is making way. Depth measurements are correspondingly affected by these vertical displacements. The displacements may be of sufficient magnitude to warrant compensation, especially when sounding at moderate to high speeds in shoal water. The factors accountable for this vertical displacement are called settlement. Major factors that influence dynamic draft are hull shape, speed, and depth of water beneath the vessel.

Settlement is the general difference between the elevations of a vessel when at rest and when making way. For lower speed, non-planing vessels, settlement is caused by a local depression of the water surface. Settlement is not an increase in the vessel displacement and, therefore, cannot be determined by reference to the water surface in the immediate vicinity. Vessels surveying at higher speeds may experience a negative settlement, or lift, when planning.

Squat refers to changes in trim of the vessel when making way and is generally manifested by a lowering of the stern and rise of the bow. Occasionally, the bow lowers on smaller vessels. Squat does not appreciably affect transducer depth on transducers mounted near amidships. Settlement, on the other hand, is almost always significant at normal sounding speeds, regardless of transducer location.

If a Heave-Roll-Pitch (HRP) sensor is used to determine changes in squat, care must be taken to ensure that squat is not corrected for twice. Conversely, if attitude corrections are not used in single beam data processing, the dynamic draft correction must include any appreciable effects due to vessel trim.

Combined effects of dynamic draft at the full range of sounding speeds must be determined to at least 0.05 meter precision, by the hydrographer at least once a year for each vessel, including launches and skiffs used for hydrographic surveying in shoal or moderate depths. Follow up measurements should be made if there are any major changes to the loading or change to the vessel power plant. When the measurements are made, each vessel should carry an average load and have an average trim. Sounding vessel speeds (or RPM) must be entered in the hydrographic records during survey operations to permit accurate corrections for dynamic draft.

The uncertainty value for Dynamic Draft will be dependent on the method that Dynamic Draft was calculated. Typically, several runs at various speeds will be used to calculate the Dynamic Draft. The uncertainty value could then be the standard deviation calculated for each speed measurement.

5.1.3.3 Speed of Sound Corrections

Special note: Sound Speed or Speed of Sound is sometimes incorrectly referred to as sound velocity in other publications and equipment literature.

General To ensure that the overall depth measurement accuracy criteria specified in Section 5.1.1 are met, speed of sound observations should be taken with sufficient frequency, density, and accuracy. The accuracy with which the speed of sound correction can be determined is a complex function of the accuracy with which salinity, temperature, and depth, or alternately, sound speed and depth, can be measured.

The speed of sound through water shall be determined using instrumentation capable of producing sound speed profiles with errors no greater than 2 meters per second. The sound speed profile must reach the deepest depths of the survey but the physical measurement of sound speed need only extend to:

- 95 percent of the anticipated water depth in 30 m or less of water. For example, if the maximum depth to be surveyed is 25 m, then the speed profile should continue to a depth of at least 23.8 m.

- 90 percent of the anticipated water depth in depths from 30 m to 100 m.
- 85 percent of the anticipated water depth in greater than 100 m of water.

Sound speed correctors must be determined accurately and often enough to ensure that the depth accuracy requirements in Section 5.1.1 are met. If changes in the temperature or salinity in the water column dictate that updated correctors are needed, additional sound speed profiles shall be acquired. Additionally, the hydrographer should establish a means of monitoring changes in the water column between subsequent speed casts.

Regardless of the sound speed determination system employed, an independent sound speed measurement system must be used to establish a confidence check. Confidence checks shall be conducted at least once per week. Include confidence check results in Separate II, Sound Speed Profile Data (see Section 8.1.3.).

A geographic distribution of profiles may be necessary to correct for spatial and diurnal variability. Speed corrections shall be based on the data obtained from the profile, and not based on an averaged sound speed reading for the water column. Survey specific sound speed information shall be included in Separate II, Sound Speed Profile Data (see Section 8.1.3 Descriptive Report Supplemental Records).

The hydrographer shall calibrate sound speed profiler(s) no earlier than six months prior to the commencement of survey operations. Calibration correctors shall be applied to all profiler data. These instrument(s) shall be re-calibrated at intervals no greater than twelve months until survey completion. In addition, the instrument(s) must be re-calibrated when the survey is complete if the completion date is later than six months from the date of last re-calibration. Copies of calibration data shall be included in Separate II, Sound Speed Profile Data (see Section 8.1.4 Descriptive Report Supplemental Records), separates to be included with the survey data.

Sound Speed Corrections for Single Beam Surveys For each individual area identified, a minimum of at least one cast each week, taken in the waters surveyed that week, is required. The variation of physical conditions throughout a survey area or any portion thereof may dictate that this minimum may not be sufficient. Where casts taken early in a project indicate that physical characteristics are extremely variable, observations of speed may be required more frequently.

Sound Speed Corrections for Multibeam Surveys The sound speed profile must be known accurately in multibeam swath sounding for two reasons. First, as in all echo-sounding, the depth is computed from the product of the speed and the elapsed time between transmission of a sound pulse and reception of its echo. Second, since sound pulses travel at oblique angles through the water column, variations in the speed profile will affect the path of sound through water. The sound path from the transducer to the bottom and back will affect not only the observed depth of water, but the apparent position of the observed sounding.

Even though sampling equipment and computer systems are capable of dividing the water column into intervals so small as to allow close approximation of the integral expression for harmonic mean speed, practical limitations may require the hydrographer to use a small number of discrete points on the speed profile for the purpose of correcting echo soundings. If the hydrographer chooses the inflection points of the smooth speed profile as the discrete points for layer boundaries, the speed curve between the points can reasonably be approximated by a straight line.

Integration of all the segments using the trapezoidal rule to approximate the area under each layer will yield very accurate results.

For multibeam operations, the following specifications apply to sound speed profile frequency and application:

- One sound speed profile shall be acquired immediately before the beginning of the data acquisition period. During the course of survey operations, changes in the water column should be monitored at a sufficient frequency such that the general requirements specified earlier in this section are met.
- Sound speed profiles shall be acquired in the immediate area where subsequent data acquisition will occur.
- When using an undulating velocimeter, the real time sound speed profiles shall extend to at least 80% of the anticipated water depth. At a minimum, one cast per 24-hour period shall extend to 95% of the anticipated water depth (30 m or less water depth).

The uncertainty value of the sound speed measurements must be part of the vessel's error model. One method used by NOAA, is to use the manufacturers uncertainty values for the measured components of conductivity, temperature and pressure. These values must then be used to compute a total uncertainty for the profile by computing how each components uncertainty is propagated through the sound speed computations.

A probe that measures speed of sound directly, could use the manufacturers advertised uncertainty value.

Ideally, sound speed uncertainty should be computed based on both the unit's accuracy and the spatial and temporal error associated with sound speed variation over the entire survey area. However, such advanced error analysis is not currently available in NOAA's processing pipeline. Therefore, NOAA field units and contractors may use the uncertainty associated with measuring the speed of sound at a specific location.

5.1.3.4 Attitude Corrections Heave, roll, pitch, heading, and navigation timing error corrections shall be recorded in the data files and applied to all multibeam soundings. Heave and heading shall be applied for all single beam data. NOAA field units should refer to section 4.2.3.6 of the OCS Field Procedures Manual for more guidance on corrections to single beam data.

Heave, roll, and pitch. Heave shall be observed in no coarser than 0.05 m increments. Roll and pitch shall be observed in no coarser than 0.1 degree increments.

Heading shall be observed in no coarser than 0.5 degree increments.

The uncertainty value for heave, roll and pitch will typically be the manufacturer's values, assuming that the equipment is properly installed and maintained. The hydrographer must explain any variance from the manufacturer's values.

Hydrographers using Kinematics shall compensate for squat if attitude is not corrected for single beam.

5.1.3.5 Error Budget Analysis for Depths The hydrographer shall discuss (in Section B.2 of the Descriptive Report) the methods used to minimize the errors associated with the determination of depth (corrections to echo soundings). Error estimate ranges for six of these errors (measurement error, transducer draft error, s dynamic draft error, sound speed error, heave error and tide/water level error) are presented below. These errors are inherent to hydrographic surveying and all have practical minimums that are usually achievable only under ideal circumstances or with highly specialized equipment. In addition, some errors may be dependent on depth (e.g. sound speed).

The error ranges provided below are first order estimates to allow hydrographers to get a basic 'feel' for the possible range in errors that may occur in practice. Hydrographers should note that the root sum square of the individual errors is used in the computation of TPU. The required depth accuracy requirements cannot be achieved if the worst error for each sensor shown below is used.

Maximum allowable errors are specified to ensure that all errors sources are properly managed. It should be noted that if the maximum value for each error source is used in an error budget (i.e. root-sum-squared), the result will exceed the prescribed accuracy standard. The minimum and maximum values discussed below are at the 95% confidence level (i.e. 2 sigma).

The hydrographer shall also discuss (in Section B.2 of the Descriptive Report) the methods used to quantify the survey systems error model. Uncertainty estimates for all components of the sounding measurement should be provided.

Measurement error: This includes the instrument error for the sounding system, the effects of imperfectly measured roll/pitch and errors in detection of the sea floor due to varying density of the bottom material. Multibeam systems are particularly susceptible to this error due to the off-nadir nature of outer beams. The minimum achievable value is expected to be 0.20 meter at 10 meters depth. The maximum allowable error is 0.30 meter plus 0.5% of the depth.

Transducer draft error: This error is controlled by variability in vessel loading, and the techniques used to measure/monitor transducer draft. This error is depth independent with an expected minimum of 0.05 meter and an allowable maximum 0.15 meter.

Dynamic Draft error: Conventional methods of determining dynamic draft are limited by sea surface roughness and proximity of a suitable location to the survey area. Careful application of modern methods (Real Time Kinematic GPS) will minimize this error. This error is also depth independent although the effect of dynamic draft is greater in shallow water. The practical expected minimum is 0.05 meter and the allowable maximum is 0.20 meter.

Sound speed error: The factors associated with this error include (1) the ability to accurately measure sound speed or calculate sound speed from temperature, conductivity and pressure, (2) the spatial and temporal changes of sound speed throughout the survey area and (3) how the sound speed profile is used to convert measured time to depth. In addition, this error encompasses depth errors associated with refraction for multibeam systems. The expected minimum is 0.20 meter and the allowable maximum is 0.30 meter plus 0.5% of the depth.

Heave error: This error is directly dependent on the sea state and the sensitivity of the heave sensor but is not dependent on depth. The expected minimum is 0.05 meter and the allowable maximum is 0.20 meter.

Tide/water level error: This error has been discussed in detail in Section 4 The practical minimum is 0.20 meter and the allowable maximum is 0.45 meter.

5.1.4 Quality Control

5.1.4.1 Multibeam Sonar Calibration Prior to commencing survey operations, the hydrographer shall conduct a system accuracy test to quantify the accuracy, precision, and alignment of the multibeam system. Testing shall include determination of residual biases in roll, pitch, heading, and navigation timing error and the uncertainty of these values. These values will be used to correct the initial alignment, calibrate the multibeam system and used in the computation of the Total Propagated Uncertainty (TPU) for each sounding. System accuracy testing should be conducted in an area similar in bottom profile and composition to the survey area, and during relatively calm seas to limit excessive motions and ensure suitable bottom detection. In addition, system accuracy tests should be conducted in depths equivalent to the deepest depths in the survey area. Static transducer draft, dynamic draft corrections, sound speed corrections, and tide corrections shall be determined and applied to the data prior to bias determination.

The order in which these biases are determined may affect the accurate calibration of the multibeam system. The hydrographer should determine the biases in the following order: navigation timing error, pitch, roll, heading. Variations from this order, simultaneous determination of all values, are other methods of determining the biases must be explained and justified.

Pitch and navigation timing error biases should be determined from two or more pairs of reciprocal lines 500–1,000 m long, over a 10–20 degree smooth slope, perpendicular to the depth curves. The lines should be run at different speeds, varied by up to 5 knots, for the purpose of delineating the along track profiles when assessing time delay. Navigation timing error bias could also be determined from running lines over a distinct feature (i.e., shoal) on the bottom, as long as the feature is pinged by the vertical (nadir) beam.

Roll bias should be determined from one or more pair of reciprocal lines 500–1000 m in length over a flat bottom. Lines should be run at a speed which will ensure significant forward overlap.

Heading bias should be determined from two or more adjacent pairs of reciprocal survey lines, made on each side of a submerged object or feature (i.e., shoal), in relatively shallow water. Features with sharp edges should be avoided. Adjacent swaths should overlap by 10–20 percent while covering the shoal. Lines should be run at a speed which will ensure significant forward overlap.

Once calibration data have been processed and final system biases determined, the new corrections shall be used in a performance check to ensure that the new system biases are adequate. The hydrographer shall discuss procedures and results in Section A. Equipment and optional Section B. Quality Control of the project Data Acquisition and Processing Report. Copies of all system alignment, accuracy, calibration reports, and performance checks shall be included in the Data Acquisition and Processing Report.

System accuracy testing shall be repeated whenever changes (e.g., sensor failure, replacement, re-installations, re-configurations, or upgrade; software changes which could potentially affect data quality) are made to the system's baseline configuration, or whenever assessment of the data indicates that system accuracies do not meet the requirements in Section 5.1.1.

5.1.4.2 Positioning System Confidence Checks Confidence checks of the primary positioning system shall be conducted and recorded in the survey records at least once every week. A successful confidence check shall compare positions from the primary system to simultaneously observed check positions from a separate, independent system with a positional accuracy better than 10 meters. The inverse distance shall not exceed 10 meters. If correctors for the primary positioning system are obtained from a non-USCG differential system, then the check system must use correctors from a reference station different from the primary systems. If correctors are obtained from a USCG differential station, the check system may use the same correctors as the primary system. The confidence checks shall be an integral part of the daily survey data record. A summary report of positioning system confidence checks shall be included in Separate I of "Separates to be Included with the Survey Data" (see 8.1.3).

5.1.4.3 Crosslines

General The regular system of sounding lines shall be supplemented by a series of crosslines for verifying and evaluating the accuracy and reliability of surveyed depths and plotted locations. Crosslines shall be run across all planned sounding lines at angles of 45 to 90 degrees. The preferred area in which to run crosslines is in an area of gently sloping bottom.

Single beam The lineal nautical miles of crosslines for single-beam surveys shall be at least 8 percent of the lineal nautical miles of all sounding lines.

The hydrographer shall make a general evaluation of the single beam crossline to mainscheme agreement, and discuss the results in Section B of the Descriptive Report. If the magnitude of the discrepancy varies widely over the survey, the hydrographer shall make a quantitative evaluation of the disagreements area by area.

Multibeam The lineal nautical miles of crosslines for multibeam surveys shall be at least 5 percent of the lineal nautical miles of all sounding lines. An independent analysis of the crossline and mainscheme data shall be conducted. An independent analysis of the crossline and mainscheme data shall be conducted. Although any crossline/mainscheme disagreements should be obvious in the attributes of the combined surface, an independent analysis is still required to ensure that the surface implementation is correct and to help find any hidden problems.

Two possible methods of conducting the independent analysis is a beam by beam statistical analysis or by a surface difference (NOAA field units should refer to section 5.1.2.2.2 of the OCS Field Procedures Manual for more information). Other methods may be used if approved in advance by the COTR or Atlantic/Pacific Hydrographic Branch.

A surface difference can be conducted by creating a surface using only mainscheme data and comparing to a surface created from only crossline data. The surfaces used to compute the difference should have at least the resolution defined in section 5.1.2.

For either method, the hydrographer shall make a general evaluation of the multibeam crossline to mainscheme agreement, and discuss the results in Section B of the Descriptive Report. If the magnitude of the discrepancy varies widely over the survey, the hydrographer shall make a quantitative evaluation of the disagreements area by area. The difference surface shall also be included in the final deliverables.

5.2 Lidar

5.2.1 Accuracy and Resolution Standards

Lidar follows the standards for multibeam see sections 5.1.1 and 5.1.1.1 for information on accuracy and resolution standards for lidar.

5.2.1.1 Lidar Resolution Standards

Spatial resolution The hydrographer shall maintain and operate the lidar system, from data acquisition to processing to detect hazardous features. As the spatial resolution (i.e., the spacing of the lidar footprint on the seafloor) is dependant on a wide range of variables: 1) propagation of light through the water 2) the received signal strength 3) the object detection algorithms used 4) changes in water depth, and 5) aircraft height above the surface the actual bottom resolution may not remain constant. The hydrographer shall make a statement in the Descriptive Report describing the areas within the survey where they are confident that the multibeam resolution standards defined in section 5.1.1.2 are met (2x2x2m cube).

Spot spacing requirement will be defined in the Statement of Work, typically 3x3 or 4x4 at 200% coverage.

5.2.1.2 Gridded Data Specifications In the Navigation Surface approach, survey data are archived as a certified digital terrain model rather than as a set of verified or certified soundings. The archived elevation model could be saved at the highest resolution supported by the sounding data. For example, if the laser spot spacing on the seafloor of a full-coverage lidar survey is 3 meters, the elevation model could be saved at a grid spacing of 3 meters. However, if environmental conditions (i.e. kelp, turbidity, or sea state) create differences in data density an alterative approach may be discussed with the COTR and clearly described in the Descriptive Report (DR). This practice has the advantage of preserving this high-resolution data for a variety of known and unknown future purposes, even if such resolution will never appear on a navigational or charting product. Charting products such as paper charts are created from scale-appropriate generalizations of the elevation model. In reality, the final resolution of the surface may be slightly coarser than "the highest resolution supported by the sounding data" due to depth ranges, bottom topography and other variables.

The data density and resulting grid resolutions created shall be discussed with the COTR during the project planning phase. Any deviations from the plan, project instructions or Specifications and Deliverables shall be discussed with the COTR and clearly described in the Descriptive Report (DR) and Data Acquisition and Processing Report (DAPR).

If in rocky nearshore areas, the least depths of many features in a relatively small area fail to be preserved, see section 5.1.1.3 for more guidance. See also section 8.1.2 for guidance on delineating and characterizing this rocky seabed area.

Uncertainty The Navigation Surface for lidar requires that each sounding have a horizontal and vertical uncertainty. The uncertainty value for the grid shall be the greater of the standard deviation and the a priori uncertainty. To do this effectively, an error model is needed for all systems supplying measurements to compute the sounding; including the GPS sensors and anything else that contributes to the calculation of a sounding. The hydrographer shall include a discussion in the

DAPR on how the uncertainty was computed on each individual sounding and how the uncertainty was computed on the grid, with a justification for that methodology.

If a complete error model is not yet available to compute the TPU for each individual sounding then the hydrographer may apply a single uncertainty value to all grid nodes that reflect the vertical error budget for a given survey. Include a discussion in the DAPR on how the uncertainty was computed with a justification for that methodology.

5.2.2 Coverage

The required spot spacing and survey coverage will be specified in the Hydrographic Survey Project Instructions or Statement of Work.

The hydrographer shall obtain 200% coverage when required to do so in the Statement of Work. In situations where poor water clarity and related environmental factors make 200% coverage impossible the COTR shall be notified. In addition the hydrographer shall identify (textually and/or graphically) those areas where full coverage was not obtained and/or further investigation using sonar may be required.

All soundings shall meet the accuracy requirements of Section 5.1.1.1. Grid resolutions shall be appropriate for the spot spacing required in the Statement of Work.

Complete lidar coverage

- Grid resolution shall nominally be 3 meters - If survey data can support higher resolutions, then use hydrographer discretion and submit a higher resolution, if appropriate.
- Maximum surface uncertainty is IHO Order 1 for depths less than 100 meters.

The hydrographer must ensure that accurate least depths are obtained on all significant features. Individual soundings that do not meet the Horizontal Position Accuracy as defined in Section 3.1 or do not meet the Vertical Accuracy as defined in Section 5.1.1., shall not be applied to the grid.

As always, the hydrographer must ensure that the data accurately reflects the condition of the seafloor at the time of the survey and adjust operations if required. Any deviations from the specifications must be clearly explained in the Descriptive Report and discussed with the COTR as they occur.

5.2.3 Corrections to Lidar Soundings

To meet the accuracy and resolution standards for measured depths specified in Section 5.1.1 and 5.1.1.1, and to create a BAG that includes an accurate uncertainty layer, the hydrographer should conduct an error analysis of their survey systems.

Precise measurements are fundamental to the field of hydrography. Synchronization of multiple sensors with the lidar system is essential for meaningful spatial analysis of the data. All measurements, however careful and scientific, are subject to some uncertainties. Error analysis is the study and evaluation of these uncertainties with the purpose of estimating the extent of the uncertainties and when necessary, reducing them.

In recognition of the possibility that some discrepancies in sounding may not be detected until the final processing phase of the survey, the determination and application of corrections to soundings must be accomplished and documented in a systematic manner. In addition, it is preferable that all corrections be applied in such a way that the on-line values may be removed and replaced with a revised set of correctors during office processing. Corrections to soundings are divided into five categories, and listed below in the sequence in which they are applied:

Instrument error corrections account for sources of error related to the sounding equipment itself.

Roll, pitch, heading, and navigation timing error (latency) corrections shall be applied to lidar soundings to correct the effect of the aircraft's motion caused by turbulence, the error in the aircraft's heading, and the time delay from the moment the position is measured until the data is received by the data collection system (navigation timing error).

The hydrographer shall also discuss (in Section B2. of the Descriptive Report) the methods used to quantify the survey systems error model. Uncertainty estimates for all components of the sounding measurement should be provided.

5.2.3.1 Instrument Error Corrections In modern digital sounding instruments, instrument errors are generally small and of a fixed magnitude independent of the observed depth. Proper set up and adjustment of Lidar equipment using internal checks will often eliminate instrument error entirely. However, to ensure the proper operation of the lidar system "confidence checks" shall be conducted periodically.

Frequent checks should be made between the overlap of mainscheme and crosslines collected on different days. These comparisons should be made frequently during data collection to find errors promptly, and not saved until final data processing after the field party has left the working grounds.

Any differences should be investigated, and if, after analysis, a corrector is necessary, it should be applied with an explanation of the cause of the difference explained in the Descriptive Report (DR) section B2., Quality Control.

5.2.4 Quality Control

5.2.4.1 Lidar Calibration Field calibration is performed by the system operator through flights over a calibration site that has been accurately surveyed using GPS or conventional survey techniques such as triangulation or spirit leveling. Typically, the calibration site may include a large, flat-roofed building whose corners have been accurately surveyed with GPS and a large, flat parking lot and runway. The calibration may include flights over the site in opposing directions, as well as cross flights. The field calibration is used to determine corrections to the roll, pitch, and scale calibration parameters. Field calibrations must be performed for each project or every month, whichever is shorter.

Prior to commencing survey operations, the hydrographer shall conduct a system accuracy test to quantify the accuracy, precision, and alignment of the lidar system. Testing shall include determination of residual biases in roll, pitch, heading, and navigation timing error and the uncertainty of these values. These values will be used to correct the initial alignment, calibrate the lidar system and used in the computation of the Total Propagated Uncertainty (TPU).

Once calibration data have been processed and final system biases determined, the new corrections shall be used in a performance check to ensure that the new system biases are adequate. The hydrographer shall discuss procedures and results in Section A. Equipment and optional Section B. Quality Control of the project Data Acquisition and Processing Report. Copies of all system alignment, accuracy, calibration reports, and performance checks shall be included in the Data Acquisition and Processing Report.

System accuracy testing shall be repeated whenever changes (e.g., sensor failure, replacement, re-installations, re-configurations, or upgrade; software changes which could potentially affect data quality) are made to the system's baseline configuration, or whenever assessment of the data indicates that system accuracies do not meet the requirements in Section 5.1.1 and 5.1.1.1.

5.2.4.2 Positioning System Confidence Checks Confidence checks of the primary positioning system shall be conducted and recorded in the survey records at least once every week. A successful confidence check shall compare positions from the primary system to simultaneously observed check positions from a separate, independent system with a positional accuracy better than 10 meters. The inverse distance shall not exceed 10 meters. If correctors for the primary positioning system are obtained from a non-USCG differential system, then the check system must use correctors from a reference station different from the primary systems. If correctors are obtained from a USCG differential station, the check system may use the same correctors as the primary system. The confidence checks shall be an integral part of the daily survey data record. A summary report of positioning system confidence checks shall be included in Separate I of "Separates to be included with the Survey Data" (see 8.1.3).

5.2.4.3 Crosslines

General The regular system of sounding lines shall be supplemented by a series of crosslines for verifying and evaluating the accuracy and reliability of surveyed depths and plotted locations. Crosslines shall be run across all planned sounding lines at angles of 45 to 90 degrees. The preferred area in which to run crosslines is in an area of gently sloping bottom.

The hydrographer shall make a general evaluation of the lidar crossline to mainscheme agreement, and discuss the results in Section B of the Descriptive Report. If the magnitude of the discrepancy varies widely over the survey, the hydrographer shall make a quantitative evaluation of the disagreements area by area.

The lineal nautical miles of crosslines for lidar surveys shall be discussed and agreed upon with the COTR during project planning. Under certain conditions (e.g., steep terrain, airspace restrictions, or relatively narrow band of coverage) crosslines may not be possible. In such cases, a deviation from this requirement shall be requested from the COTR and explained in the DR.

An independent analysis of the crossline and mainscheme data shall be conducted. Although any crossline/mainscheme disagreements should be obvious in the attributes of the combined surface, an independent analysis is still required to ensure that the surface implementation is correct and to help find any hidden problems. Include a statement regarding the results of the comparison in Section B of the Descriptive Report. If created, the difference surface shall also be included in the final deliverables.

6 Towed Side Scan Sonar

During hydrographic surveys, the use of side scan sonar may be required for supplementing echo-sounding by searching the region between regular sounding lines for additional indications of dangers and bathymetric irregularities. Any requirement for side scan sonar coverage in conjunction with a hydrographic survey will be specified in the Hydrographic Survey Project Instructions or Statement of Work.

6.1 Coverage

Scanning coverage is the concept used to describe the extent to which the bottom has been covered by side scan sonar swaths, that is, the band of sea bottom which is ensonified and recorded along a single vessel track line. For hydrographic purposes, scanning coverage of an area is expressed in multiples of 100 percent, and is cumulative. One hundred percent coverage results in an area ensonified once, and two hundred percent coverage results in an area ensonified twice. Advisory note: Side scan coverage may not be achieved as planned due to varying water conditions, such as thermoclines, limiting such coverage.

The scanning coverage requirements will be stated in the Hydrographic Survey Project Instructions or Statement of Work. Approved 200-percent coverage techniques are as follows:

Technique 1. Conduct a single survey wherein the vessel track lines are separated by one-half the distance required for 100-percent coverage.

Technique 2. Conduct two separate 100-percent coverages wherein the vessel track lines during the second coverage split the difference between the track lines of the first coverage. Final track spacing is essentially the same as technique 1.

Technique 3. Conduct two separate 100-percent coverages in orthogonal directions. This technique may be advantageous when searching for small man-made objects on the bottom as the bottom is ensonified in different aspects. However, basic line spacing requirements for single-beam echosounders may not be met when using this technique.

6.2 Side Scan Acquisition Parameters and Requirements

6.2.1 Accuracy

The side scan sonar system shall be operated in such a manner that it is capable of detecting an object on the sea floor that measures 1 m x 1 m x 1 m from shadow length measurements.

6.2.2 Speed

The hydrographer shall tow the side scan sonar at a speed such that an object 1 m on a side on the sea floor would be independently ensonified a minimum of three times per pass.

The number of pulses per unit time, or pulse repetition rate, determines the speed at which the transducer (i.e. the vessel) can move along the track and still maintain the required coverage of the bottom. Longer operating ranges have slower pulse repetition rates, which requires the vessel speed to be slower if the entire bottom is to be ensonified.

The maximum vessel speed for three ensonifications can be calculated if the pulse repetition rate (prr) or the pulse period (pp) is known. The rate is the reciprocal of the period. This rate and/or period is usually published in the operating manual for the side scan sonar system. The calculation is as follows: Maximum vessel speed (meters/second) = target size (meters) X prr/3 (sec-1).

6.2.3 Towfish Height

The hydrographer shall operate the side scan sonar system with a towfish height above the bottom of 8 percent to 20 percent of the range scale in use. For any towfish height below 8 percent of the range scale in use, the effective scanning range is defined to equal 12.5 times the towfish height, provided adequate echoes have been received.

6.2.4 Horizontal Range

The achievable horizontal range of a side scan sonar is a function of several parameters. Among these are sonar conditions, sea bed composition, the range scale in use, side scan sonar system characteristics, and towfish height. Actual conditions in the survey area will determine the effective range of a particular side scan sonar system. The maximum allowable range scale for any towed side scan sonar is 100 m.

If the effective range scale of the side scan sonar is reduced due to external factors, then the representation of the swath coverage should be reduced accordingly. For example, changes in the water column or inclement weather may distort the outer half of the 100 m range scale. In this case, only 50 m of effective range could be claimed.

6.3 Quality Control

6.3.1 Confidence Checks

Confidence checks of the side scan sonar system shall be conducted at least once daily. These checks should be accomplished at the outer limits of the range scales being used based on a target near or on the bottom. Each sonar channel (i.e., port and starboard channels) shall be checked to verify proper system tuning and operation. Confidence checks can be made on any discrete object, offshore structure, or bottom feature which is convenient or incidental to the survey area. Targets can include wrecks, offshore structures, navigation buoy moorings, distinct trawl scours, or sand ripples.

Confidence checks can be made during the course of survey operations by noting the check feature on the sonargram. If a convenient or incidental target is not available, a known target may be placed on or near the bottom and used for confidence checks. Confidence checks shall be an integral part of the daily side scan sonar operation and shall be annotated in the side scan sonar data records.

6.3.2 Significant Contacts

In depths of water less than or equal to 20 m, contacts with computed target heights (based on side scan sonar shadow lengths) of at least 1 m should be considered "significant." In depths of water greater than 20 m, contacts with computed target heights rising above the bottom at least 10 percent of the depth should be considered "significant". Other contacts without shadows may also be considered "significant" if the sonargram signature (e.g., size, shape, or pattern qualities) is notable. In addition, contacts with less than 1 m target heights should be considered "significant" if they are found near the critical navigation depths of the local area. For example, if a 0.5 m contact is discovered in 10 m of water at the seaward approach to a dredged channel with a controlling depth of 10 m, then the contact should be considered significant.

6.3.3 Contact Correlation

The hydrographer shall examine and correlate targets between successive side scan sonar coverages (i.e., compare the first 100 percent with the second 100 percent sonar coverage). If applicable, the hydrographer shall examine the multibeam data and correlate anomalous features or soundings with the side scan sonar data. Anomalous features or targets which appear consistently and correlate in each type of data record provide increased confidence that acquisition systems are working correctly and help to confirm the existence of these features or targets. The hydrographer shall cross reference and remark on each target correlation in the Remarks column (column 7) of the Side Scan Sonar Contact List (see Section 8.3.2).

6.3.4 Identification of Potential Field Examinations

The hydrographer shall use the sonar contact list, in conjunction with an analysis of echosounder least depths and BAG attributes (standard deviation, uncertainty, etc), to identify hydrographic features which may require further examination.

7 Other Data

7.1 Bottom Characteristics

When required in the Hydrographic Survey Project Instructions or Statement of Work, the hydrographer shall obtain samples of the bottom sediment. In general, the distance between bottom samples should not exceed 1200 meters in charted anchorage areas, and the distance between samples in all other areas should not exceed 2000 meters. Bottom samples will not be required in depths greater than 100 meters. NOAA field units should refer to section 2.5.3.6.1 of the Field Procedures Manual.

When sampling is required, the hydrographer shall record position and depth data for each sample obtained. In addition, each sample shall be described and completely attributed in the S-57 feature file. A table listing the position and description of the bottom sample obtained shall also be included in Appendix V of the Descriptive Report.

7.2 Aids to Navigation

The hydrographer shall investigate all U.S. Coast Guard (USCG) and privately maintained fixed and floating aids to navigation located within the survey limits. Upon inspection of the most recent edition of the largest scale chart of the survey area and the latest edition of the USCG Light List, the hydrographer shall confirm the aid's characteristics and determine whether the aid adequately serves the intended purpose for which it was established.

If the hydrographer determines that an aid to navigation is located off station, is damaged to the extent that it does not serve its intended purpose or its characteristics are incorrectly charted, the facts should be reported immediately in the form of a danger to navigation letter (see Section 8.1.2Danger to Navigation Report).

If an uncharted fixed or floating aid to navigation is discovered within the survey area, the hydrographer shall obtain a differential GPS position on the aid and report the new aid to navigation promptly to the nearest USCG district and submit a Danger to Navigation Report. Include geographic position, characteristics, apparent purpose, and by whom the aid is maintained (if known).

Other fixed and floating aids to navigation and landmarks within the survey area may require specific positioning methods. Positioning specifications and requirements will be provided in the Hydrographic Survey Project Instructions/Field Procedures Manual or Statement of Work.

8 Deliverables

8.1 Field Reports

Reported horizontal positions shall be recorded in meters, with a precision of at least decimeters (refer to section 5 regarding requirements for vertical (depth) positions). This precision shall be maintained throughout the processing pipeline and be maintained in the digital data.

8.1.1 Progress Sketch and Survey Outline

The hydrographer shall submit a Monthly Progress Sketch digitally via email, to the addresses specified in the Hydrographic Survey Project Instructions or Statement of Work no later than 5 calendar days from the end of the reported month. Progress sketches will typically be constructed using a desktop Geographic Information System. NOAA field units shall submit their progress sketches in MapInfo format and a separate statistics sheet in Excel, in accordance with section 2.2.2.10 and 5.2.3.2.1 of the OCS Field Procedures Manual. Contractors may refer to the separate statistics spreadsheet example (Figure I.1) in Appendix 9.

The following provides clarification of the columns within the spreadsheet:

- The "LNM VBES" (vertical beam echo sounder), "LNM MB" (multibeam), and "LNM SSS" (side scan sonar) are for the purpose of reporting operations using only one sonar sensor.
- The "LNM Combo" is for reporting LNM if a combination of sensors is used, such as side scan and single beam or multibeam and side scan.
- The LNM above are to be subdivided between ship and launch platforms as appropriate.
- "Items Investigated" includes AWOIS items or newly discovered items that require extra survey time.
- "DAS" (day at sea)
- "Time Lost Days" are to be reported as days using decimals (i.e., 1.5) as determined from the Vessel Utilization Report by subtracting "Vessel Utilization" value (see c.5 below) from 1.0.

Contractors shall submit their progress sketches in MapInfo format or as an Adobe Acrobat .pdf file. The Progress Sketch is a page-size graphic that portrays survey accomplishments. All portions of the sketch must be neat and legible for reproduction. Every Progress Sketch shall be overlayed onto a large scale chart of the survey area that includes land area to give geographic context (do not include the raster chart file in email attachment, only reference chart used, if submitting in MapInfo format) and depict the following information, if applicable:

- Title block
- Statistics block
- Latitude and longitude tick marks
- Sheet limits
- Survey area limits

- Sheet letters and registry numbers

The title block consists of the title “Progress Sketch”, project number, locality, type of survey, inclusive dates of survey, and name of survey party (vessel or contractor name).

The statistics block contains monthly columns showing, in rows, the following items, if applicable:

- Lineal nautical miles of sounding lines (list side scan sonar, multibeam and/or single beam separately) with separate statistics for the ship vice launches; if multiple sensors are used (SSS/single beam or SSS/MB) the miles should be reported separately along with indication of the sensors used. NOTE: Lineal nautical miles of shoreline/nearshore buffer lines (with or without sonar) should be included with the statistics for single beam.
- Square nautical miles of each survey sheet completely surveyed (the sum of all the monthly progress sketches for the survey should approximately equal the final total area surveyed at the end of the project).
- Number of bottom samples collected
- Number of items investigated including those from the Automated Wreck and Obstruction Information System (AWOIS) and newly discovered items that require additional field work.
- Number of tide gauges installed/removed
- Number of days of down time due to weather
- Number of days of down time due to equipment
- Number of days of down time for other reasons
- Number of days field unit was on site working on project (for instance, the field unit may have departed on the 15th, meaning the monthly progress sketch only reflects 15 days of work)

Distinctive hatching or a percentage complete value should be used to differentiate the sheet areas surveyed each calendar month. Additional symbols may be used on the Progress Sketch as necessary, but should be explained in the legend.

Survey Outlines:

After completion of all field work for a survey, the hydrographer shall provide a survey outline region in MapInfo compatible format, Latitude/Longitude coordinate system, NAD 83, that shows the extent of hydrography completed for the registered survey. Contractors shall forward the outline via email to the COTR. NOAA field units shall forward the outline directly to 'survey.outlines@noaa.gov (see OCS Field Procedures Manual, section 5.2.3.3.3). The outline should be submitted as soon as practical after completion of field work.

If the outline has not been submitted within 30 days of completion of field work, the hydrographer shall contact HSD Operations Branch or the COTR to explain the delay and provide an estimate for delivery. Any large differences (± 10%) between the total square miles reported via the progress sketches for the survey and the area defined by the survey outline should be explained in the cover e-mail.

8.1.2 Danger to Navigation

As soon as practicable after discovery, the hydrographer shall submit a Danger to Navigation Report. Timeliness is a critical issue in reporting dangers to navigation. The hydrographer should ensure that the discovery of a potential danger to navigation is reported immediately to the appropriate authority. Further, should additional dangers be discovered during the processing of the survey, a danger report shall be immediately forwarded.

A danger to navigation is considered to be any natural feature (e.g., shoal, boulder, reef, rock outcropping) as well as any cultural feature (e.g., wreck, obstruction, pile, wellhead) which, during the course of survey operations was found by the hydrographer to be inadequately charted as described below. Potential dangers shall be evaluated in the context of the largest scale nautical chart of the area. Unless specified otherwise in the Hydrographic Survey Project Instructions or Statement of Work, all submerged features with depths of 11 fathoms (66 feet) or less in navigable waters should be considered potential dangers to navigation and subject to reporting. During the course of reviewing survey data for potential dangers to navigation, the hydrographer should be aware of the types of vessels transiting the area along with usual and seasonal vessel routes throughout the survey area.

Danger to Navigation Reports are required for:

- Significant uncharted rocks, shoals, wrecks, and obstructions
- Depths from the present survey which are found to be significantly shoaler than charted depths or features, and are navigationally significant (typically depths of 11 fathoms (66 feet) or less)
- Uncharted or inadequately charted clearances for bridges and overhead cables or pipelines
- A fixed or floating aid to navigation found to be off station to an extent that the aid does not serve its purpose adequately
- A fixed or floating aid showing significantly different characteristics than those charted or described in the Light List
- Other submerged or visible features, or conditions considered dangerous to surface navigation

Once all dangers to navigation (DTON) are identified by using the criteria above, they must be reviewed in context with the largest scale chart covering the survey area. DTONs submitted should include the date that the feature data was acquired and should not cause undue clutter in relation to other soundings or features on the chart. When multiple distinct features are located within 3mm of each other, as depicted on the largest scale chart of the area, then the most significant DTON located within the 3mm radius shall be submitted as a single danger to navigation.

In cases where dangers are too complex to be adequately identified as discrete features, they should be appropriately depicted on a chartlet that accompanies the danger letter. For example, widespread shoaling would be represented as a series of depths with appropriate depth curves instead of listing individual soundings and geographic positions. Danger submission shall include a chartlet that portrays the raster chart and the Danger features. Include Multibeam and side scan imagery of the danger (see Appendix 6).

NOAA field units shall use Pydro and submit all Danger to Navigation Reports via e-mail directly to Marine Chart Division's (MCD) Nautical Data Branch at e-mail address mcd.dton@noaa.gov, with courtesy copies to Chief, Operations Branch and to the chief of the appropriate Processing Branch, in accordance with section 4.4.4.6 of the OCS Field Procedures Manual.

Contractors shall submit all Danger to Navigation Reports via e-mail to the COTR and ACOTR at processing branch stated in the Statement of Work.

The contractor reports will be submitted as follows:

1. Letter in the format shown in Appendix 6 (Figure F.1) ,
2. An ascii text file of the format; 'latitude, longitude, depth, feature, date, time'.

The ACOTR will review the DTON, import the ascii file into Pydro, and create the .xml file (ACOTR's should see section 4.4.4.6 for more information). A letter and .xml file will then be forwarded to the Nautical Data Branch at mcd.dton@noaa.gov.

MCD will process the Danger to Navigation Reports and send the information to the USCG for inclusion in the Local Notice to Mariners. MCD will notify the submitting party of any changes made to the Dangers to Navigation Report by return e-mail. The Processing Branches will submit any dangers to navigation detected during office processing to MCD as stated above. If the Processing Branch is submitting a DTON that changes an earlier DTON submitted by a field unit, please explain the change in the cover letter.

A copy of the Danger to Navigation Report shall be included in Appendix I of the Descriptive Report.

8.1.2.1 Charted Feature Removal Request Charted features, particularly "Position Approximate" wrecks and obstructions that are located in major shipping corridors should be expeditiously removed from the chart if adequately disproved. The Charted Feature Removal Request is similar to a Danger to Navigation Report, except it is used to remove a charted feature that represents a hazard, which does not exist, rather than add a newly found hazard. This process should be used sparingly, usually by responding to a request from local pilots or other authorities that a charted feature is a hindrance to operations. If removal of a feature is not time critical, utilize the descriptive report to recommend removal from the chart rather than the Charted Feature Removal Request.

The Operations Branch, within the Hydrographic Surveys Division, is responsible for defining the search criteria for all AWOIS items. If local authorities request the hydrographer to investigate a feature that has not been assigned, contact Operations Branch for a determination of the search criteria. Once the hydrographer meets the search criteria and determines the feature does not exist, they should expeditiously prepare the Charted Feature Removal Request and forward it to the appropriate Processing Branch for verification. The format for the request is the same as a Danger to Navigation Report. The Processing Branch will review the request and, if the verifier concurs with the hydrographer's recommendation, will forward the request to the Marine Chart Division. See Figure F.1 in Appendix 6 for an example of a Charted Feature Removal Request.

8.1.3 Descriptive Report (DR)

A Descriptive Report is required for each hydrographic survey completed, unless specified otherwise in the Project Instructions or Statement of Work.

The primary purposes of a Descriptive Report are to: 1) help cartographers process and evaluate the survey; 2) assist the compilers producing or revising charts; 3) document various specifications and attributes related to the survey and its by-products; and 4) provide a legal description of the survey standards, methods, and results. The cartographers will have no knowledge of the particulars of a survey, other than what is documented in the Hydrographic Survey Project Instructions or Statement of Work, digital survey data, Descriptive Report, and supplemental reports referenced in the Descriptive Report. The Descriptive Report is archived as a historical and legal record for the survey.

The Descriptive Report supplements the survey data with information that cannot be depicted or described in the digital data. The Descriptive Report describes the conditions under which the survey was performed, discusses important factors affecting the survey's adequacy and accuracy, and focuses upon the results of the survey. It contains required information on certain standard subjects in concise form, and serves to index all other applicable records and reports.

General statements and detailed tabulations of graphically evident data, such as inshore rocks, shoals, or coral heads already shown in the S-57 feature file or compiled in Pydro, should normally not be included in the Descriptive Report. Hydrographic characteristics of the survey area such as nearshore features, shoreline, currents, water levels, and changes to the chart that are otherwise not clearly defined by the digital products should be completely described in the Descriptive Report.

The following information is required in each Descriptive Report in the order listed below:

COVER SHEET (NOAA Form 76-35A, see (Figure B) in Appendix 2)

Appropriate entries are made to identify the survey. For each survey, the Registry Number, Sublocality, General Locality, and State will be provided in the Hydrographic Survey Project Instructions or Statement of Work.

TITLE SHEET (NOAA Form 77-28, see Figure C.1 in Appendix 3)

The "Hydrographic Title Sheet" is often referred to for information pertaining to the survey. The "State", "General locality", and "Locality" entries are to be identical to those on the Cover Sheet. The "Date of survey" entries are the inclusive dates of the fieldwork.

For "Vessel", enter the name and hull number of the surveying vessel. The name(s) listed after "Surveyed by" are the personnel who supervised sounding operations and/or data processing.

The "Remarks" section should contain any additional information, including the purpose of the survey and survey area information that will identify the project or clarify the entries above. Other Descriptive Reports or special reports containing information or data pertinent to the survey that are not listed in Section E of the Descriptive Report text should be referenced here. Note the time zone used during data acquisition (e.g., All times are recorded in UTC). If applicable, list the name and address of the contractor and any major subcontractors. If applicable, include the UTM zone number.

DESCRIPTIVE REPORT TEXT

A hard copy of the Descriptive Report (DR) need not be submitted. Two digital copies of the DR shall be provided: in Microsoft Word format and Adobe PDF. The Microsoft Word format shall be converted to an Adobe PDF file when the DR has been finalized and shall have an approval sheet with a digital signature in accordance with section E.

The main body of the DR (sections A through E) shall be contained in a single file. Text shall be Times New Roman, with a font size of 12. Include all information required for complete understanding of the field records. When referring to a hydrographic feature in the S-57 feature file, give the latitude and longitude of the feature. Discussions and explanations should be written in a clear and concise manner. Avoid using geographic names in the text of the Descriptive Report that do not appear on the nautical chart. Avoid verbosity.

On each page of the DR body, include registry number and field unit as a header. Pages shall be numbered consecutively from the first page of text, continuing through the page preceding the Approval Sheet (page numbers as a footer, centered on page). Include a Table of Contents with page numbers.

A. AREA SURVEYED

Include a coverage graphic inclusive of the survey area. The information related to the present survey should be clearly shown and highlighted in some way to draw attention to its location within the project area. A second small scale graphic should be included if necessary to provide additional geographic context of where the survey is located.

List for each vessel (ship and/or launch number(s)) and the combined total of all vessels, the following information:

- Lineal nautical miles of single beam only sounding lines (mainscheme only)
- Lineal nautical miles of multibeam only sounding lines (mainscheme only)
- Lineal nautical miles of lidar sounding lines (mainscheme only)
- Lineal nautical miles of side scan sonar only lines (mainscheme only)
- Lineal nautical miles of any combination of the above techniques (specify methods)
- Lineal nautical miles of crosslines from single beam and multibeam combined
- Lineal nautical miles of lidar crosslines
- Lineal nautical miles of developments other than mainscheme lines
- Lineal nautical miles of shoreline/nearshore investigation (total length of the inshore buffer line)

NOTE: Any lineal nautical miles that are deleted for any reason should not be included in the above statistics.

List for the total survey the following information:

- Number of bottom samples collected
- Number of items investigated that required additional time/effort in the field beyond the above survey operations (these can be either from dive operations or obtaining a detached position but should not include items developed by sonar only or items deconflicted by "observations" only)
- Total number of square nautical miles
- Specific dates of data acquisition (e.g. June 5-9,16-19,22,24, 2005)

B. DATA ACQUISITION AND PROCESSING

B1. Equipment

In this section of the Descriptive Report list by manufacturer and model number only the major systems used to acquire survey data or control survey operations (e.g., single beam sonar, multibeam sonar, side scan sonar, lidar system, vessel attitude system, positioning system, sound speed system). Include a brief description of the vessel (e.g., length overall and draft). A detailed description of the systems used to acquire survey data or control operations shall be included in the project-wide Data Acquisition and Processing Report. See Section 8.1.4.1 for additional information.

Include in a narrative description, with figures when useful, of any deviations from the vessel or equipment configurations described in the Data Acquisition and Processing Report.

B2. Quality Control

Discuss the internal consistency and integrity of the survey data. State the percentage of crossline miles as compared to main scheme miles. Evaluate their general agreement. If the magnitude of the discrepancy varies widely over the sheet, make a quantitative evaluation of the disagreements by area. Explain the methods used to reconcile significant differences at crossings, and give possible reasons for crossline discrepancies that could not be reconciled. See section 5.1.4.3 and 5.2.4.3 for additional information.

Discuss the uncertainty values of the submitted CARIS BASE surface(s) and/or BAG(s). Explain and/or justify any areas that have an uncertainty greater than the IHO levels allowed as described in section 5.1.2and 5.2.2..

Evaluate survey junctions in this section. Junctions are made between adjoining contemporary surveys to ensure completeness and relative agreement of depths. List, by registry number, scale, date, and relative location, each survey with which junctions were made. Include a summary of each junction analysis. Explain methods used to reconcile significant differences at junctions, and give possible reasons for junction discrepancies that could not be reconciled. Include recommendations for adjustments to soundings, features, and depth curves, if applicable.

Discuss sonar system quality control checks.

Discuss any unusual conditions encountered during the present survey which would downgrade or otherwise affect the equipment operational effectiveness. Discuss any deficiencies that would affect the accuracy or quality of sounding data. Document these conditions; including how and when they were resolved.

Describe any other factors that affected corrections to soundings, such as sea state effects, the effect of sea grass or kelp, and unusual turbidity, salinity, or thermal layering in the water column. Provide a brief discussion on how the sound speed instruments (CTD, Moving Vessel profiler, Thermosalinograph etc.) were used and the frequency of the SVP casts. If appropriate, describe how the survey area was zoned to account for sound speed variations from differing water masses.

Discuss the specific equipment and survey methods used to meet the requirements for object detection and coverage for different areas of the survey. Any deviations from the specifications must be clearly explained in the Descriptive Report.

B3. Corrections to Echo Soundings

Discuss any deviations from those described in the Correction to Echo Soundings section of the Data Acquisition and Processing Report.

Discuss the results of any sounding system calibration (e.g. patch test) conducted after the initial system calibration that affect the survey data and were not included in the Data Acquisition and Processing Report. Comment on the reason a new calibration was conducted.

B4. Data Processing

Discuss details of the submitted CARIS BASE surface(s) and/or BAG(s). For instance, how many grids cover the survey area, what grid resolutions were used, why were the different grid resolutions selected, how do the resolutions change over the depth range of the survey, etc.

C. VERTICAL AND HORIZONTAL CONTROL

Include in this section of the Descriptive Report a summary of the methods used to determine, evaluate, and apply tide or water level corrections to echo soundings on this survey.

Describe how the preliminary zoning was determined to be accurate and/or describe any changes made to the preliminary zoning scheme.

State the horizontal datum and projection used for this survey. Briefly discuss the control stations used during this specific survey. If USCG DGPS stations are used, only list the station name in this section. Explain in detail any difficulties that may have degraded the expected position accuracy.

See Section 8.1.4 for additional information to be provided in the project Horizontal and Vertical Control Report. NOAA field units should also refer to section 5.2.3.2.3 in the OCS Field Procedures Manual.

D. RESULTS AND RECOMMENDATIONS

D.1 Chart Comparison

Compare the survey with all corresponding bathymetric products available (e.g. Electronic Nautical Charts (ENCs) and Raster Nautical Charts (RNCs)) to prove or disprove any exceptional bathy features attained by the survey coverage. Identify the chart by number, scale, edition number, and edition date. In addition, Notices to Mariners affecting the survey area which were issued subsequent to the date of the Hydrographic Survey Project Instructions or Statement of Work and before the end of the survey must be specifically addressed. Identify the last Weekly and Local Notices to Mariners compared to during the survey by notice number and date. Any Notice that prompts a chart comparison item must be identified by its Notice to Mariners number and date.

There are two aspects of chart comparison: (1) general comparison between survey depths and charted soundings and (2) detailed comparison between survey data and charted shoals and potentially dangerous features. On method for accomplishing the first is a comparison between the digital surfaces generated from the survey data and the ENC using appropriate GIS software. Comment on the degree of general agreement with charted soundings and discuss general trends, such as shoaling or deepening occurring in the survey area. List significant charted depths that have been disproved but do not do a detailed evaluation of every charted sounding.

Greater effort is needed when conducting the detailed comparison between the survey data and all charted shoals and potentially hazardous features. Describe the methods of investigation and include least depths for significant changes. Contractors shall list charted features not found during the present survey. NOAA units should reference section 5.2.3.3.2 Pydro Reports regarding features protocol.

Discuss the methods used for both aspects of chart comparison in sufficient detail to demonstrate that the chart comparison was accomplished adequately.

List and discuss comparisons of survey depths with controlling depths, tabulated depths, and reported depths of all maintained channels. Also discuss soundings in designated anchorages, precautionary areas, safety fairways, traffic separation schemes, pilot boarding areas and along channel lines and range lines.

Briefly describe assigned Automated Wreck and Obstruction Information System (AWOIS) items investigated by single beam or multibeam echosounder, side scan sonar, divers, and/or other methods in this section. Include an analysis of any differences between past and present survey findings and make a specific charting recommendation. Also, include any official salvage documentation that would expunge the feature from the chart without having to further investigate with a survey platform.

Any charted features that contain the label PA, ED, PD, or Rep (see Chart No. 1 for definitions.), not specifically assigned as an AWOIS item and investigated in this survey, should be documented and discussed in this section. The source of the charted feature should be listed if known. Also, discuss features such as wrecks and obstructions from miscellaneous sources. Describe the condition and distinguishing characteristics of all items mentioned. NOAA units should reference the Pydro generated "For Descriptive Report" feature report as necessary for this requirement (see section 5.2.3.3.2 of the OCS Field Procedures Manual).

Refer to any Danger to Navigation Reports submitted for this survey. A negative statement is required if no Danger to Navigation Reports were submitted.

D.2 Additional Results

If specified in the Hydrographic Survey Project Instructions or Statement of Work, describe and discuss the shoreline investigation results.

If applicable, briefly discuss prior survey comparisons conducted by the hydrographer. In general, prior survey comparisons are not required by field personnel, but may be used at the discretion of the hydrographer for quality control purposes. Prior survey comparisons can be very helpful to the hydrographer both in the field and during final data processing. Prior surveys may be obtained by contacting the appropriate Processing Branch or by contacting the COTR (if not already provided on the project CD).

Discuss aids to navigation which do not serve their intended purpose, are damaged, or whose characteristics do not match the chart or Light List (see Section 7.2). A statement shall be made in this section of the Descriptive Report if all aids serve their intended purpose. NOAA units should refer to section 3.5.3.3 of the OCS Field Procedures Manual and Hydrographic Survey Project Instructions for specific guidance on positioning aids to navigation.

List all bridges, overhead cables, and overhead pipelines. State the status or condition of each feature. Provide applicable clearances determined by the survey party or by an authoritative source (e.g., the U.S. Coast Guard or U.S. Army Corps of Engineers). Include the geographic coordinates directly below the minimum clearance point. All such charted overhead features that no longer exist must also be listed. Include written documentation, if available, and photographs with the survey records. Invalid or uncharted overhead clearance information, or ongoing construction of bridges or overhead cables and pipelines, constituting a potential danger to navigation, should be reported to the U.S. Coast Guard and the U.S. Army Corps of Engineers. Mention any submarine cables and pipelines and any associated crossing signs on the shoreline. Include coordinates for signage or the water entry point of the feature. Note ferry routes and list position of each ferry terminal, if not shown on the chart or contemporary NOS remote sensing maps.

For each drilling structure, production platform, and well head within the survey area (excluding temporary jack up rigs), make a comparison between the new survey position and the largest scale chart on which the feature is shown and discuss any differences.

Provide information of significant scientific or practical value resulting from the survey. Unusual submarine features such as abnormally large sand waves, shifting or migrating shoals, mounds, valleys, and escarpments should be described. Discuss anomalous tidal conditions encountered, such as the presence of swift currents not previously reported. Discuss any environmental conditions encountered, which have a direct bearing on the quality and accuracy of the hydrographic data. If special reports have been submitted on such subjects, refer to them by title, author, and date of preparation or publication.

Mention present or planned construction or dredging in the survey area that may affect the survey results or nautical charts. Recommend new surveys for any adjacent areas that need them. As appropriate, include recommendations for further investigations of unusual features or sea conditions of interest that go beyond routine charting requirements. Recommend insets to be shown on the published chart of the area, if requested by chart users or needed for clarity.

E. APPROVAL SHEET

The approval sheet with a digital signature shall be part of the digital DR file. It is important to note that there is a distinct difference between a true digital signature and a digitized signature. The latter is simply an image or other capture of a person's pen-and ink signature. By using a document scanner or an electronic pen capture device, a person's signature may be digitized. However, simply attaching this type of signature to an electronic document is not the same as attaching a digital signature.

A digital signature, by contrast, appends a cryptographic "key" to the document that can be used to verify the identity of the signer (authentication), ensure that no changes have been made to the document since signing (integrity), and ensuring that the signer cannot deny having signed the document (non-repudiation). Until such time as an organization-wide digital signature solution is implemented, the nature of self-signed digital signatures will limit authentication and non-repudiation capabilities of the system. The mechanism of applying the digital signature may include a digitized version of a person's signature, or it may not.

Use of the Adobe PDF format provides a standard vehicle for delivery of descriptive reports. PDF supports digital signatures, and has been identified as an archive format by the National Archives and Records Administration. The use of PDF combined with digital signatures provides reasonable protection and assurance against inadvertent document modification, as well as a means for tracking intentional document modification.

The approval sheet shall contain the following:

- Approval of the deliverable files, Descriptive Report, digital data, and all accompanying records. This approval constitutes the assumption of responsibility for the stated accuracy and completeness of the hydrographic survey.

- A statement as to whether the survey is complete and adequate for its intended purpose or if additional work is required.
- The amount and degree of personal supervision of the work.
- Additional information or references helpful for verifying and evaluating the survey.

List all reports and data not included with the survey records or Descriptive Report that have been submitted to the processing office or to another office (e.g., Data Acquisition and Processing Report, Vertical and Horizontal Report, Tides and Water Levels Package, Coast Pilot Report). Include date of the report or date of submission.

If appropriate, other personnel responsible for overseeing or directing operations on this survey sheet may also sign the Approval Sheet.

DESCRIPTIVE REPORT APPENDICES

The Appendices shall be submitted as a separate Adobe Acrobat file from the DR and in a digital format only. NOAA units should refer to section 5.1.2.2 of the OCS Field Procedures Manual for additional guidance on the content of DR Appendices.

I. DANGER TO NAVIGATION REPORTS

Include copies of Danger to Navigation Reports and correspondence. List each document by some type of unique identifier, such as date for a letter or e-mail.

II. SURVEY FEATURE REPORT

Include a copy of all AWOIS item investigation reports and associated graphic correlation output. Include any official salvage documentation that supports an AWOIS charting recommendation. NOAA units shall meet this requirement by submitting the "For Descriptive Report" feature report generated in Pydro as Appendix II.

III. FINAL PROGRESS SKETCH AND SURVEY OUTLINE

Include a copy of the final Progress Sketch and final survey outline that were submitted as per the requirements in Section 8.1.1.

IV. TIDES AND WATER LEVELS

Include the following (if applicable):

- Field Tide Note (see section 4.2.2)
- Final Tide Note (see section 4.5.3)
- Abstract of Times of Hydrography (lists every day during which hydrography was conducted and the start and end times hydrography was conducted each day)
- A copy of the "Request for Approved Tides/Water Levels" letter
- Any other correspondence directly relating to tides and/or water levels

V. SUPPLEMENTAL SURVEY RECORDS AND CORRESPONDENCE

Include any additional survey records not previously addressed in the Descriptive Report, Appendices or Separates (e.g., MapInfo tables) and a summary table of bottom samples obtained (if applicable). Any letter or email correspondence relating to the present survey should also be included. Contractors shall submit supplementary correspondence in a format that can be an easily read (e.g *.txt) such that it is not proprietary to an email program.

SEPARATES TO BE INCLUDED WITH THE SURVEY DATA

The following "SEPARATES TO BE INCLUDED WITH THE SURVEY DATA" supplementing the Descriptive Report shall be submitted with each survey. The Separates shall be submitted as a separate Adobe Acrobat file from the DR and in a digital format only. NOAA units should refer to section 5.1.2.2 of the OCS Field Procedures Manual for additional guidance on the content of DR Separates.

I. ACQUISITION AND PROCESSING LOGS

Include all acquisition and processing logs in digital format from the present survey. Include positioning confidence checks and sounding system comparison checks.

II. SOUND SPEED DATA

In previous versions of this manual, a table was required which identified the specific sound speed profiles used during the present survey. Now the requirement is to submit a list that can be imported into a GIS for office verifiers to analyze the distribution and frequency of the SVP casts. This deliverable should identify the positions and dates of all casts used; the maximum cast depth; and the dates/times for which the profiles were applied. CARIS users can fulfill this requirement with the submission of the SVP data that is within the CARIS project. Contractors and NOAA field units should refer to the location where the digital sound speed files are located, and include a directory listing of the files.

A vessel with a Moving Vessel Profiler (MVP) may use thousands of profiles for a single survey. In such cases, a table of each individual cast is not required. Instead, replace the table with a brief discussion on how the MVP was used (frequency, which areas of the survey, vessels and/or lines it was used, etc.) If individual casts were conducted as well, those casts should be included in a table.

Include confidence check results. Include copies of sound speed profiler calibration report(s), if calibration occurred after submission of the Data Acquisitions and Processing Report (DAPR).

III. HYDROGRAPHIC SURVEY PROJECT INSTRUCTIONS/STATEMENT OF WORK

Include copies of the Hydrographic Survey Project Instructions or Statement of Work. Include all changes/modifications which apply to the survey being submitted.

IV. CROSSLINE COMPARISONS

Include the summary plot analysis as a function of beam number if conducted for the mainscheme/crossline intersections as required in Section 5.1.4.35.1.4.3 and 5.2.4.35.2.4.3, if applicable. Include any other crossline quality reports required by the Hydrographic Survey Project Instructions or Statement of Work.

V. SIDE SCAN CONTACT LISTING AND IMAGES OF SIGNIFICANT CONTACTS

Include the side scan contact listing, along with images of all significant contacts. Side scan contacts are included as part of a normal Pydro data submission, which fulfils this requirement. Non-Pydro users must submit significant contact images in a manner which allows the Processing Branch to easily review and correlate specific contacts with other supporting data sets.

8.1.4 Descriptive Report Supplemental Reports

8.1.4.1 Data Acquisition and Processing Report The Data Acquisition and Processing Report (DAPR) is a project-wide report that shall be submitted before, or not later than, the submission of the first survey of the project. For contract surveys, the DAPR shall be sent to the COTR and appropriate Processing Branch specified in the Statement of Work with each survey. For NOAA field units, the DAPR shall be sent to the Chief, Hydrographic Systems and Technology Program (HSTP) and the appropriate Processing Branch specified in the Hydrographic Survey Project Instructions. This report is separated into three sections: Equipment, Quality Control, and Corrections to Echo Soundings. These sections shall contain a detailed discussion on the project specific information addressed below.

A digital copy of the main text of the DAPR shall be provided in Adobe Acrobat format.

Include a cover sheet and title sheet which contain the following general information:

Cover Sheet. Include the type of survey(s), state, general locality and year (see Figure G.1 in Appendix 7).

Title Sheet. This contains additional descriptive information relative to the project. Include project number, date of Hydrographic Survey Project Instructions/Statement of Work, vessel(s), field unit/contractor, sub-contractors, and Chief of Party/Lead Hydrographer.

A. Equipment

Describe the major operational systems used to acquire survey data or control survey operations. Include the manufacturer, firmware version and model number, operational settings and how the equipment was used. Include a description of the vessel(s) used.

Specifically discuss single beam, multibeam, lidar and side scan sonar systems and operations in this section. Include range scales, number of beams, resolution, alongtrack coverage, and quality assurance tools used during data acquisition. Include discussion of other depth determination systems, such as, diver depth gauges, lead line, sounding poles, etc. If applicable, explain the calibration or determination of correctors, the dates of most recent calibrations, state whether or not checks were made on their accuracy and describe any nonstandard procedures used.

Discuss the computer hardware and software used for all data acquisition and processing. Describe acquisition and processing methods, procedures, and parameters used. Provide a complete list of all software versions and dates.

Include a description of equipment used to conduct shoreline verification. Briefly describe the method of conducting shoreline verification, including the processing of detached positions and depiction of shoreline features in the S-57 feature file.

B. Quality Control

Provide a description of the data processing routines for converting raw sounding data to the final Navigation Surface grids. Include a description of the methodology used to maintain data integrity, from raw sounding data to final soundings. Processing flow diagrams are helpful. Any methods used to derive final depths such as cleaning filters, sounding suppression/data decimation parameters, gridding parameters, and surface computation algorithms shall be fully documented and described in this section.

Discuss the methods used to minimize the errors associated with depth determination and provide details of how the error models and TPU for each sounding is computed (see Section 5.1.3.5(multibeam) or 5.2.1.2 (lidar)). Any deviation from this requirement shall be explained here.

Discuss how under the navigation surface concept individual sounds are propagated or combined into a node that is consistent with any specific object detection requirements for the project.

Methods and standards used to examine side scan sonar records should be noted and a brief description of processing procedures should be provided. Include the methods for establishing proof of swath coverage and the criteria for selecting contacts. Additionally, include a brief description of how your review of digital side scan data meets the object detection and accuracy requirements per section 6.2. The number of pixels used to display digital side scan data on a computer is constrained by the width of the display window and the screen resolution. Any compression method used in the review of the side scan display must be discussed (e.g., whether an average or maximum pixel intensity within a regularly-spaced acrosstrack interval X meters is used).

C. Corrections to Echo Soundings

This section addresses the methods used for the determination of all corrections to echo soundings that apply to the entire project. Describe the methods used to determine, evaluate, and apply the following corrections to echo soundings, including the uncertainties for each item:

- Instrument corrections
- All vessel configuration parameters, offsets, layback, etc include diagrams, pictures, or figures of the equipment as installed onboard
- Static and dynamic draft measurements
- Heave, roll, pitch biases, and navigation timing errors. State the manufacturer, model, accuracy, and resolution of heave, roll, and pitch sensor(s). Discuss accuracy and alignment test procedures and results. Include copies of system alignment, accuracy, and calibration reports.
- Discuss the source of tide or water level correctors used for data processing and final sounding reduction

D. Approval Sheet

The Chief of Party or Lead Hydrographer shall furnish a digitally signed statement of approval for all information contained within the Data Acquisition and Processing Report using the procedures prescribed in section E under the Descriptive Report Approval Sheet.

If appropriate, other personnel responsible for overseeing or directing operations on this project report may also sign the Approval Sheet.

8.1.4.2 Horizontal and Vertical Control Report The Horizontal and Vertical Control Report is a project-wide report which shall be submitted before, or not later than, the submission of the last survey in project area. NOAA field units should also refer to section 5.2.3.2.3 in the OCS Field Procedures Manual.

A digital copy of the main text of the Horizontal and Vertical Control Report shall be provided in Adobe Acrobat format.

Include a cover sheet and title sheet which contain the following general information:

- Cover Sheet - Include the type of survey(s), state, general locality and year.
- Title Sheet - This contains additional descriptive information relative to the project. Include project number, survey registry numbers to which this report applies (with associated dates of survey and locality), date of Hydrographic Survey Project Instructions/Statement of Work, vessel(s), field unit/contractor, sub-contractors, and Chief of Party/Lead Hydrographer.

A. Vertical Control

The Vertical Control section of the project Horizontal and Vertical Control Report shall document all Tide and Water Level activities that took place as part of this project. Specific information pertaining to an individual survey sheet and the Request for Approved Tides letter shall be documented in the Descriptive Report for the individual survey. This section shall contain a discussion of:

- All stations established by the field unit (include gauge model/type). Give station number, latitude/longitude, and the dates/times of operation.
- The method by which correctors for the field data were obtained and applied.
- The time meridian used to annotate the tide records.
- A list of any unusual tidal, water level, or current conditions.
- The height and time corrections, and zoning if different from that specified in the Hydrographic Survey Project Instructions or Statement of Work.
- Ellipsoidal benchmark positioning techniques and procedures

B. Horizontal Control

The Horizontal Control section of the project Horizontal and Vertical Control Report shall document Hydrographic Position Control activities that took place as part of this project. Specific information pertaining to an individual survey sheet shall be documented in the Descriptive Report for the individual survey.

For horizontal control stations established by the field unit, describe the survey methods used to establish the station, and state the standards of accuracy used. Include position accuracy plots (see Section 3.2.2). For all horizontal control stations established by the field unit, list:

- The latitude to at least the nearest 1/100th of a second.
- The longitude to at least the nearest 1/100th of a second.
- The station elevation (ellipsoidal height).

- The geodetic station name and year it was established.
- Briefly, describe the methods and adequacy of positioning system confidence checks.

C. Approval Sheet

The Chief of Party or Lead Hydrographer shall furnish a digitally signed statement of approval for all information contained within the Horizontal and Vertical Control Report using the procedures prescribed in section E under the Descriptive Report Approval Sheet.

If appropriate, other personnel responsible for overseeing or directing operations on this project report may also sign the Approval Sheet.

8.2 S-57 Feature File

The International Hydrographic Organization (IHO) Special Publication 57 (IHO S-57) is the IHO Transfer Standard for Digital Hydrographic Data (current version is edition 3.1). The IHO intends for the standard to be used for the exchange of digital hydrographic data between hydrographic offices, and for the distribution of hydrographic data to manufacturers, mariners and other data users. It was developed so that the transfer of all forms of hydrographic data would take place in a consistent and uniform manner. IHO Special Publication 57 may be downloaded free of charge at `www.iho.shom.fr`

Smooth sheets will no longer be required of Contractors or NOAA field units. The Processing Branches will use the S-57 feature file in conjunction with the BAG and other survey deliverables to compile the survey data into navigational products.

The deliverables for a survey shall be:

1. Features contained in a single S-57 (.000) base cell file.
2. A collection of Bathymetric Attributed Grids (BAG).
3. Metadata contained in the DR and associated reports.

NOAA field units may meet the features requirement using Pydro or Notebook deliverables (see section 4.4.9 and 4.10 of the OCS Field Procedures Manual)

The hydrographer shall submit BAGs or BASE surfaces at the highest appropriate resolution for the bathymetry and feature detection requirements set in the Project Instructions. The BAG should be in the NAD83 datum. The BAG should be UTM projected. The metadata for the BAG shall include the NAD83 datum and UTM projection with the proper zone and resolution of the grid. The S-57 feature file shall be in the WGS84 datum and unprojected.

The S-57 feature file contains all the attributed information on specific objects that cannot be portrayed in a simple depth grid. Features to include in the S-57 feature file include; wrecks, obstructions, shoreline, rocks, islets, oil platforms, nature of seabed (bottom samples) and all other objects that may need to be compiled to a navigational product and require additional information that cannot be included in the BAG.

U.S. Coast Guard maintained aids to navigation shall NOT be included in the S-57 feature file. The hydrographer shall investigate all aids to navigation and report results as required in section 7.2 and

8.1.4.1 Privately maintained aids and/or mooring buoys should be included in the S-57 feature file, unless they are transitory.

The S-57 feature file shall include shoreline data only if the hydrographer conducted shoreline verification. New features and changes to the source shoreline shall be portrayed in the S-57 feature file and be fully attributed.

General soundings, contours and depth areas will NOT be included in the S-57 feature file since these objects will be derived from the final BAGs during chart compilation. In rare cases, an isolated sounding may be part of the S-57 feature file if it needs a danger circle and/or additional attributions.

8.2.1 S-57 Attribution

These Specifications and Deliverables will not attempt to include all possible objects and attributions that may be required for a hydrographic survey. For a full reference the hydrographer should refer to the resources described in section 8.2.

A list of the more common objects and attributions that may be used during a typical hydrographic survey is given below. If the hydrographer has any questions on the appropriate attribution for an object, they should contact the COTR and/or the appropriate Processing Branch for clarification.

All S-57 mandatory attributes for an object shall be completed. The hydrographer shall attempt to provide as much additional information as possible on an object to facilitate the Branches in final chart compilation of the survey. Whenever possible, additional information should be associated with the object itself. The attributes, INFORM, TXTDSC and PICREP can be used to provide additional information. If it is not practical to communicate additional information using an attribute associated with the object, then the hydrographer can provide the information using the DR, Item Investigation Report, Detached Position log (with photo), or other means.

All objects in the S-57 feature file must be properly attributed. S-57 feature file attributions can be divided into three broad categories; depths, features, meta-objects. The most common items for each category and the related mandatory attributes are described below.

ALL objects (depths, features and meta-objects), unless otherwise noted, will have the attributes SORDAT and SORIND populated. For features that originate from an ENC or raster chart, use the SORDAT and SORIND from that source. For other features:

SORIND (Source indication)

Format: ‘Country code, Authority code, Source, ID Code’. Example, “US,US,surve,H11393”, if data came from a survey. Country (US), Authority (US for OCS), Source (survey), ID code (registry number). If feature is from RSD provided GC, the ID code becomes the GC number, if the feature is carried forward from a chart or ENC the ID code is the chart number (i.e. ‘chart 16707’).

SORIND Source Code	Features File Source
survy	For surveyed features: Bottom samples; Features with heights or elevations (exposed rocks and wrecks, etc.) obtained using rangefinder or similar device; Navigation aids; Mooring buoys, Piles and dolphins; Shoreline construction or other features gathered using portable GPS device; Kelp or other observed features where no discrete position was taken; Features digitized from extents obtained by the field (ledges, reefs, piers and fish pens, shoreline construction, etc.); Meta area objects.
nsurf	For soundings, depth contours and depth areas from the BASE Surface; For submerged rocks, wrecks, obstructions and other features from the BASE Surface.
digit	For digital map sources, such as GC shoreline.
graph	Reserved for all features compiled to the Features file from raster charts or ENC's.
reprt	Reserved for MCD's use for letters, reports, NTM's or digital documents.

SORDAT (Source date)

Is the date associated with the SORIND above. For a hydrographic survey, it is the last day of field operations. For a GC shoreline, the date the survey was flown, from the metadata. From a raster chart, the chart date. From the ENC, it is the date that the ENC has for the SORIND.

DEPTHS

Depth information is stored in three different forms, points (SOUNDG), lines (DEPCNT) and Areas (DEPARE). The S-57 feature file will have all depth units in meters.

SOUNDG (Sounding)

A measured water depth or spot which has been reduced to a vertical datum (may be a drying height). Soundings are bundled together by survey and share most attributes. The number of soundings included is appropriate for the scale of the survey as defined in the Statement of Work.

Mandatory Attributes:

- QUASOU (Quality of Sounding Measurement) - Generally set to '1', for depth known.
- TECSOU (Technique of Sounding Measurement) – see table below

Technique of Measurement for Height or Depth	S-57 Attribute ID
Single beam echosounder (alone)	'1' if found by echo-sounder
Side Scan sonar (alone)	'2' if found by side scan sonar
Multibeam (alone)	'3' if found by multibeam
Diver depth	'4' if found by diver
Lidar (alone)	'7' if found by laser
Heights on rocks or islets using rangefinder	'12' if found by leveling
Navigation surface resulting from combinations of sounding techniques, such as multibeam mixed with single beam or side scan mixed with multibeam and/or single beam (skunk-striping), or single beam or multibeam mixed with lidar)	'14' computer generated

FEATURES

All features should be attributed as fully as possible, with a few exceptions. Several common features are listed below, followed by the mandatory attributes required for them. Mandatory attributes for all features (WRECKS, UWTROC and OBSTRN) are listed after the OBSTRN explanation. Do NOT attribute SCAMIN (Scale minimum) on any objects.

<u>WRECKS</u> (Wreck)

The ruined remains of a stranded or sunken vessel which has been rendered useless. (IHO Dictionary, S-32, 5th Edition, 6027)

Mandatory Attributes:

- CATWRK (Category of Wreck) – For instance '1' for non-dangerous wreck, '2' for dangerous wreck, '3' for distributed remains of wreck, etc. or VALSOU (Value of Sounding) - Least depth of the wreck.

<u>UWTROC</u> (Underwater/awash rock)

A concreted mass of stony material or coral which dries, is awash or is below the water surface (See Rock Attribution Figure H.1 in Appendix 8)

<u>OBSTRN</u> (Obstruction)

In marine navigation, anything that hinders or prevents movement, particularly anything that endangers or prevents passage of a vessel. The term is usually used to refer to an isolated danger to navigation... (IHO Dictionary, S-32, 5th Edition, 3503)

Mandatory Attributes for all features:

- TECSOU (Technique of sounding measurement) - Typically '1' if found by echo-sounder, '3' if found by multi-beam, '4' if found by diver, '7' if found by laser.
- QUASOU (Quality of Sounding Measurement) - Generally set to '1', for depth known.
- VALSOU (Value of Sounding) – Least depth of the wreck.
- WATLEV (Water Level Effect) – For instance, '1' for partly submerged at high water, '2' for always dry, '3' for always under water/submerged, '4' for covers and uncovers, etc.

<u>SBDARE</u> (Seabed area) Objects

The nature of bottom includes the material of which it is composed and its physical characteristics. Also called character (or characteristics) of the bottom, or quality of the bottom. (IHO Dictionary, S-32, 5th Edition, 515). The S-57 point object SBDARE is typically used to report characteristics from bottom samples taken.

Mandatory Attributes:

Bottom characteristic objects will have one or the other or both of the following attributes (usually NATSUR):

- NATSUR (Nature of surface) – Refer to S-57 library for codes, for instance, '1' is mud, '2' is clay, '3' is silt, '4' is sand, etc.
- NATQUA (Nature of surface - qualifying terms) – Refer to S-57 library for codes, for instance, '1' is fine, '2' is medium, '3' is coarse, etc.

Where SBDARE is used to describe bottom characteristics obtained through bottom sampling, NATSUR must be attributed. NATQUA is optional. Multiple characteristics and qualifiers may be used. If a bottom sample was attempted but not achieved, use NATQUA (hard). Where SBDARE is used to describe a rocky seafloor, NATSUR (rock) is used.

SBDARE line or area objects may also be used to characterize areas of the seafloor that are rocky in nature (See Section 5.1.1.3 for additional details regarding these areas). In rocky nearshore areas, the least depths of many features in a relatively small area may fail to be preserved, even by very high resolution BASE surfaces. In these instances the hydrographer shall designate the least depths on the shoalest of features. The extents of the area should then be delineated and characterized as SBDARE (seabed area), and the attribute NATSUR (nature of surface) encoded as "rock", as follows:

- NATSUR (Nature of surface) – '9' rock
- NATQUA (Nature of surface - qualifying terms) – (none)

SHORELINE

Shoreline information, if required by project, should be encoded in S-57 using the following feature objects and attributes.

<u>COALNE</u> (Coastline)

MHW line determined from bathy/topo data or geo-referenced orthophotos. COALNE is attributed with CATCOA (Category of Coastline), if known. ELEVAT should not be attributed for this object.

<u>LNDARE</u> (Land area)

A rock becomes an islet at 2 feet (0.6 meters) above MHW. LNDARE point, line or area objects may be used to characterize islets (see "S-57 Encoding Guidelines for Rocks and Islets for the Pacific Coast and Alaska"). LNDARE objects should be accompanied by LNDELV point or line object, denoting the highest point of the feature.

<u>LNDELV</u> (Land elevation)

Elevation for islets is encoded using the object LNDELV, with attribute ELEVAT, which is given relative to the MHW datum (taken from "S-57 Encoding Guidelines for Rocks and Islets for the Pacific Coast and Alaska").

META-OBJECTS

Meta-Objects provide metadata and additional information for large areas of the survey, or to attribute the entire survey area. The required meta-objects with their mandatory attributes are listed below.

Areas of different coverage types should be separated and attributed using CATZOC (Category of zone of confidence in data) according to the following table:

S-57 Attribute ID	CATZOC Description
A1	Object detection multibeam
A2	100% multibeam coverage or 200% sidescan coverage with skunk-striping using multibeam
B	Single beam bathymetry or developments, or skunk-striping using VBES (single beam) or Lidar alone
C	Single beam lines for reconnaissance
U	For features with heights obtained with methods other than sonar, or where extents were collected for islets, reefs, ledges, shoreline construction, etc.

- POSACC (Positional Accuracy, in meters) – For USCG beacons or other modern Differential GPS systems, will typically be 10 meters.
- SURSTA (Start date of survey) - When compiling from a hydrographic survey, enter the start date of the field operations in format, CCYYMMDD.
- SUREND (End date of survey) - When compiling from a hydrographic survey, enter the end date of the field operations in format, CCYYMMDD.
- INFORM (Information) - Contains the Following String: Registry Number, Project Number, and Contractor Name (H10934, OPR-D904-00, World Surveys Inc.)

M_COVR (Coverage)

A geographical area that describes the coverage and extent of spatial objects. The area that comprises the compiled data or extents of survey.

Mandatory Attribute:

- CATCOV (Category of coverage) – '1' for coverage available: continuous coverage of spatial objects is available within this area. '2' for no coverage available: an area containing no spatial objects (i.e. an area within the survey limits, not addressed by the hydrographer.)

8.2.2 Cartographic Specifications and Conventions

Generalization of Features If the hydrographer determines an area unsafe, a foul area can may be shown, but all available survey data that exists for any and all feature objects will be included in the S-57 feature file (see the following sections regarding rocky areas: 5.1.1.3 and 5.1.2 for multibeam data, 5.2.1.2 for lidar data and 8.1.2).

Determination of the MHW Elevation A MHW value is required for compilation of all Feature files containing shoreline or intertidal areas. It is used for defining DRVAL1 (Depth Range Value) attribute field for intertidal DEPARE's where DRVAL2 will always be 0.0. Example: -3.2 to 0.0 meters. If an ENC covering the survey area exists, use the MHW value of the ENC. (This is easily accomplished by querying any reef, ledge or other intertidal area on the ENC. Use the DRVAL1 or drying contour value, always indicated by a negative value.) If no ENC exists, use the smallest listed Mean High Water value in the paper chart TIDAL INFORMATION box. If no MHW category is shown, use the smallest listed Mean Higher High Water value. If none of the above is available, use the MHW from the tide note associated with the hydrographic survey. If there is no tide note, then the MHW value should be -999999999.0, this is equivalent to "UNKNOWN".

Rocky Areas Rather than encoding numerous discrete submerged UWTROC objects in a relatively small area it is acceptable to delineate the extents of the rocky area, using the Navigation Surface as a reference, then encode as an area object: SBDARE, attribute: rock.

Rocks and Islets A rock will be depicted as an islet at 1 ft above MHW for Atlantic and Gulf coasts, and 2 feet above MHW for Pacific and Alaska coasts. Only four of the seven possible WATLEV categories will be used for equating VALSOU to WATLEV for rocks and islets. (See Rock Attribution Figure H.1 in Appendix 8, for use of S-57 attribution of rocks and islets for Feature files.)

If applicable, the S-57 feature file should have the following parameters set;

- Producing Agency = US Office of Coast Survey,
- Navigational Purpose = 1 thru 5 according to chart compilation scale,
- Individual Cell Code = H number of survey, H12345 becomes '12345',
- Horizontal Datum = WGS84 (datum of S-57 file),
- Vertical Datum (for heights) = MHW,
- Sounding Datum = MLLW,
- Units = metric
- Compilation Scale = survey scale,
- Coordinate Multiplication Factor = 10,000,000,
- Sounding Multiplication Factor = 1,000.

8.3 Side Scan Sonar

8.3.1 Side Scan Sonar Mosaic

A separate side scan mosaic for each 100 percent coverage shall be used as a graphic means for demonstrating bottom coverage. Pixel resolution of the side scan mosaics should be 1 m by 1 m. The hydrographer shall submit a digital file of each 100% coverage (see Section 8.4.4).

If possible, the mosaics should be generated in one complete image file. If the survey area is too large and/or creates a large image file that is unmanageable due to file size, then the hydrographer shall subdivide the area into smaller more manageable subsections. Contact the COTR and/or appropriate Processing Branch to discuss file size limitations for each survey. However, do not create mosaics for individual side scan line files.

8.3.2 Side Scan Sonar Contact List

Contact List

A Sonar Contact List of all contacts, both significant (Section 6.3.2) and insignificant, are required and must include the specific elements of information which are described below, along with a brief discussion of how each is to be derived. Specific entries may vary by hydrographer. The format should be reviewed by the COTR and/or Processing Branch before data collection is conducted.

A digital copy of the contact list, ideally in spreadsheet format, shall be submitted with the survey deliverables.

Column 1: Search Track Number—identifies the particular search track from which the contact was observed.

Column 2: Contact Number—uniquely identifies the contact. An example of a contact number is a number based on the date/time the contact was observed, followed by a letter indicating the port or starboard (P or S) channel. For example, if a port-side contact is observed on day 181 at 150125, the contact number will be 181/150125P. Using signed (+ or -) contact range in column 4 eliminates the need for the P or S indicator.

Column 3: Towfish Layback—the approximate distance in meters from the positioning system antenna to the towfish. Unless computed by an automated system, the towfish may be assumed to be directly astern of the towing vessel and on the search track.

Column 4: Contact Range—the horizontal distance from the towfish track to the contact, expressed in meters.

Column 5: Contact Position—the preliminary position as determined by reconstruction of the vessel position, towfish layback, towfish position, port or starboard channel, and contact range at the time the contact was observed. The Contact Position shall be stated as a latitude/longitude (decimal degress) or X/Y (easting, northing) values.

Column 6: Estimate of contact height computed from range and shadow length.

Column 7: Remarks—used to denote first impressions of the contact's identity (e.g., wreck, rock, etc.), or to make any comments deemed appropriate. If, after examining the records and correlating targets from overlapping coverage, the hydrographer determines that a contact does not warrant further investigation, it shall be noted as such. A brief statement of the reasons must be made. Any abbreviations should be defined on the list.

Column 8: Comparison with shallow water multibeam data—used to note the corresponding shallow water multibeam data (day/time, line number, etc.), the results of comparing the side scan sonar data with the multibeam data (e.g., contact did not appear in the multibeam data, swmb least depth = x.x—sss least depth = y.y).

Column 9: Contact is depicted in the S-57 feature file—answered in one of three ways: (1) yes, obstr, (2) yes, sounding only or (3) no.

Once added to the list, a contact should never be removed. If, after further processing, a contact is deemed not significant by the hydrographer, it shall be labeled as such in column 7. The contact list, and any subsequent field examination lists and records developed from the contact list, shall be included with the data submission in digital form.

The contact list should be created such that it can be imported into a GIS for office verifiers to analyze the distribution of contacts. However, if the hydrographer creates any image files showing the distribution of contacts and/or other products to assist with processing and analysis of the data, they may be included with the survey deliverables.

In some areas, significant contacts may be clustered (e.g., debris, boulder field). Such an area may lend itself to being depicted as a single feature within the S-57 feature file: a danger curve depicting the limit with accurately positioned least depth(s). If the hydrographer has any questions to how the feature should be portrayed and attributed within the S-57 feature file, they should contact the appropriate Processing Branch.

Contact Images

For each significant contact in the contact list, the hydrographer shall provide an image of the contact. Digital images shall be in a standard image format (e.g., tif, gif, jpg). Copies of the images shall be included in the Separates, Section V. Digital file names shall coincide with the contact name as depicted on the contact list.

8.3.3 Data Acquisition and Processing Abstracts

All sonargrams and data acquisition/processing comments shall be submitted digitally. Time references shall be made in Coordinated Universal Time (UTC).

The hydrographer shall have a system to clearly indicate the status of the side scan acquisition system. Historically, this was accomplished by annotating the paper sonargram as the data was being collected. Further annotations could be made during field and/or office review of the sonargrams. Modern survey systems acquire the data digitally, therefore, separate data acquisition/processing logs may be used to record the needed information.

The following comments (or annotations) shall be made in a manner that they can be correlated by time or other method back to the digital side scan sonar record.

System-Status Annotations

System-status annotations are required to describe the recorder settings and the towing situation. System-status annotations shall include:

- Mode of tuning (manual or auto).
- Range-scale setting.
- Operator's name or initials.
- Length of tow-cable deployed (tow point to towfish).
- Depressor in use (yes or no).
- Weather and sea conditions.

System-status annotations shall be made:

- Prior to obtaining the first position of the day.
- While on-line, whenever the system set up or status changes.

First Position/Last Position Annotations

The following annotations shall be made at the first position on each survey line:

- Line begins (LB) or line resumes (LR).
- Tow-vessel heading (degrees true or magnetic).
- Towing speed (engine rpm, and pitch if applicable).
- Index number and time (at event mark).

The following annotations shall be made at the last position on each survey line:

- Line turns (LTRA, LTLA), line breaks (LBKS), or line ends (LE) index number and time (at event mark).

Special Annotations

The occurrence of any of the following events shall also be annotated:

- Change in operator (new name or initials).
- Change in range-scale setting.
- Confidence checks.
- Individual changes to recorder channel settings.
- Change in tow-cable length (tow point to towfish).
- Change in towing speed (engine rpm and pitch) or vessel heading.
- Change in tow point.
- Significant contact observed.
- Surface phenomenon observed (wakes, passing vessels, etc.).
- Passes by buoys or other known features within sonar range (identify object).
- Interference (state source if known).
- Time corresponding to the index marker.

The hydrographer shall make any other annotations necessary to note any occurrence which may later serve to reconstruct the operation. Too much information is always better than not enough.

Annotation Methods Header and system-status annotations may be made using any of the following methods:

- By use of an automatic annotator, if available.
- Typed entries in the data acquisition system.
- Typed entries in a separate annotation file.

The method is left to the hydrographer's discretion, but should be used consistently throughout the operation.

8.4 Digital Data Files

The survey data will be supplied in a digital format. Hard copy plots and hard copy printouts of reports are no longer required.

This section is provided as a summary for the major digital deliverables that may be required for a typical hydrographic survey. Not all sections will apply to all surveys. For both single beam and multibeam data, Contractors should separate digital deliverables into two data types: raw and processed. Raw should be uncorrected or with exception of online corrections. Processed data should include the Caris HDCS format or GSF.

NOAA units should refer to Chapter 5 of the OCS Field Procedures Manual for specific format and other guidance pertaining to survey deliverables.

8.4.1 Media

Digital data shall be submitted on USB hard drives. Each registered survey shall be submitted on a separate USB drive unless prior agreement is obtained from the COTR or Processing Branch. The hydrographer shall include a directory listing of each drive, or other method to enable the Processing Branch to determine where specific data sets are located. Other formats may be allowed if agreed upon in advance with the appropriate Processing Branch. The hydrographer shall work with NOAA to ensure no compatibility problems exist after data submission.

Network Attached Storage Units, specifically MaxAttach or equivalent may also be used to submit data. The hydrographer should contact the appropriate Processing Branch ahead of time to determine proper shipping methods, directory structure and reach agreement on when (or if) the Processing Branch will return the device.

8.4.2 Single-beam Data

The single-beam data format will be specified in the Hydrographic Survey Project Instructions or Statement of Work. Typically, the data will be submitted in a CARIS HIPS compatible format.

8.4.3 Shallow-Water Multibeam and Lidar Data

The hydrographer's multibeam data format shall provide complete traceability for all positions, soundings, and correctors including sensor offsets, biases, dynamic attitude, sound speed, position, sensor position, date and time, vertical datum reducers, and sounding data from acquisition through postprocessing. Data quality and edit flags must be traceable.

Full Resolution Multibeam Data

The hydrographer shall submit full resolution multibeam data in a format readable by CARIS HIPS (Version 6.1, by CARIS). Full resolution multibeam data shall be delivered fully corrected for tides, sound speed, vessel offsets, draft and dynamic draft. These corrections may be made within CARIS, with data submitted as a complete CARIS project (including HDCS files, sound speed files, Vessel Configuration, CARIS tide files, etc.). Contractors that process with Caris, shall submit the fieldsheet directory so that re-computation could occur if necessary.

Or the data may be submitted fully corrected, such that it will be read in CARIS HIPS using a 'zeroed' Vessel Configuration file (.vcf or .hvf) and a 'zero' tide file (.tid), etc. Full resolution data are defined as all data acquired and logged during normal survey operations. Information and specifications on CARIS HIPS and data formats may be obtained from CARIS at 506-458-8533.

Full Resolution Lidar Data

The contractor shall submit the full resolution lidar data in CARIS compatible format (Version 6.1, by CARIS). The submission will include the appropriate CARIS converter, lidar data before conversion, and all necessary CARIS files so that NOAA can reconvert all files, if desired. Contractors that process with Caris, shall submit the fieldsheet directory so that re-computation could occur if necessary.

CARIS BASE Surface and/or BAG

The final depth information from the survey will be composed of a collection of grids. This collection of grids must reflect the state of the seafloor at the time of the survey. The finalized uncertainty of the grids shall be the greater of the standard deviation and a priori uncertainty. The hydrographer must take steps to ensure that all data has been correctly processed and that appropriate designated soundings have been selected (see section 5.1.1.3, 5.1.2 and 5.2.1.2). The collection of grids representing the final reviewed results of the hydrographic survey shall be submitted as CARIS BASE or BAG surfaces. NOAA field units typically process hydrographic data using CARIS HIPS software. CARIS' format for the Navigation Surface is a Bathymetry Associated with Statistical Error (BASE) surfaces, either an Uncertainty or CUBE Surface. Non-CARIS users may submit their Navigation Surfaces as a Bathymetric Attributed Grid (BAG).

The grids shall have a sequential naming convention, such as H12345_1_of_5.BAG, H12345_2_of_5.BAG, H12345_3_of_5.BAG, etc.

Specific Multibeam Data

The hydrographer shall submit data used for determining navigation time latency, pitch, roll, and yaw biases in a separate directory on the submitted drive. The data format shall be such that CARIS HIPS can convert the data, thus making it compatible as described earlier in this Section.

8.4.4 Side Scan Sonar Data

The hydrographer shall submit digital side scan data in a format readable by CARIS SIPS (version 6.1, by CARIS, phone: (506) 458–8533). Digital side scan sonar shall be geocoded using the towfish position (towfish position corrected). Information and specifications on CARIS SIPS and data formats may be obtained from CARIS.

Side Scan Contact Images

The hydrographer shall submit digital images of all significant side scan contacts within the contact list (see Section 8.3.2). Digital images shall be in a standard image format (e.g., .tif, .gif, .jpg). The file name shall coincide with the contact name as depicted on the contact list.

Side Scan Mosaics

The hydrographer shall submit a digital image file for each 100 percent coverage. The digital image file shall be in a standard geo-referenced image format (section 8.3.1). Contractors that process with Caris, shall submit the fieldsheet directory so that re-computation could occur if necessary and include the referenced image file.

8.4.5 Other Data

Tide and Sound Speed Data

The hydrographer shall submit tide data and sound speed data applied to all multibeam depths on the project data drives. The hydrographer shall identify the data format and all data element descriptions (e.g., ASCII text file or Excel spreadsheet file; date/time referenced to UTC, tide relative to MLLW datum to the nearest centimeter). All tide data required by 4, shall be sent directly to the appropriate CO-OPS office.

Vessel Configuration File

The hydrographer shall submit a CARIS HIPS compatible HIPS Vessel File (HVF) for each vessel used during survey operations. CARIS-compatible HVF shall contain those static and dynamic correctors, offsets and uncertainties which are to be applied to the "Full Resolution Multibeam Data" set submitted as referenced in Section 8.4.3 If the data is submitted fully corrected with uncertainties already associated with each sounding, then the CARIS HVF may be "all zeros". In such a case, the hydrographer must provide details on what values were derived for all the static and dynamic correctors, offset and uncertainties and other information that is usually contained within a HVF in the DR and/or DAPR. Information and specifications on the HVF format may be obtained from CARIS.

Metadata

The following reports shall be included on the submitted data drive in a clearly labeled directory;

- The main body of the Descriptive Report in Microsoft Word format.
- The Appendices and Separates to the DR in Adobe Acrobat .PDF format.
- The Data Acquisition and Processing Report in Adobe Acrobat .PDF format.
- The Horizontal and Vertical Control Report in Adobe Acrobat .PDF format.

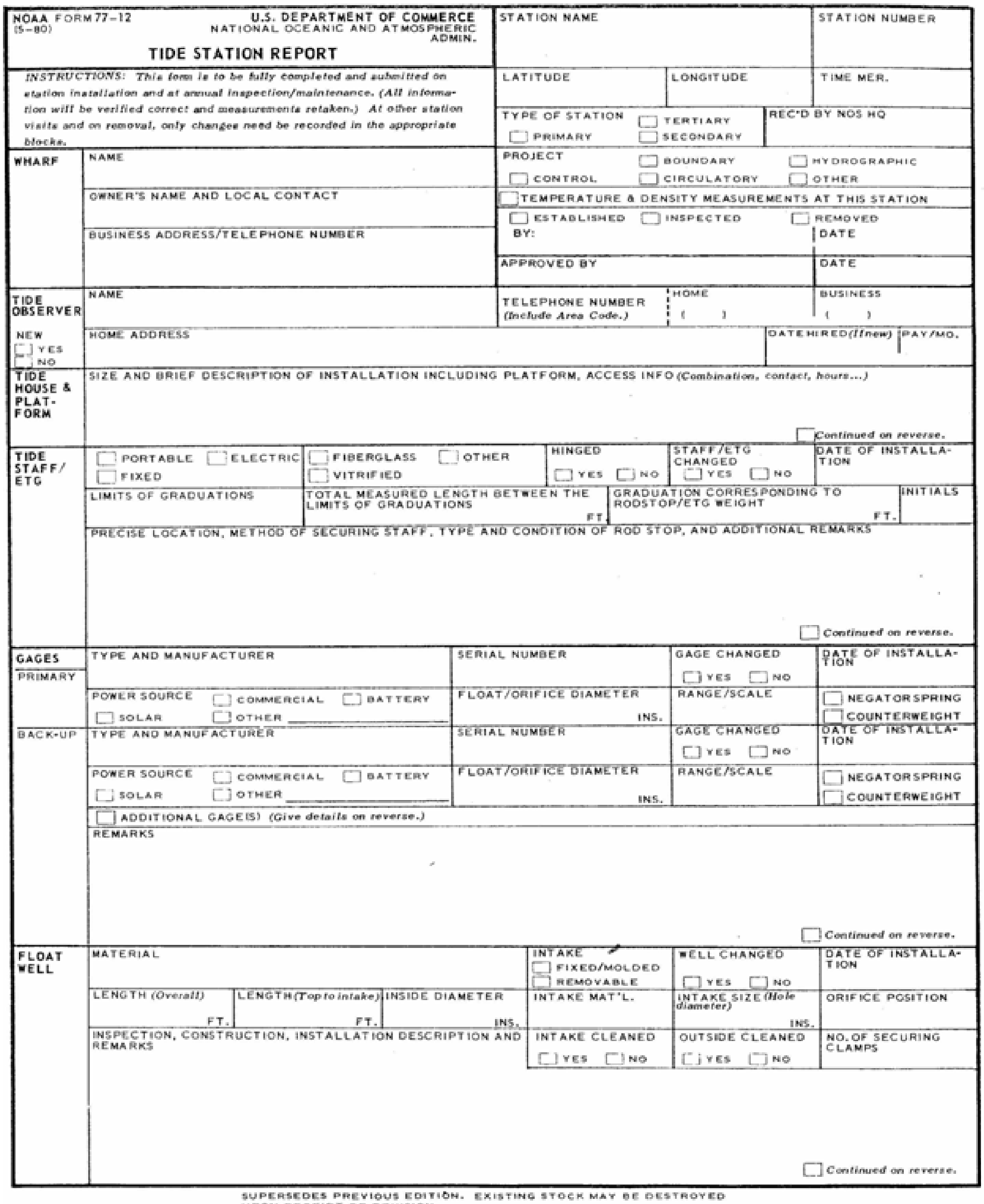
S-57 Feature File

The S-57 feature file shall be included on the submitted drive in a clearly labeled directory.

Supporting Data

- Any associated text or image files to support S-57 feature file objects.
- Other interim data products that may help the Processing Branch verify the survey and understand the pipeline from acquisition to final product.

A Appendix 1: Tide Station Report and Next Generation Water Level Measurement System Site Report



NOAA FORM 77-12 (5-80) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMIN.

TIDE STATION REPORT

STATION NAME | STATION NUMBER

INSTRUCTIONS: This form is to be fully completed and submitted on station installation and at annual inspection/maintenance. (All information will be verified correct and measurements retaken.) At other station visits and on removal, only changes need be recorded in the appropriate blocks.

LATITUDE | LONGITUDE | TIME MER.

TYPE OF STATION: PRIMARY, TERTIARY, SECONDARY | REC'D BY NOS HQ

WHARF: NAME; OWNER'S NAME AND LOCAL CONTACT; BUSINESS ADDRESS/TELEPHONE NUMBER

PROJECT: CONTROL, BOUNDARY, CIRCULATORY, HYDROGRAPHIC, OTHER

TEMPERATURE & DENSITY MEASUREMENTS AT THIS STATION

ESTABLISHED, INSPECTED, REMOVED BY: | DATE

APPROVED BY | DATE

TIDE OBSERVER: NAME | TELEPHONE NUMBER *(Include Area Code.)* HOME ( ) | BUSINESS ( )

NEW: YES, NO | HOME ADDRESS | DATE HIRED *(If new)* | PAY/MO.

TIDE HOUSE & PLATFORM: SIZE AND BRIEF DESCRIPTION OF INSTALLATION INCLUDING PLATFORM, ACCESS INFO *(Combination, contact, hours...)*

Continued on reverse.

TIDE STAFF/ETG: PORTABLE, ELECTRIC, FIXED, FIBERGLASS, VITRIFIED, OTHER | HINGED: YES, NO | STAFF/ETG CHANGED: YES, NO | DATE OF INSTALLATION

LIMITS OF GRADUATIONS | TOTAL MEASURED LENGTH BETWEEN THE LIMITS OF GRADUATIONS FT. | GRADUATION CORRESPONDING TO RODSTOP/ETG WEIGHT FT. | INITIALS

PRECISE LOCATION, METHOD OF SECURING STAFF, TYPE AND CONDITION OF ROD STOP, AND ADDITIONAL REMARKS

Continued on reverse.

GAGES

PRIMARY: TYPE AND MANUFACTURER | SERIAL NUMBER | GAGE CHANGED: YES, NO | DATE OF INSTALLATION

POWER SOURCE: COMMERCIAL, BATTERY, SOLAR, OTHER | FLOAT/ORIFICE DIAMETER INS. | RANGE/SCALE | NEGATOR SPRING, COUNTERWEIGHT

BACK-UP: TYPE AND MANUFACTURER | SERIAL NUMBER | GAGE CHANGED: YES, NO | DATE OF INSTALLATION

POWER SOURCE: COMMERCIAL, BATTERY, SOLAR, OTHER | FLOAT/ORIFICE DIAMETER INS. | RANGE/SCALE | NEGATOR SPRING, COUNTERWEIGHT

ADDITIONAL GAGE(S) *(Give details on reverse.)*

REMARKS

Continued on reverse.

FLOAT WELL: MATERIAL | INTAKE: FIXED/MOLDED, REMOVABLE | WELL CHANGED: YES, NO | DATE OF INSTALLATION

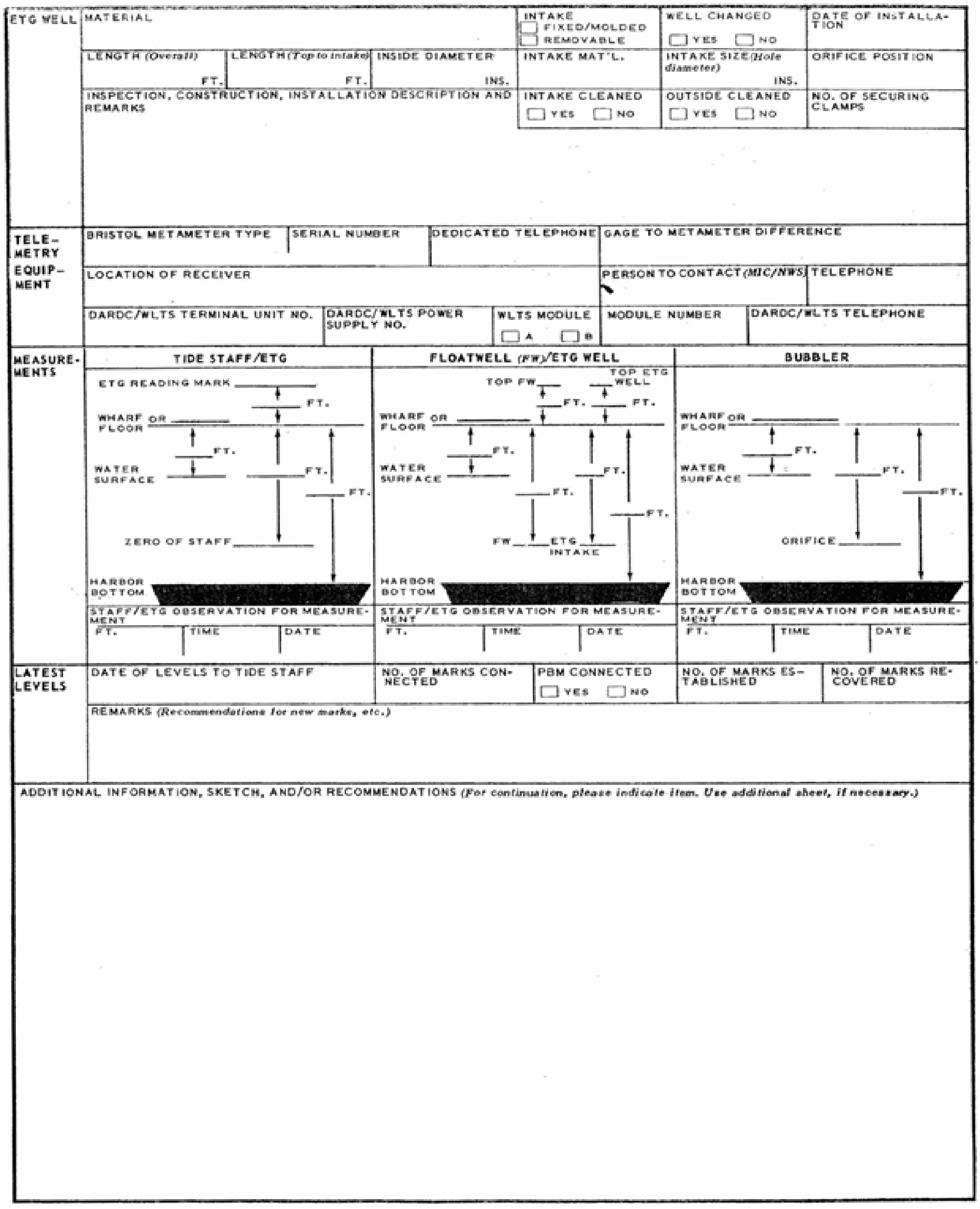
LENGTH *(Overall)* FT. | LENGTH *(Top to intake)* FT. | INSIDE DIAMETER INS. | INTAKE MAT'L. | INTAKE SIZE *(Hole diameter)* INS. | ORIFICE POSITION

INSPECTION, CONSTRUCTION, INSTALLATION DESCRIPTION AND REMARKS | INTAKE CLEANED: YES, NO | OUTSIDE CLEANED: YES, NO | NO. OF SECURING CLAMPS

Continued on reverse.

SUPERSEDES PREVIOUS EDITION. EXISTING STOCK MAY BE DESTROYED UPON RECEIPT OF REVISION.

Figure A.1: NOAA Form 77-12 Tide Station Report



ETG WELL
MATERIAL
INTAKE ☐ FIXED/MOLDED ☐ REMOVABLE
WELL CHANGED ☐ YES ☐ NO
DATE OF INSTALLATION
LENGTH (Overall) FT.
LENGTH (Top to intake) FT.
INSIDE DIAMETER INS.
INTAKE MAT'L.
INTAKE SIZE (Hole diameter) INS.
ORIFICE POSITION
INSPECTION, CONSTRUCTION, INSTALLATION DESCRIPTION AND REMARKS
INTAKE CLEANED ☐ YES ☐ NO
OUTSIDE CLEANED ☐ YES ☐ NO
NO. OF SECURING CLAMPS

TELEMETRY EQUIPMENT
BRISTOL METAMETER TYPE
SERIAL NUMBER
DEDICATED TELEPHONE
GAGE TO METAMETER DIFFERENCE
LOCATION OF RECEIVER
PERSON TO CONTACT (MIC/NWS)
TELEPHONE
DARDC/WLTS TERMINAL UNIT NO.
DARDC/WLTS POWER SUPPLY NO.
WLTS MODULE ☐ A ☐ B
MODULE NUMBER
DARDC/WLTS TELEPHONE

MEASUREMENTS
TIDE STAFF/ETG
ETG READING MARK
FT.
WHARF OR FLOOR
FT.
WATER SURFACE
FT.
FT.
ZERO OF STAFF
HARBOR BOTTOM
STAFF/ETG OBSERVATION FOR MEASUREMENT
FT. | TIME | DATE

FLOATWELL (FW)/ETG WELL
TOP FW
TOP ETG WELL
FT.
FT.
WHARF OR FLOOR
FT.
WATER SURFACE
FT.
FT.
FT.
FW
ETG INTAKE
HARBOR BOTTOM
STAFF/ETG OBSERVATION FOR MEASUREMENT
FT. | TIME | DATE

BUBBLER
WHARF OR FLOOR
FT.
WATER SURFACE
FT.
FT.
ORIFICE
HARBOR BOTTOM
STAFF/ETG OBSERVATION FOR MEASUREMENT
FT. | TIME | DATE

LATEST LEVELS
DATE OF LEVELS TO TIDE STAFF
NO. OF MARKS CONNECTED
PBM CONNECTED ☐ YES ☐ NO
NO. OF MARKS ESTABLISHED
NO. OF MARKS RECOVERED
REMARKS (Recommendations for new marks, etc.)

ADDITIONAL INFORMATION, SKETCH, AND/OR RECOMMENDATIONS (For continuation, please indicate item. Use additional sheet, if necessary.)

*U.S. GPO: 1988-554-006/81003

Figure A.2: Tide Station Report(cont.)

8200 DATA RECORDER

8200 S/N	DATE 8200 INSTALLED	PROGRAM VERSION	POWER SOURCE ☐ DC ☐ SOLAR	DESICCANT CHANGED? ☐ YES ☐ NO	CPU S/N	INTERCONNECT S/N
					AMP GAIN	SENSOR SLOPE

DESCRIPTION, REMARKS (Mounting, location, etc)

☐ Continued below

BACKUP WATER LEVEL SENSOR

SENSOR MANUFACTURER ☐ DRUCK ☐ IMO ☐ PAROSCIENTIFIC ☐ OTHER ______	SENSOR S/N	DATE SENSOR INSTALLED	SENSOR CONFIGURATION ☐ WATER ☐ BUBBLER	PARALLEL PLATES? ☐ YES ☐ NO

DESCRIPTION, REMARKS (Sensor location, installation details, etc)

☐ Continued below

OTHER SENSORS

AIR TEMPERATURE ☐ YES ☐ NO	DATE INSTALLED	BAROMETER S/N	DATE INSTALLED	CONDUCTIVITY S/N	DATE INSTALLED
WATER TEMPERATURE ☐ YES ☐ NO	DATE INSTALLED	WIND SENSOR S/N	DATE INSTALLED	MET TOWER TYPE: STEEL ☐ FIBERGLASS ☐	DATE INSTALLED

DESCRIPTION, REMARKS (Sensor/tower location, installation details, etc)

☐ Continued below

LATEST LEVELS

DATE OF LEVELS	NUMBER OF BENCH MARKS CONNECTED	NUMBER OF BENCH MARKS ESTABLISHED	NUMBER OF BENCH MARKS RECOVERED	PBM CONNECTED? ☐ YES ☐ NO, EXPLAIN	DOWNSHOT LEVELING FIXTURE REQUIRED? ☐ YES ☐ NO

REMARKS

☐ Continued below

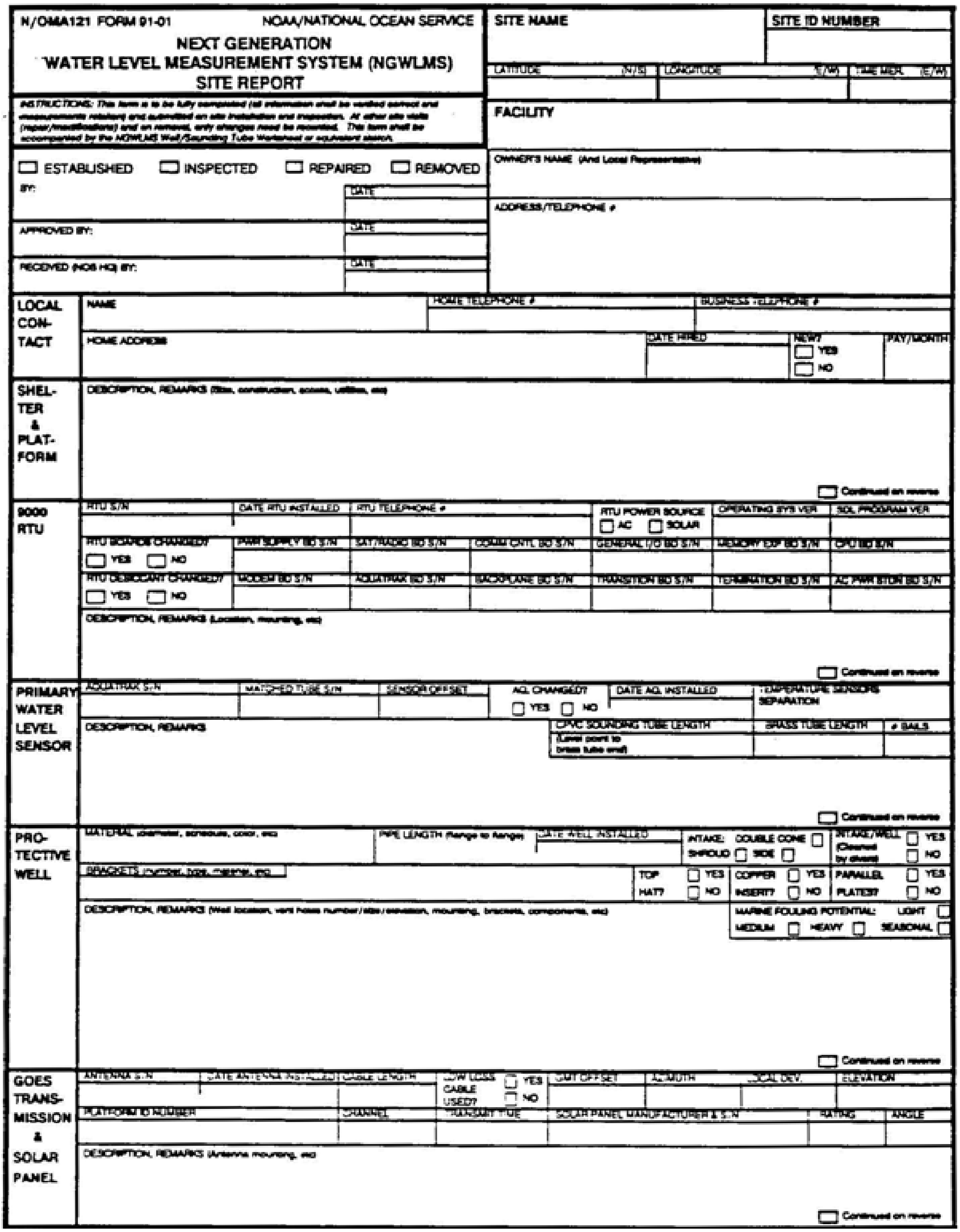
AQUATRAK COEFFICIENT 2A (PBM above site datum: from HQ)

AQUATRAK COEFFICIENT 2B (Leveling point above PBM: from levels) +

AQUATRAK COEFFICIENT 2 (2A + 2B = 2) =

REMARKS (Continuations, recommendations, etc)

Figure A.3: Tide Station Report(cont.)



N/OMA121 FORM 91-01 NOAA/NATIONAL OCEAN SERVICE

NEXT GENERATION
WATER LEVEL MEASUREMENT SYSTEM (NGWLMS)
SITE REPORT

SITE NAME | SITE ID NUMBER

LATITUDE (N/S) | LONGITUDE (E/W) | TIME MER. (E/W)

FACILITY

OWNER'S NAME (And Local Representative)

ADDRESS/TELEPHONE #

☐ ESTABLISHED ☐ INSPECTED ☐ REPAIRED ☐ REMOVED

BY: | DATE

APPROVED BY: | DATE

RECEIVED (NOS HQ) BY: | DATE

LOCAL CONTACT: NAME | HOME TELEPHONE # | BUSINESS TELEPHONE # | HOME ADDRESS | DATE HIRED | NEW? ☐ YES ☐ NO | PAY/MONTH

SHELTER & PLATFORM: DESCRIPTION, REMARKS (Size, construction, access, utilities, etc) ☐ Continued on reverse

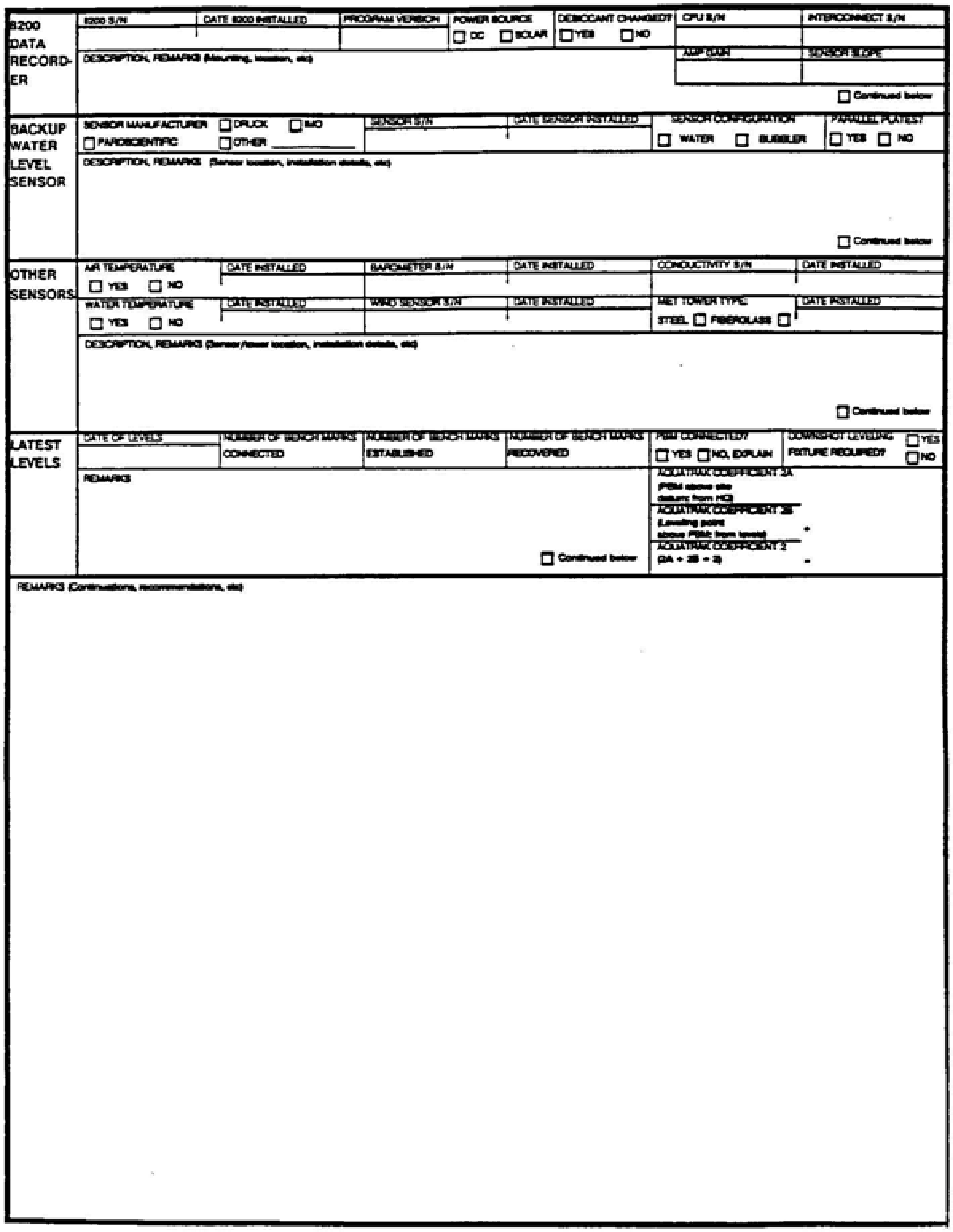
9000 RTU: RTU S/N | DATE RTU INSTALLED | RTU TELEPHONE # | RTU POWER SOURCE ☐ AC ☐ SOLAR | OPERATING SYS VER | SDL PROGRAM VER
RTU BOARDS CHANGED? ☐ YES ☐ NO | PWR SUPPLY BD S/N | SAT/RADIO BD S/N | COMM CNTL BD S/N | GENERAL I/O BD S/N | MEMORY EXP BD S/N | CPU BD S/N
RTU DESICCANT CHANGED? ☐ YES ☐ NO | MODEM BD S/N | AQUATRAK BD S/N | BACKPLANE BD S/N | TRANSITION BD S/N | TERMINATION BD S/N | AC PWR STGR BD S/N
DESCRIPTION, REMARKS (Location, mounting, etc) ☐ Continued on reverse

PRIMARY WATER LEVEL SENSOR: AQUATRAK S/N | MATCHED TUBE S/N | SENSOR OFFSET | AQ. CHANGED? ☐ YES ☐ NO | DATE AQ. INSTALLED | TEMPERATURE SENSORS SEPARATION
DESCRIPTION, REMARKS | CPVC SOUNDING TUBE LENGTH (Level point to brass tube end) | BRASS TUBE LENGTH | # BAILS
☐ Continued on reverse

PROTECTIVE WELL: MATERIAL (diameter, schedule, color, etc) | PIPE LENGTH (flange to flange) | DATE WELL INSTALLED | INTAKE: DOUBLE CONE ☐ SHROUD ☐ SIDE ☐ | INTAKE/WELL (Cleaned by divers) ☐ YES ☐ NO
BRACKETS (number, type, material, etc) | TOP HAT? ☐ YES ☐ NO | COPPER INSERT? ☐ YES ☐ NO | PARALLEL PLATES? ☐ YES ☐ NO
DESCRIPTION, REMARKS (Well location, vent holes number/size/elevation, mounting, brackets, components, etc) | MARINE FOULING POTENTIAL: LIGHT ☐ MEDIUM ☐ HEAVY ☐ SEASONAL ☐
☐ Continued on reverse

GOES TRANSMISSION & SOLAR PANEL: ANTENNA S/N | DATE ANTENNA INSTALLED | CABLE LENGTH | LOW LOSS CABLE USED? ☐ YES ☐ NO | XMIT OFFSET | AZIMUTH | LOCAL DEV. | ELEVATION
PLATFORM ID NUMBER | CHANNEL | TRANSMIT TIME | SOLAR PANEL MANUFACTURER & S/N | RATING | ANGLE
DESCRIPTION, REMARKS (Antenna mounting, etc) ☐ Continued on reverse

Figure A.4: N/OMA121 Form 91-01 Next Generation Water Level



8200 DATA RECORDER

8200 S/N	DATE 8200 INSTALLED	PROGRAM VERSION	POWER SOURCE	DESICCANT CHANGED?	CPU S/N	INTERCONNECT S/N
			☐ DC ☐ SOLAR	☐ YES ☐ NO		

DESCRIPTION, REMARKS (Mounting, location, etc)

AUX GAIN | SENSOR SLOPE

☐ Continued below

BACKUP WATER LEVEL SENSOR

SENSOR MANUFACTURER	SENSOR S/N	DATE SENSOR INSTALLED	SENSOR CONFIGURATION	PARALLEL PLATES?
☐ DRUCK ☐ IMO ☐ PAROSCIENTIFIC ☐ OTHER ______			☐ WATER ☐ BUBBLER	☐ YES ☐ NO

DESCRIPTION, REMARKS (Sensor location, installation details, etc)

☐ Continued below

OTHER SENSORS

AIR TEMPERATURE	DATE INSTALLED	BAROMETER S/N	DATE INSTALLED	CONDUCTIVITY S/N	DATE INSTALLED
☐ YES ☐ NO					
WATER TEMPERATURE	DATE INSTALLED	WIND SENSOR S/N	DATE INSTALLED	MET TOWER TYPE	DATE INSTALLED
☐ YES ☐ NO				STEEL ☐ FIBERGLASS ☐	

DESCRIPTION, REMARKS (Sensor/tower location, installation details, etc)

☐ Continued below

LATEST LEVELS

DATE OF LEVELS	NUMBER OF BENCH MARKS CONNECTED	NUMBER OF BENCH MARKS ESTABLISHED	NUMBER OF BENCH MARKS RECOVERED	PBM CONNECTED?	DOWNSHOT LEVELING FIXTURE REQUIRED?
				☐ YES ☐ NO, EXPLAIN	☐ YES ☐ NO

REMARKS

AQUATRAK COEFFICIENT 2A (PBM above site datum; from HQ)

AQUATRAK COEFFICIENT 2B (Leveling point above PBM; from levels) +

AQUATRAK COEFFICIENT 2 (2A + 2B = 2) =

☐ Continued below

REMARKS (Continuations, recommendations, etc)

Figure A.5: Next Generation Water Level (cont.)

B Appendix 2: Descriptive Report Cover Sheet (NOAA Form 76-35A)

NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DESCRIPTIVE REPORT

Type of Survey ______________________
Project No. ______________________
Registry No. ______________________

LOCALITY

State ______________________
General Locality ______________________
Sub-locality ______________________

CHIEF OF PARTY

LIBRARY & ARCHIVES

DATE

Figure B.1: Descriptive Report Cover Sheet(NOAA Form 76-35A)

C Appendix 3: Descriptive Report Title Sheet (NOAA Form 77-28)

NOAA FORM 77-28
(11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTRY No

HYDROGRAPHIC TITLE SHEET

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

State ______________________

General Locality ______________________

Sub-Locality ______________________

Scale ______________________

Date of Survey ______________________

Instructions Dated ______________________

Project No. ______________________

Vessel ______________________

Chief of Party ______________________

Surveyed by ______________________

Soundings by echosounder ______________________

Verification by ______________________

Soundings in fathoms feet at MLW MLLW ______________________

REMARKS:

____

Figure C.1: Descriptive Report Title Sheet (NOAA Form 77-28)

D Appendix 4: Abstract of Times of Hydrography for Smooth Tides or Water Levels

Project: OPR-P385-KR[1] Registry No.: H-xxxxxx[1]
Contractor Name:
Date:
Sheet Letter: [1]
Inclusive Dates: [2]
Field work is complete.

Time (UTC)

Day[3]	Start[4]	End[4]	Year

[1]Project Number, Registry Number, and Sheet Letter from SOW Or Hydrographic Survey Letter Instructions.

[2]Dates of the first and last days of data acquisition.

[3]Day of the year (e.g. April 30, 1998 = 120)

[4]Start and end time of hydrography for the day.

Figure D.1: Abstract of Times of Hydrography for Smooth Tides or Water Levels

E Appendix 5: Example Request for Smooth Tides/Water Levels Letter

TO: NOAA, National Ocean Service
Chief, Requirements and Engineering Branch
SSMC4, Station 6515, N/CS41
1305 East-West Highway
Silver Spring, MD 20910-3281

FROM: <Hydrographer>

SUBJECT: Request for Approved Tides/Water Levels

Please provide the following data:

1. Approved Tides/Water Level Note
2. Final Zoning in MapInfo format (or the Hydrographer may request the data in ArcView format)
3. Six Minute Water Level Data posted to CO-OPS web site.

Transmit the data to:
<Insert hydrographer's name and shipping address>

These data are required for the processing of hydrographic survey:

Project: OPR-xxxx-KR
Registry Number: H-xxxxxx
Sheet Letter: A
Locality: xxxxxxxxxxxxxxx

A progress Sketch or chartlet showing the survey area and Abstract of Times of Hydrography are attached.

Tide/water level data are required within 45 days of this receipt. If this schedule cannot be met, please advise HSD Operations at 301-713-2702 x112.

Figure E.1: Example Request for Smooth Tides/Water Levels Letter

F Appendix 6: Danger to Navigation Report

REPORT OF DANGERS TO NAVIGATION

Hydrographic Survey Registry Number: H10851

Survey Title:	State:	TEXAS
	Locality:	GULF OF MEXICO
	Sublocality:	15 NM SSE OF GALVESTON

Project Number: OPR-L304-KR-99
Survey Dates: July 10, 1999 - July 29, 1999
Survey Danger Acquisition Date and Time: July 20, 1999; 2024 UTC

Features are reduced to Mean Lower Low Water using verified tides and are positioned on NAD83.

Charts affected: 11323 55th Edition/July 5, 1997, scale 1:80,000, NAD 83
11330 11th Edition/September 30, 1999, scale 1:250,000, NAD 83

DANGERS TO NAVIGATION

FEATURE	DEPTH (FT)	LATITUDE (N)	LONGITUDE (W)
Shoal	25	29/45/31	094/20/20
Obstruction	31	28/45/14	094/20/10
Wreck	39	29/44/21	094/19/43

Buoy R “2" which is charted at 29/30/15N, 094/23/35W, was not found at its charted location. The current position of buoy R “2" is 29/28/35N, 094/21/10W. The purpose of buoy R “2" is to mark the northeast entrance into the Galveston Ship Channel.

Questions concerning this report should be directed to the Chief, Atlantic Hydrographic Branch at (757) 441-6746.

Figure F.1: Example of Danger to Navigation Report

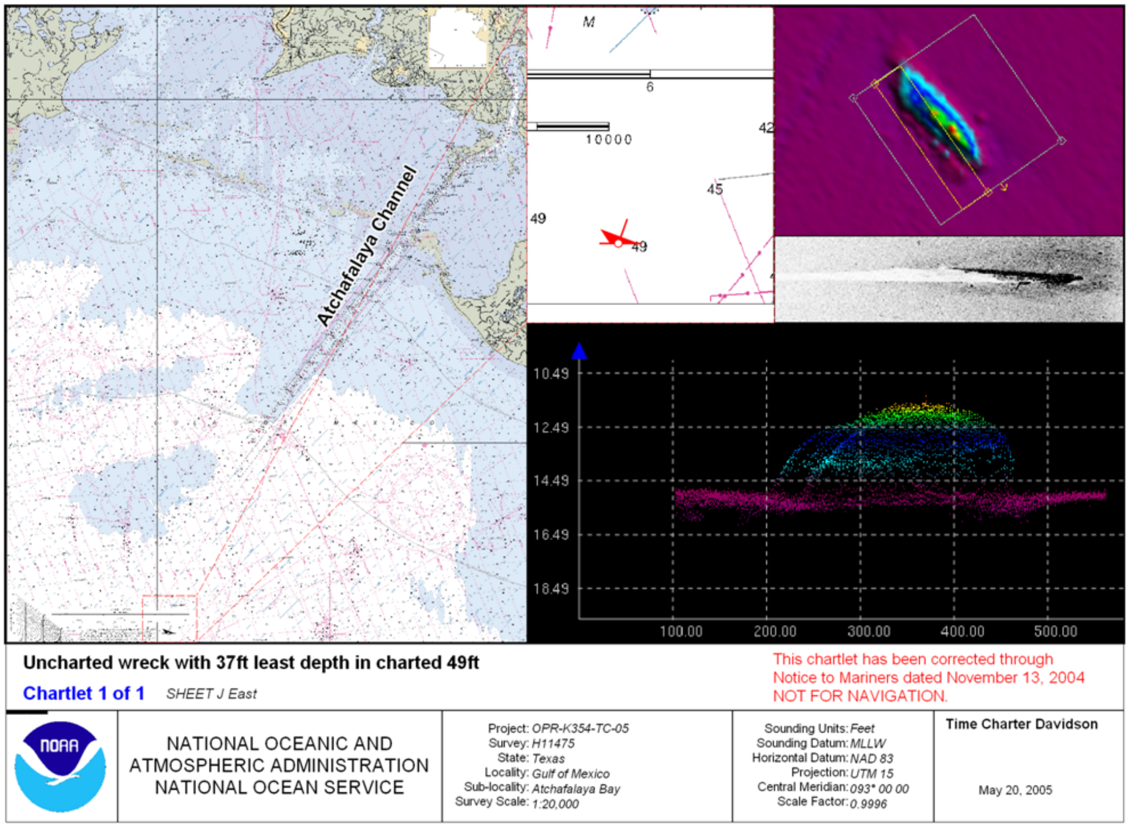
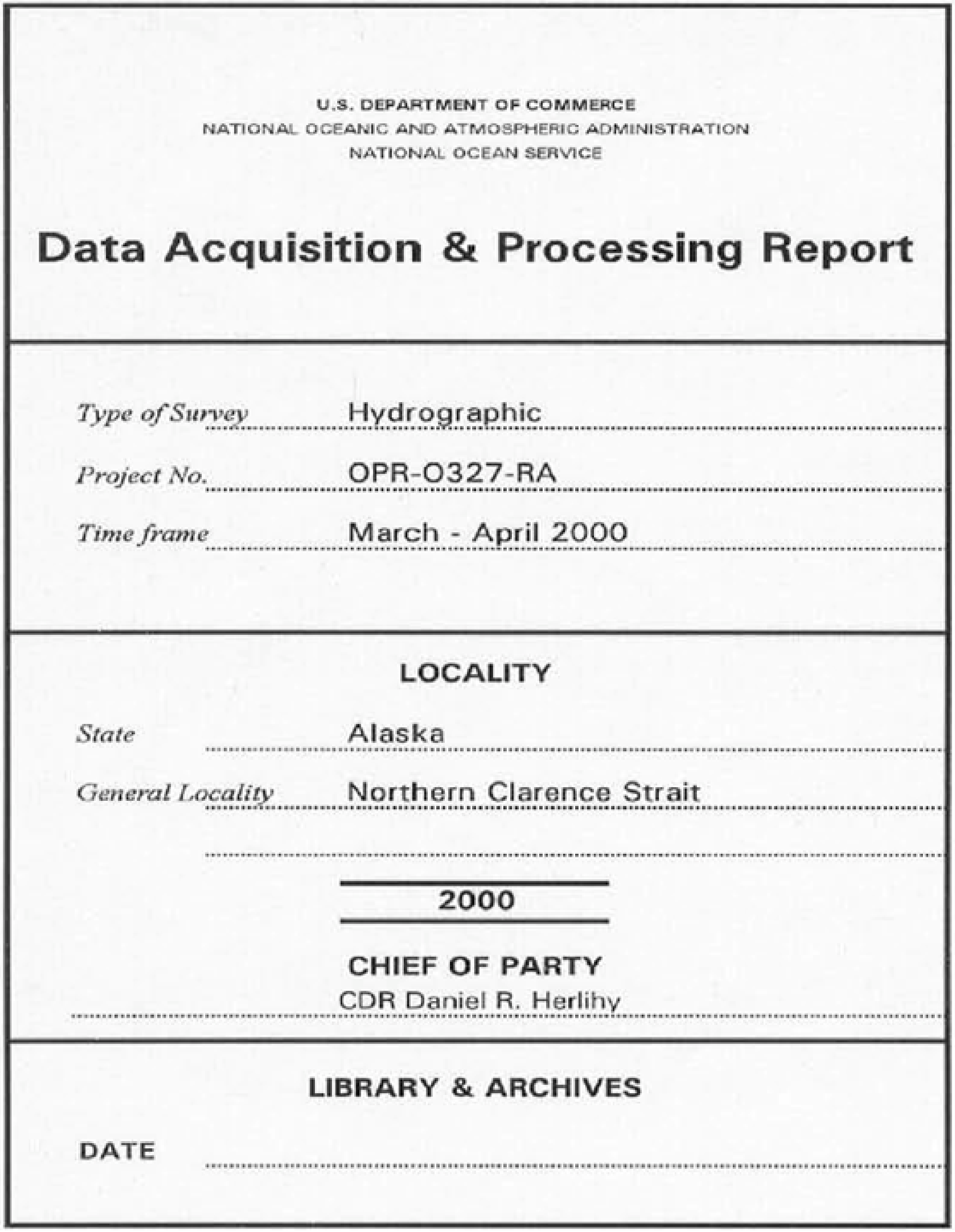


Figure F.2: Example of Chartlet to Accompany Danger to Navigation Report

G Appendix 7: Data Acquisition and Processing Report



U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

Data Acquisition & Processing Report

Type of Survey Hydrographic

Project No. OPR-O327-RA

Time frame March - April 2000

LOCALITY

State Alaska

General Locality Northern Clarence Strait

2000

CHIEF OF PARTY
CDR Daniel R. Herlihy

LIBRARY & ARCHIVES

DATE

Figure G.1: Data Acquisition and Processing Report

H Appendix 8: Rock Attribution

Rock attribution contained in a Feature file shall be in accordance with the NOAA Nautical Chart Manual Section 4.9. Excerpts from this manual are shown below.

Atlantic Coast and Gulf of Mexico

NOAA Classification	Sunken	Awash at Sounding Datum	Awash that Uncovers	Bare
Depth	> 1ft below	< 1ft above MLLW to 1ft below MLLW	1ft above MLLW to 1ft above MHW	> 1ft above MHW
S-57 Object	UWTROC	UWTROC	UWTROC	LNDARE and LNDELV (height)
Mandatory Attributes	WATLEV = 3 VALSOU > 0	WATLEV = 5 VALSOU = 0	WATLEV = 4 VALSOU < 0	ELEVAT > 0

Pacific Coast

NOAA Classification	Sunken	Awash at Sounding Datum	Awash that Uncovers	Bare
Depth	> 2ft below MLLW	< 2ft above MLLW to 2ft below MLLW	2ft above MLLW to 2ft above MHW	> 2ft above MHW
S-57 Object	UWTROC	UWTROC	UWTROC	LNDARE and LNDELV (height)
Mandatory Attributes	WATLEV = 3 VALSOU > 0	WATLEV = 5 VALSOU = 0	WATLEV = 4 VALSOU < 0	ELEVAT > 0

Great Lakes
LWD = Low Water Datum

NOAA Classification	Sunken	Awash at Sounding Datum	Awash that Uncovers	Bare
Depth	> 2ft below LWD	< 2ft above LWD to 2ft below LWD	2ft above LWD to 4ft above LWD	> 4ft above LWD
S-57 Object	UWTROC	UWTROC	UWTROC	LNDARE and LNDELV (height)
Mandatory Attributes	WATLEV = 3 VALSOU > 0	WATLEV = 5 VALSOU = 0	WATLEV = 4 VALSOU < 0	ELEVAT > 0

Figure H.1: Rock Attribution

I Appendix 9: Statistics Spreadsheet Example

NOAA Ship THOMAS JEFFERSON
FY 2007 Statistics

Projects (CY2006)	Location	Month(s)	LNM VBES		LNM MB		LNM SSS		LNM Combo *		Combo Type ^		Items Investigated	Tide Gauges Installed / Removed
			Ship	Launch	Ship	Launch	Ship	Launch	Ship	Launch	Ship	Launch		
OPR-B310-TJ-06	App. To New York Harbor	October	0		870.8		0		0			0		
Sub Total			**0**		**870.8**		**0**		**0**					

Projects (CY2006)	Location	Month(s)	LNM VBES		LNM MB		LNM SSS		LNM Combo *		Combo Type ^		Items Investigated	Tide Gauges Installed / Removed
			Ship	Launch	Ship	Launch	Ship	Launch	Ship	Launch	Ship	Launch		
Sub Total			**0**		**0**		**0**		**0**					
Total			**0**		**871**		**0**		**0**					

* (e.g., SSS/VB)
^ (e.g., SSS/VB or SSS/MB)

Figure I.1: Statistics Spreadsheet Example