Hydrographic Surveys Specifications and Deliverables (2012 Edition)

Specification

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Manager / Process Owner Approval

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NOS HYDROGRAPHIC SURVEYS SPECIFICATIONS AND DELIVERABLES

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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, Fifth Edition, February 2008, specifically for Order 1a surveys. Hydrographic surveys classified as Order 1a 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 and contractors or in the Statement of Work (contractors only).

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 COR 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. Field units should contact the COR or HSD project manager to ensure they are using the correct and approved version of any sofware mentioned in these Specifications.

1.1 Definitions

1.1.1 Hydrographer:

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.

1.1.2 Navigable Area Survey

All modern NOAA hydrographic surveys are Navigable Area Surveys, unless explicitly stated otherwise in the Hydrographic Survey Project Instructions. Navigable Area Surveys are basic hydrographic surveys with a restricted inshore limit of coverage.

The shoreline depicted on NOAA's nautical charts approximates the line where the average high tide, known as Mean High Water (MHW), intersects the coast and includes the attached cultural features that are exposed at MHW. In addition, nearshore natural and man-made features such as rocks, reefs, ledges, foul areas, aids to navigation, and mooring facilities are typically included in the colloquial definition of "shoreline." NGS Remote Sensing Division (RSD) is responsible for acquisition and compilation of shoreline data, which it provides directly to MCD for nautical chart updates. However, NOAA's hydrographic field parties may be tasked with verifying that shoreline details are adequately and accurately depicted in source datasets and the corresponding nautical charts.

The inshore limit of hydrography and feature verification for Navigable Area Surveys is the Navigable Area Limit Line (NALL), unless stated otherwise in the Hydrographic Survey Project Instructions. By default, the NALL is defined as the most seaward of the following:

1. The surveyed 4-meter depth contour.

2. The line defined by the distance seaward from the observed MHW line[1] which is equivalent to 0.8 millimeters at the scale of the largest scale nautical chart covering any portion of the survey area (e.g., for a 1:80,000 scale chart, this line would fall 64 meters seaward of the MHW line)[2]

3. The inshore limit of safe navigation for the survey vessel, as determined by the Chief-of-Party in consultation with his or her field personnel. If kelp, rocks, breakers, or other hazards make it unsafe to approach the coast to the limits specified in 1 and 2 above, the NALL shall be defined as the shoreward boundary of the area in which it is safe to survey.

In rare instances, the Chief-of-Party may determine that the NALL lies inshore of the limits defined in 1 and 2. For example, this could be the case in confined waters such as harbors or passes which are inshore of the NALL as defined above, but are regularly utilized by vessels depending on NOAA chart products for safe passage. It could also occur in deep water ports where modern bathymetry is required along wharf faces. In these cases, the Chief-of-Party shall consult with the Chief, HSD Operations Branch or COR, prior to dedicating significant survey resources to these areas.

Also, on some occasions the hydrographer may be tasked with investigation of specific items (e.g., AWOIS items, Chart Evaluation File items, or USCG Aids to Navigation) which fall inshore of the NALL as defined by criteria 1 and 2 above. The hydrographer may also encounter unassigned natural or anthropogenic features inshore of the NALL which are such exceptionally prominent aids to visual navigation that accurate positions for depiction on nautical charts are required. In these cases, the hydrographer shall proceed inshore of the NALL to accomplish investigation of these features, so long as this can be accomplished safely and in accordance criterion 3 above. Note that the hydrographer is not required to extend bathymetric coverage inshore of the NALL when investigating features with vertical extents above MLLW.

The hydrographer shall discuss in the Descriptive Report all areas where NALL definition deviated from the default criteria. Note that offshore surveys which do not approach the coast will end at their assigned survey limits.

Working near shore is inherently dangerous, and all field units are reminded that safety shall always be the primary consideration when conducting operations. Verification of

[1] For the purposes of this section "observed MHW line" means the approximate mean high water line estimated visually by the hydrographer from the survey launch.

[2] For surveys which cross a chart scale boundary (e.g., a portion of the survey area is covered at large scale, while the remainder is covered at a smaller scale), the MHW offset for the entire survey shall be based on the largest scale chart covering any portion of the survey area. (Contact the Operations Branch or COR for clarification if required.) Note that the chart scale referenced by this requirement is determined individually for each survey, not for an entire project, i.e., different surveys in the same project may have different maximum chart coverage scale, and thus different MHW offsets for the purpose of NALL determination.

near shore features should not be attempted unless conditions are favorable. Even though an initial assessment is made by the Chief-of-Party, conditions at the actual survey area may be different or degrade as the day progresses. In such cases, the launch or skiff personnel should defer near shore operations until conditions are favorable.

1.2 Changes from April 2011

Several clerical changes have been made in the 2012 Edition of this document. Significant technical and organizational changes are summarized below:

A majority of the changes in the 2012 edition focus on feature management. Many of the changes were incorporated to standardized the supporting project files from HSD Operations to all field units and deliverables from the field units to the processing branches.

Chapter 1 Introduction

1. Section 1.0 Introduction, included a statement for the field units to contact HSD or the COR to ensure they are using the correct and approved version of any software.

Chapter 4 Tides and Water Level Requirements

1. Section 4.1.4 Data Quality Monitoring, revised when the gauges will be listed on the hydro hot list.

2. Section 4.2.4 Tide Staffs, updated Staff section to mention “staff stop” instead of “rod stop”. Updated Staff Observation section to updated the staff-to-gauge observation time. Added Figure 4.2: Relationship of Station Datum, Orifice and Staff. Re-numbered all of the figures throughout Chapter 4.

3. Section 4.2.8 Additional Field Requirements, added number 4 to include progress sketch requirement.

4. Section 4.2.9 Geodetic Connections and Datum Relationship, added section to include how to publish your OPUS solution.

5. Section 4.6.4 Tide Reducers and Final Zoning and Final Tide Note, revised the compatible formats for the final tidal zoning scheme. And added note to mention if no subordinate water level station was installed then preliminary tidal zoning may be used as final tidal zoning.

6. Section 4.6.5 Submission and Deliverables – Documentation and Time lines, added when final zoning schemes with methodological documentation should be submitted. Revised a few items in the standard station documentation package list.

Chapter 5 Depth Soundings

1. Section 5.2.1.2 General Requirement, revised to mention multiple echosounding sources can be in a single grid or multiple grids. Includes an exception for crossline data. Added that soundings on features that would not be charted with a depth shall not be designated.

2. Section 5.2.2 Coverage and Resolution, revised “skunk stripe” with ‘set line spacing’. Added that approved deviations need to be included in the Descriptive Report Appendices.

3. Section 5.2.2.1 Object Detection Coverage, revised coverage requirements.

4. Section 5.2.2.2 Complete Multibeam Coverage, revised coverage requirements

5. Section 5.2.2.3 Set Line Spacing, revised coverage requirements and grid-resolution thresholds. Changed multiple vs single grid requirements for different bathymetry types.

6. Section 5.2.3.3 Speed of Sound Corrections, updated that confidence checks need to be conducted at least once per leg instead of once per week. Added that for any multibeam operations, any deviations from the general requirement for the sound speed profile checks shall be documented in the descriptive report. Added requirement to monitor difference between surface sound speed and cast values to trigger new cast requirement.

7. Section 5.3.2 Coverage and Resolution, added section on Attribution.

8. Section 5.3.4.3 Lidar Crosslines, added Lidar to the title of this section.

Chapter 6 Towed Side Scan Sonar

1. Section 6.0 Towed Side Scan Sonar, added clarification to meet object detection requirements.

2. Section 6.2.3 Towfish Height, added paragraph to address areas with excessive bathymetry or when hull mounted systems are used.

Chapter 7 Other Data

1. Section 7.1 Bottom Characteristics, added paragraph to include guidance on empty samples.

Chapter 8 Deliverables

1. Section 8.1.2 Survey Outlines, added another exception for providing a survey outline, Lidar surveys.

2. Section 8.1.3 Danger to Navigation, revised section to address NOAA field unit DTON recommendations and Contractor DTON recommendations and provided additional guidance on where the verification email and the final format for DTON features.

3. Section 8.1.4 Data Acquisition and Processing, updated B2 to include ensuring continuity in survey coverage when evaluating survey junctions. Descriptive Report Appendices section completely revised; removed the original sections I-IV, now only contain I and II. Separates to be Included with the Survey Data section completely revised; removed sections I-V, now contain I, II, and III.

4. Section 8.1.5.2 Horizontal and Vertical Control Report, removed the requirement for a Title Sheet.

5. Section 8.2 S-57 Soundings and Features Deliverables, section rewritten to include guidance on the Composite Source Files (CSF), Project Reference Files (PRF) and Prior Survey Feature Files (PRI). New tables added to identify the PRF features represented by S-57 feature objects and NOAA extended attributes. Updated; All Feature Objects and Features to include the correct objects for each section.

6. Section 8.3.2 Side Scan Sonar Contact List, Contact Images, revised the location for the copies of the images to be included in the Multimedia folder.

7. Section 8.4.1 Media, added a requirement that all field units submit a check sum as well as verify that all files are present and none have become corrupt during transfer to a portable media.

H Appendix 8: Feature Attribution, updated NOAA Extended Attribution, NOAA Discretionary Attribution, and updated Figure H.3, the Expected input values for NOAA enumeration attributes.

J Appendix 10: Bottom Classifications, added Figure J.5 NATQUA/NATSUR Allowable Attribute Combinations.

L Appendix 12: Data Directory Structure, added new tables to reflect the required data directory structure for Contractors and the required data directory structure for NOAA field units as well as the raw data directory structure.

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 Position Uncertainty and Precision

3.1.1 Horizontal Position Uncertainty

The NOS specification for hydrographic positioning is that the Total Horizontal Uncertainty (THU) 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 uncertainty of the vessel position can be considered the THU 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 uncertainty 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. See Section 5.2.3.6, ”Uncertainty Budget Analysis for Depths", for a more detailed discussion of those specifications related to horizontal positioning uncertainty.

Positions reported in survey records and deliverables shall be recorded in meters, with a precision of at least decimeters. This precision shall be maintained throughout the processing pipeline and digital data.

3.1.2 Vertical Position Uncertainty

This section applies to depths or heights obtained through 3D-positioned surveying. Total allowable vertical uncertainty for reduced soundings is detailed in Section 5.1.3, ”Uncertainty Standards”. There is no intrinsic maximum allowable uncertainty prescribed for vertical positioning accuracy. The hydrographer must account for all of the uncertainties which contribute to the vertical position, and ensure that their combined effect does not cause the total vertical uncertainty for soundings to exceed the allowable limits.

3.2 Differential Global Positioning System (DGPS)

The term differential GPS refers to the general positioning methodology wherein two or more GPS receiver-antenna units are used to position an unknown point relative to a known (control) point or control network. Differential GPS aims to improve upon the positioning accuracy (relative to the control) otherwise attainable in standalone GPS point-positioning methods.

The acronym DGPS refers to the particular technique of differential GPS techniques whereby reference receiver-satellite pseudo range corrections observed at the control point(s) are used to improve the imprecise pseudo range observations made elsewhere in real time. DGPS is the primary horizontal positioning technique used in NOAA hydrographic surveys for nautical charting where meter-level positioning uncertainty is acceptable. DGPS correctors may 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. Differential positioning utilizing Global Navigation Satellite Systems (GNSS) other than the U.S. GPS (e.g. GLONASS) has largely been unused in NOAA hydrographic surveying and requires further investigation, but may be possible for NOAA hydrographic survey work, at the discretion of HSD.

Kinematic GPS (KGPS) refers to the form of differential (mobile) positioning which uses matched GPS carrier-phase measurements to achieve centimeter-level precision in positioning relative to survey control. An Ellipsoidally-Referenced Survey (ERS) is hydrographic surveying using GPS centimeter-level positioning such as KGPS. In contrast to the practice of using DGPS for horizontal positioning of heights and depths measured relative to the in situ water level, ERS hydrography is made with respect to a reference ellipsoid in three dimensions. ERS specifications are discussed in Section 9; the remainder of this section is devoted to DGPS specifically.

3.2.1 DGPS Specifications

Unless specified otherwise in the Hydrographic Survey Project Instructions, 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 uncertainty 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 3.1.1.

3.2.2 DGPS Site Confirmation

If any non-USCG differential reference stations are used (e.g. a ”fly-away” DGPS beacon established by the hydrographer, the Federal Aviation Administration’s Wide Area

Augmentation Service, or commercial satellite-based correction services), the hydrographer shall conduct a certification to ensure that no multipath or other site specific problems exist. The system shall be re-certified annually for each project area in which the non-USCG correctors are utilized.

Certification of non-USCG differential correctors shall be accomplished as follows:

1. Identify a point ashore in close proximity to the project area for which the position is known to at least the THU given in Section 3.1.1
2. Occupy this position with a GPS receiver utilizing the non-USCG correctors for at least 24 hours, logging data at 1-second intervals.
3. Create a plot compare surveyed positions to the known position. Certification is successful if the surveyed and established positions agree to the requirements of Section 3.1.1
4. Include a description of the certification process plots in the Horizontal Control Report for each project (see Section 8.1.5.2)

Additionally, all sources of GPS correctors must be checked periodically while utilized for NOAA hydrographic surveying. Many large scale differential correction systems, such as the USCG differential beacons, FAA WAAS, and commercial services such as C-Nav and Starfire, have integrated 24-hour monitoring and quality assurance, which fulfills this requirement. However, differential beacons or other high accuracy positioning sources established by the hydrographer must be monitored and validated by the survey team. See Section 3.4 below.

3.3 Kinematic GPS

Kinematic GPS (KGPS) refers to the form of differential (mobile) positioning which uses matched GPS carrier-phase measurements to achieve centimeter-level precision in positioning relative to survey control. An Ellipsoidal Referenced Survey (ERS) is hydrographic surveying using GPS centimeter-level positioning such as KGPS. In contrast to the practice of using DGPS for horizontal positioning of heights and depths measured relative to the in situ water level, ERS hydrography is made with respect to a reference ellipsoid in three dimensions. ERS specifications are discussed in Section 9.

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.

3.4 Position Uncertainty Checks for Reference Stations

The positions of all base stations maintained by the hydrographer shall be verified at least once per week while utilized for survey operations. This verification shall typically be performed computing a new position solution for the base station through the National Geodetic Survey Online Positioning User Service (OPUS), and comparing this with the accepted station position (the published position of the reference bench mark or position established at station inception). Differences between the accepted and check positions exceeding the 95% confidence interval shall be investigated and corrected if possible. Alternate methods of verification may be utilized if approved by the Operations Branch or COR as appropriate. The method and results of these position checks shall be included in the Horizontal and Vertical Control Report.

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-based vertical datum requirements for operational support of hydrographic surveys and photogrammetric surveys conducted as part of the NOAA Nautical Charting Program. ERS vertical datum requirements are discussed in Section 9. 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 hydrographic surveys, 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 210 (as of October 2010) 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 a 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. Once these gauges are transmitting data, they will be listed on the hydro hot list by CO-OPs. 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 Hydrographic Survey Project Instructions. 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 COR 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. Preferably, the duration of continuous data acquisition would be a full calendar month which could significantly reduce the error in the datum calculated. 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 ParoScientific 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 a high accuracy pressure sensor (such as the ParoScientific sensor) is installed and 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 GenerationWater 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 4.6.2 for further details about the water level data format specifications.

Close coordination is required between hydrographer and Engineering Division (ED) 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 ED. 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 n 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 Hydrographic Survey 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 (COR), 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 overtime. 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 staff stop shall be measured before the staff is installed and after it is removed and the staff 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 each deployment shall consist of at least 1 hour of observations at a 6 minute interval. The staff-to-gauge observations shall be performed two 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 cannot be performed two 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, which ever is convenient.

The performed staff-to-gauge observations shall be forwarded to CO-OPS ED within 10 business days.

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 table 1 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.

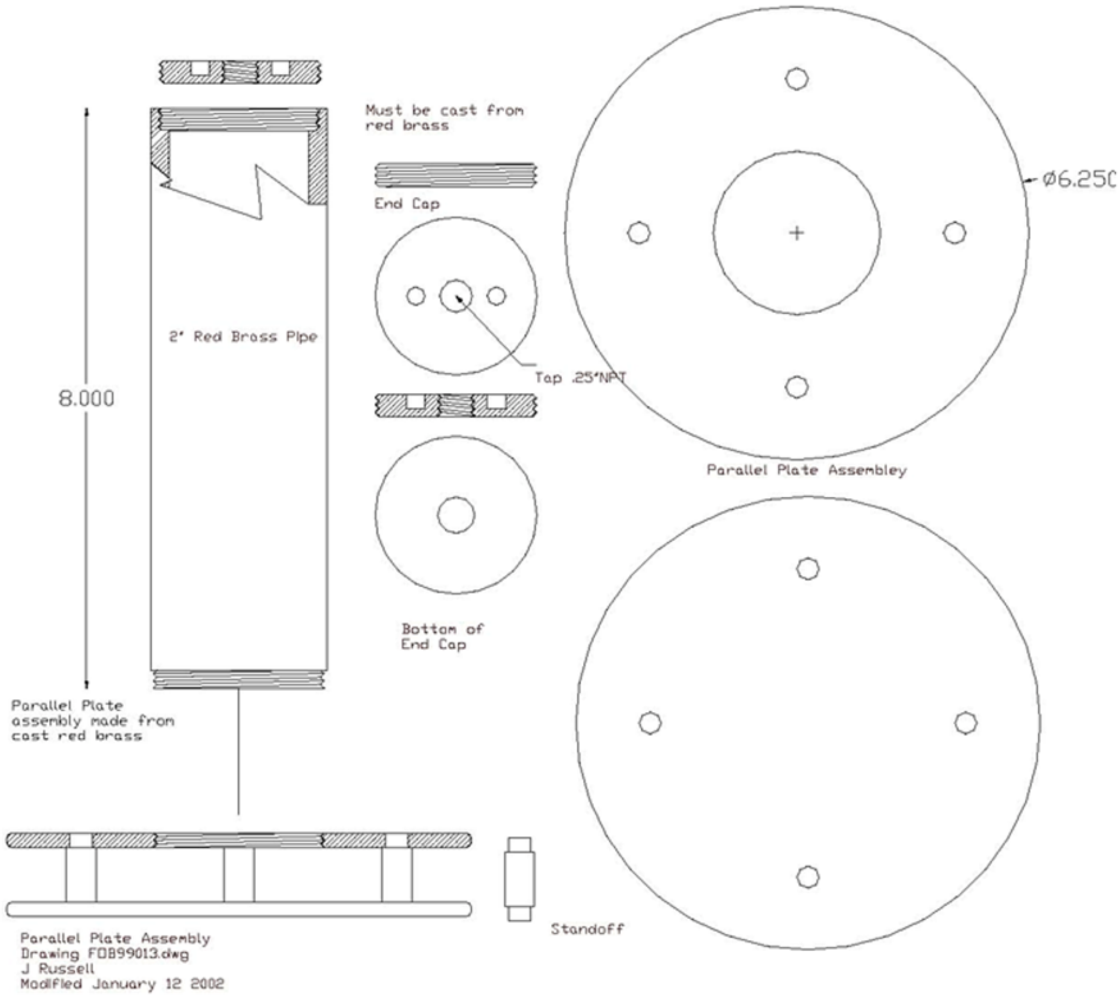

Figure 4.1: Bubbler Orifice Bottom Assembly

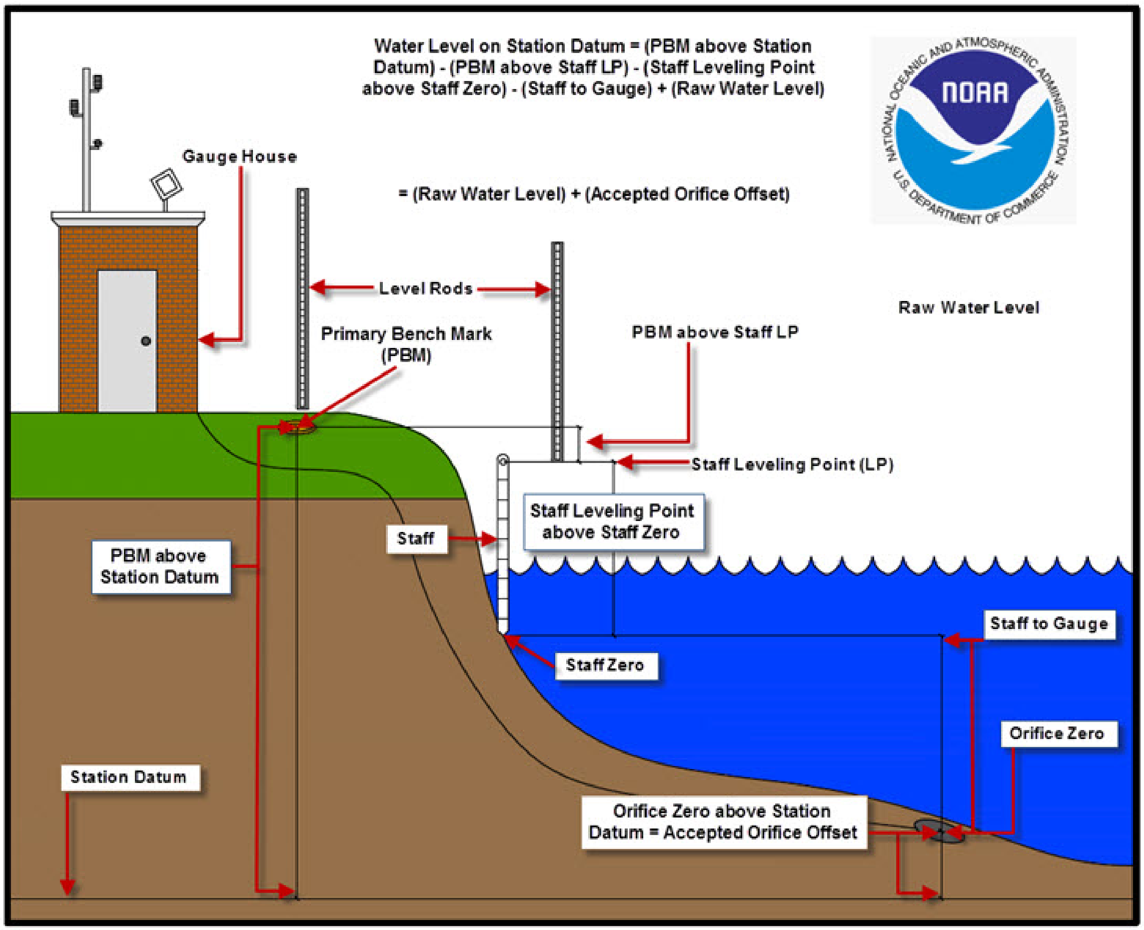

Figure 4.2: Relationship of Station Datum, Orifice and Staff

Pressure Tide Gauge Record

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

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

Table 1: Example Tide Gauge Record

4.2.5 Bench Marks

According to the NGS geodetic glossary, a bench mark is a relatively permanent, natural or artificial, material object bearing a marked point whose elevation above or below an adopted surface (datum) is known. A bench mark is 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.

Unless specified otherwise in the work order or contract documents, the total number of bench marks in the leveling network shall be a minimum of ten marks for the NWLON stations and a minimum of five marks for subordinate stations installed for hydrographic and photogrammetric surveys, special projects, or contract projects for the U. S. Army Corps of Engineers, unless otherwise directed by CO-OPS Engineering Division (ED).

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

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

New bench mark sketches shall use CO-OPS' standard bench mark sketch title block, or electronic equivalent. If a digital sketch is used, submit the digital file in JPEG format with the leveling files and photos. If AutoCAD or AutoCAD LT is used to generate the benchmark sketch, both a JPEG format and the AutoCAD DWG format shall be submitted. Submission of updated bench mark sketches are required only when necessary to document newly established marks or physical changes in the area.

If a bench mark is discovered disturbed or mutilated during the visit to a station, include it in the level run to determine if it is holding its elevation relative to the Primary Bench Mark (PBM) and report it to CO-OPS ED and the supporting FOD field office.

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

4.2.5.1 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, which is available at the following `http://tidesandcurrents.noaa.gov/publications/users_guide_for_installation_of_Bench_Mark.pdf` specifies the installation and documentation requirements for the bench marks. Each water level station will have one bench mark designated as the PBM, which shall be leveled on every run. The PBM is typically the most stable mark in close proximity to the water level measurement station. The surveyor shall select a PBM at sites where the PBM has not already been designated. For historic water level station reoccupations, CO-OPS will furnish the designation/stamping of the PBM and PBM elevation above station datum, 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 User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, Updated December 2009 (or the most recent update of the document) which is available at the following URL for further information: http://www.tidesandcurrents.noaa.gov/publications/Users_Guide_for_GPS_Observations_updated_December_2009.pdf

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 Writing Bench Mark Descriptions, updated January 2011 (http://tidesandcurrents.noaa.gov/publications/bmguide5.pdf).

4.2.5.2 Digital Photographs of the Bench Marks Digital photographs of water level station components (station, DCP, sensors, well, supporting structure, equipment, and bench marks) shall be taken and submitted. GPS photos shall be taken according to the User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, Updated December 2009 (or the most recent update of the document).

A minimum of four photos for each bench mark shall be taken: close-up of the disk face; chest or waist level view of disk and setting; and horizontal views of location of bench mark from two different (perpendicular) cardinal directions. Photos shall also be taken of station components such as protective wells, staffs, houses, shelters, met towers (if applicable), 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 photographs shall be submitted in JPEG format. All digital station photo files should be named such that the name of the file will indicate the station number and the type of photo taken. For example, the acoustic sensor photo for DCP1 at Los Angeles shall be named as 94106601 sensor A1.jpg.

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

All digital station bench mark photo files should be named such that the name of the file will indicate the station number, dash, PID number (if available), dash, stamping or designation, dash, photo type, dash, date, dot.jpg. For a new mark, the PID is not applicable as it is unavailable. Close-up photo vertically taken of the bench mark is photo type 1, eye level photo vertically taken of the bench mark is photo type 2, and the horizontal view taken of the bench mark is photo type 3. For photo type 3 include the cardinal direction (N, NE, S, SE, etc) that the camera is pointing. If there are more than one type of photo is taken then re-name them as 1A, 1B, 2A, 2B, 3A, 3B, etc. If a PID is available, then use designation instead of stamping for the naming of the file. Use a maximum of 30 alpha numeric characters to the left of the dot. So if you are exceeding 30 alpha numeric characters in the name, then truncate the stamping or designation so that maximum characters in the name are 30. For example, the bench mark E close-up photo for Seattle water level station should be named as 9447130-7130E1990-1-20090101.jpg.

Sample file names for photo files

New bench mark without a PID and disk face photo	9414290-4290A2008-1-20090101.jpg
Existing bench mark with a PID and eye level view photo	9410660-DY2512-BM N-2-20090101.jpg
Existing bench mark without a PID and north direction photo	9447130-7130E1990-3N-20090101.jpg

In addition, put a caption for each photograph, indicating the stamping or designation of the mark, PID, photo type with cardinal direction, and the date of photograph taken.

The above naming convention for the bench mark photo files shall be applicable for all of CO-OPS' work and OCS hydrographic surveys.

4.2.5.3 Obtaining and Recording of Positions of Stations, Data Collection Platform, Sensors, and Bench Marks Using a Hand Held GPS Receiver Latitude and longitude of the station, DCP, all sensors, and bench marks shall be recorded using a hand-held GPS receiver and recorded as degrees, minutes, seconds, and tenth of seconds (e.g. 45 degrees, 34 minutes, 32.6 seconds). The positions of the primary and backup DCP (if applicable) and all sensors that are installed in a tide house (gauge house) shall be recorded as that of a station. This position will be obtained in front of the tide house (gauge house) at the center of the front door/front wall of the tide house (gauge house). The front portion of the roof of the tide house (gauge house) may also be used as applicable if the GPS satellites are blocked from the structure. For standalone DCP or met sensors that are 3 m (10 ft) or greater from the station, obtain positions and report appropriately on the Site Report.

For Aquatrak sensors or Paroscientific sensors that are installed 3 m (10 ft) or greater from the station location, obtain the positions of the sensors at the center of the sensor. If the Aquatrak sensor or Paroscientific sensor is installed inside a tide house (gauge house), then report the latitude and longitude as that of the station, but report the elevation above station datum.

For bench marks, obtain positions using the hand-held GPS receiver and placing the receiver on the (horizontal) bench mark. For bench marks that are installed vertically, obtain the position as close to the mark as satellite coverage will allow.

4.2.6 Leveling

At least, geodetic third-order levels (refer to reference 2 in Section 4.7, 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 Hydrographic Survey 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.

4.2.6.1 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 a gauge is in operations for more than 30 days but less than 12 months (b) or if final tides are required, or (c) after 6 months for stations collecting data for long term hydrographic projects.

4.2.6.2 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. If the vertical stability cannot be verified, contact CO-OPS Engineering Division. This threshold of 0.006 m should not be confused with the closure tolerances used for the order and class of leveling.

4.2.7 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 4.6.5.

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.)

4.2.7.1 NOAA Nautical Charts and USCG Quad Maps

NOAA Raster Navigational Charts

The link below provides an interactive map to search for NOAA Raster Navigational Charts. This link will provide Chart numbers which CO-OPS uses on documents such as the station chartlet and published bench mark sheet. `http://www.charts.noaa.gov/InteractiveCatalog/nrnc.shtml#`

USGS Quad NamesThe USGS quad name is required on both the station chartlet and for use on the header of the published bench mark sheet. A digital image of the quad map showing the station location is not required. There is a Google Earth layer which will display USGS Quad names within the US. The only input needed is the latitude and longitude information. It is also listed by states if GPS information is not available. USGS quad maps (7.5 minute x 7.5 minute) can be obtained using this Google Earth layer. See the following link to download the Google Earth layer: http://www.usgsquads.com/index.php/map-indexes/mapfinder

4.2.8 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 bench mark and tide station location sketch, field tide note, Xpert Site report, NGWLMS Site Report or Tide station report.

4.2.9 Geodetic Connections and Datums Relationship

Tidal datums are local vertical datums which may change considerably within a geographic 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 Spatial Reference System (NSRS) and is officially supported by the National Geodetic Survey (NGS) through a network of GPS Continuously Operating Reference Stations (CORS). Elevations can also be referenced to ellipsoid and the current accepted ellipsoid is GRS80.

The relationship of tidal datums to geodetic datums and ellipsoidal datums is needed to support many coastal mapping, hydrographic surveying, VDatum, engineering and oceanographic applications including monitoring sea level changes, surveying on ellipsoid, and the deployment of GPS electronic chart display and information system, etc.

GPS requirements are specified in the latest published edition of CO-OPS “User’s Guide for GPS Observations at Tide and Water Level Stations which is available at http://tidesandcurrents.noaa.gov/pub.html or the specific document at http://tidesandcurrents.

noaa.gov/publications/Users_Guide_for_GPS_Observations_updated_December_2009.pdf. All GPS work shall be done according to this document and the required deliverables shall be submitted as specified.

For Surveying on ellipsoid and Ellipsoidally Referenced Surveys (ERS), select the most stable bench mark that is obstruction free for GPS observations and collect minimum of a 4-hours of GPS observations and submit the data through OPUS and submit the published OPUS datasheet. Where OPUS is not able to provide solutions (e.g. in remote Pacific Islands), provide the data to CO-OPS and CO-OPS will submit the data to NGS and get the solutions through PAGES software. The tidal, geodetic, and ellipsoidal datums connection is required for VDatum modeling and supports coastal applications decision making.

Publish your OPUS solution using http://geodesy.noaa.gov/OPUS with options: publish and the following criteria:

Careful Field Procedures

- 4+ hour GPS data file
- Verify antenna type, height, and plumb
- Fixed height tripod recommended, brace the legs with sandbags or chain

Permanent Mark of Public Interest

- Durable, stable setting, with good satellite visibility
- Description & photos to aid future recovery

High-quality OPUS Solution Involves

- $\geq$ 70% observations used
- $\geq$ 70% ambiguities fixed
- $\leq$ 3 cm RMS
- $\leq$ 4 cm peak-to-peak, lat. & long.
- $\leq$ 8 cm peak-to-peak, ellipsoid height

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 Tides

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 subordinate stations where datum control does not exist, a first reduction datum computation must be used on 30 days of continuous data. 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. A tide by tide datum computation (TBYT) should only be used when a full calendar month of data is not available. Data series of less than a full calendar month may not meet NOS quality control standards, therefore, if data collection is anticipated to be less than a calendar month for logistical reasons survey personnel should notify HSD Ops and CO-OPS at their earliest convenience to determine data utility for survey support. For stations that collect complete months of data a simultaneous comparison of full months (MMSC) must be used for datum computations. Datum computations for data series of a year or more should be computed on complete years of data using MMSC methodology. Datum computations of complete months and complete years reduces error due to any seasonal bias in the data. 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
End:	Jul 14 2005 23:54
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
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          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
```

(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
										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    __________  ____
```

(c)

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

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)

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

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:

TABULATED ____________________

VERIFIED ____________________

(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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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

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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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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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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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 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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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)

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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

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.

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`.

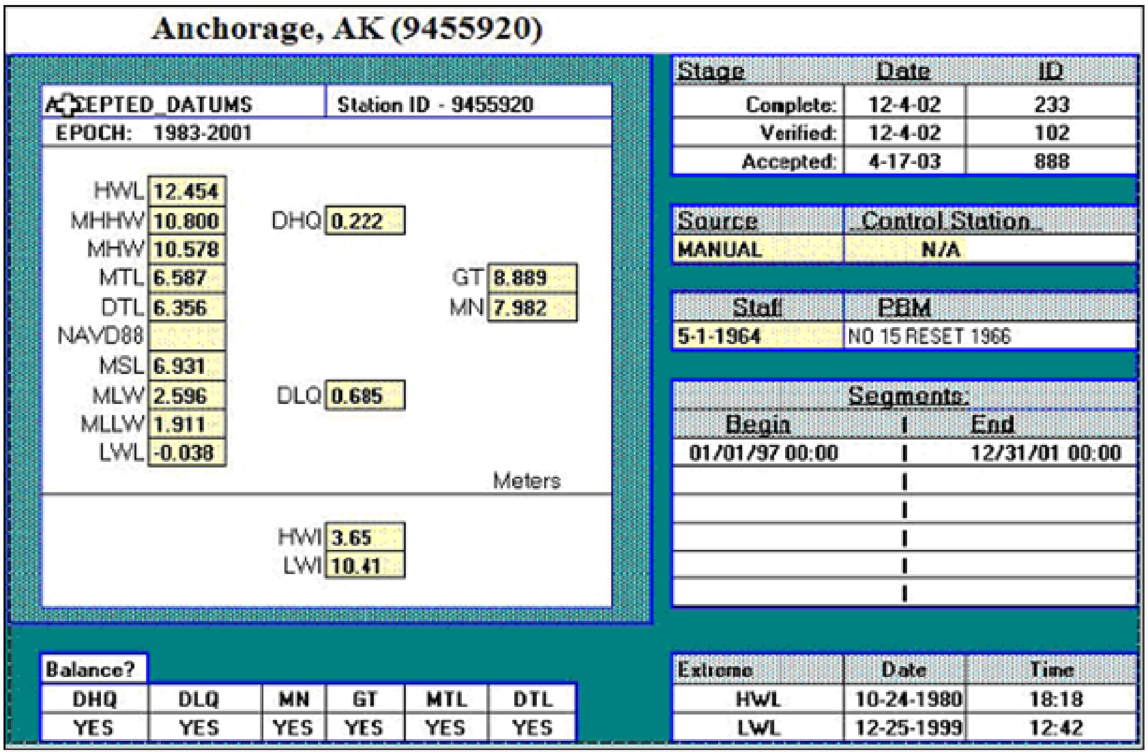


Figure 4.9: Tide Station Summary

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	0.78	2.38	30.11		224H/L,1918	N/A	Anchorage staff		61.233333333	-149.916666667
9455497	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	128H/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,Jun95	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	0.78	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	7.58	N/A	N/A	13.30	0.68	2.23	18.21	60-78	1Mo,Jul78	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	18.4					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	20.78	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	18.22	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	18.5	0.8	2.20	19.50		22H,12L,1910	N/A	Seldovi/1st Red.		60.801666667	-151.776666667
9455787	GRAY CLIFFE	AK	1.95	8.58	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	9.18	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	18.40	41-59	1Mo,Jul75	N/A	Nikiski		60.301666667	-152.385000000

Figure 4.10: GIS Summary Data File

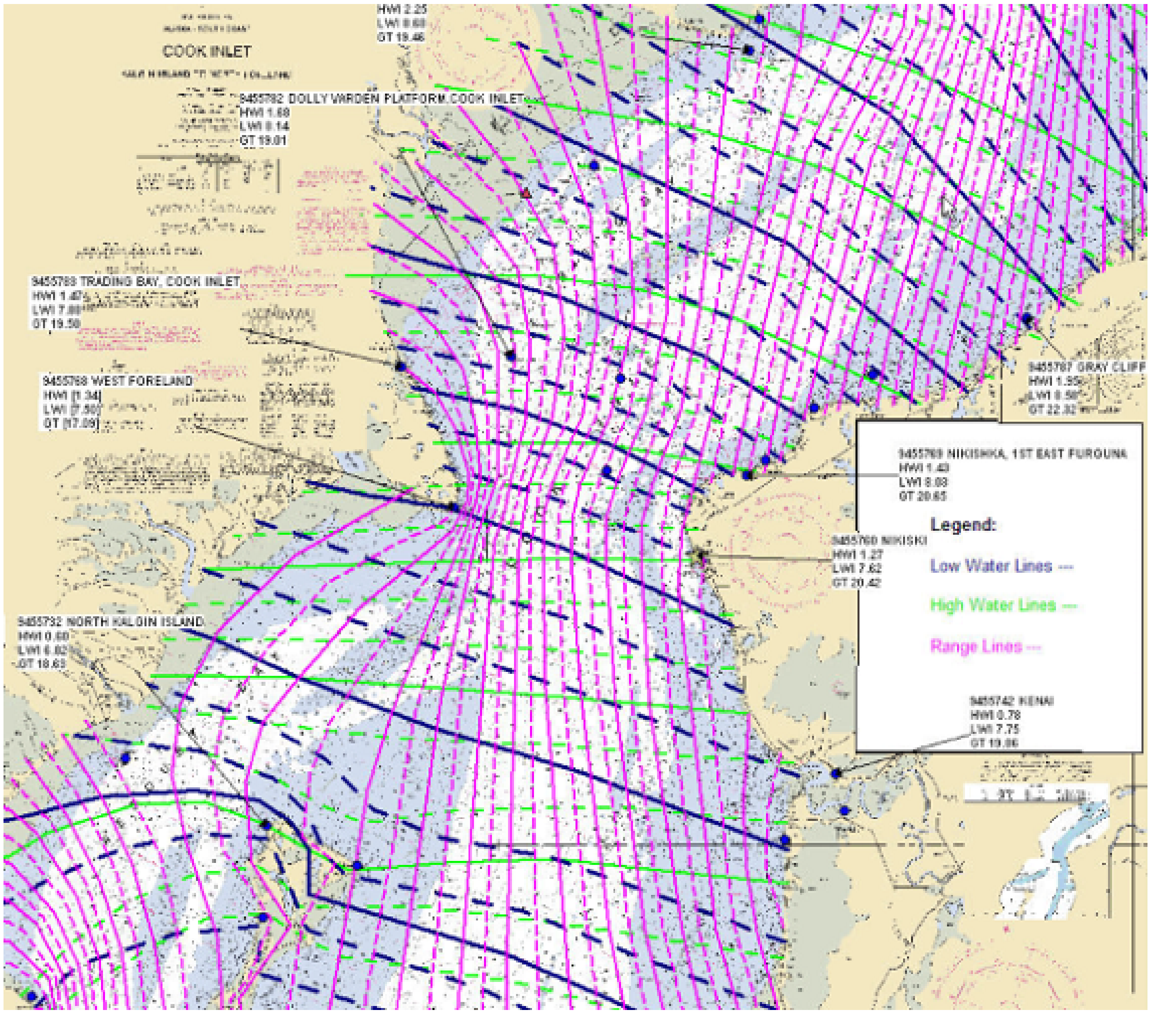


Figure 4.11: Corange Line of Greenwich, High and Low Water Intervals (in hours)

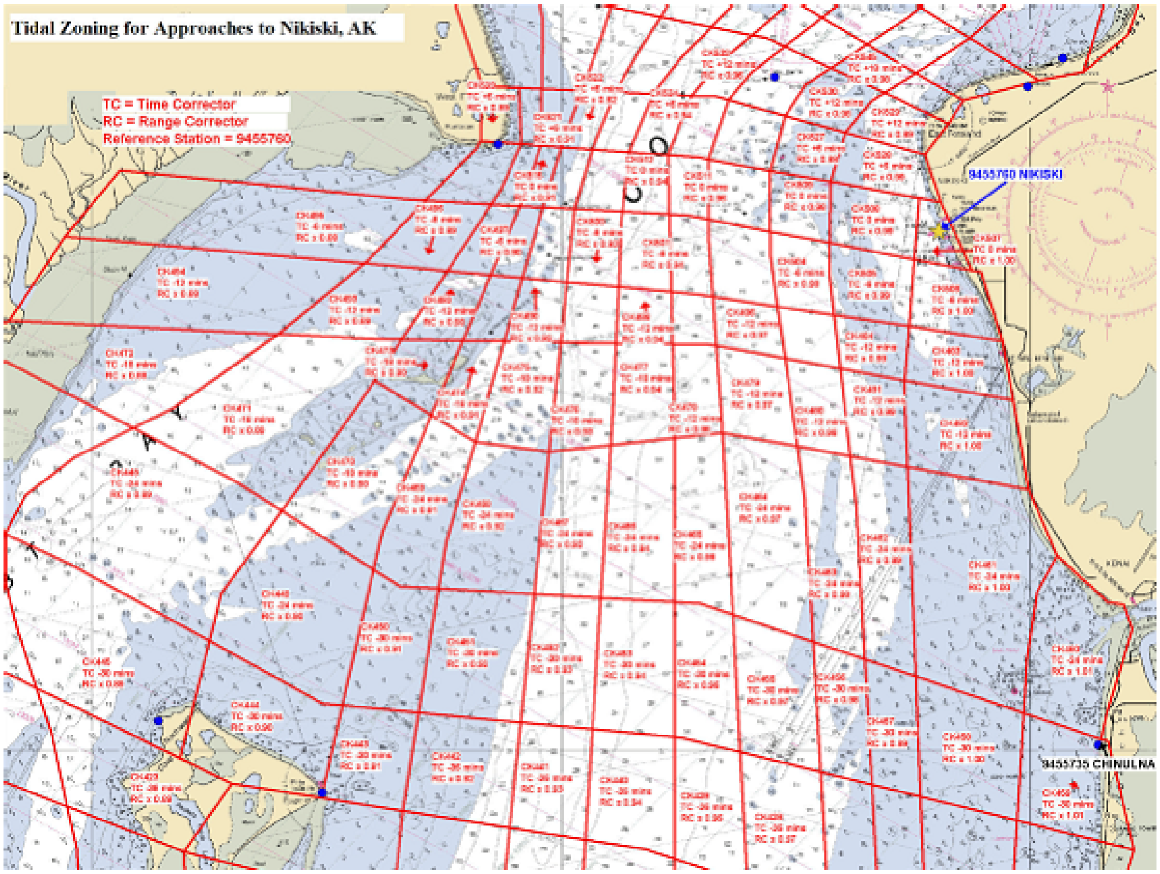


Figure 4.12: Tidal Zoning for Approaches to Nikiski, Alaska

		WL VALUE	WL			quality control flags:	
STATION	DATE/TIME utc	on MLLW meters	SIGMA meters	inferred	flat	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

4.5.4 Tidal Constituents and Residual Interpolation (TCARI)

The Office of Coast Survey (OCS) designed Tidal Constituent and Residual Interpolation (TCARI) for total water levels relative to Mean Lower Low Water (MLLW) at selected hydrographic survey areas along the coast utilizing the spatial interpolation of tidal data. The model spatially interpolates the harmonic constants (used to predict the astronomic tide), tidal datums, and residual water levels (i.e. the non-tidal component or the difference between the astronomically predicted tide and the observed water level) using the values at a combination of operational and historical stations. The method works best in regions where there is an abundance of high quality tidal data surrounding the survey area. The use of TCARI, just as in discrete zoning, requires the oceanographer to evaluate and understand the tidal characteristics of the survey areas. Success in both methods requires that tide stations be in operation during survey operations as well as information from historical tide stations and other sources. Gaps in information limit both methodologies and CO-OPS will not provide revised TCARI grids for surveys conducted while the required tide gauges are not in operation.

TCARI first requires the development of a model grid to cover the survey area. TCARI then requires a spatial field of accepted harmonic constituents from historical stations for the interpolation instead of just the average time and range of tide which tidal zoning requires. Finally, TCARI planning requires an analysis of the non-tidal residual across the survey area to determine the location and number of stations to be in operation during the survey. TCARI grid files, interpolation weighting functions, and harmonic constant files are created during planning and delivered to the survey platform. Survey platforms must obtain the observed data from the specified tide stations during the survey so that TCARI can apply the interpolated water level residuals to the tide reducing process.

CO-OPS makes a decision when to use TCARI for projects based upon available data and other criteria. Currently, TCARI is used for NOAA in-house hydro projects only.

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.

Please refer to the latest copy of CO-OPS' User's Guide for GPS Observations at Tide and Water Level Station Bench Marks. See Section 4.7

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 4.6.5 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. For stations with Aquatrak sensors, provide the Aquatrak Sounding Well Diagram.
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. All required GPS deliverables (OPUS published data sheet and bench mark photos) as specified in CO-OPS ”User’s Guide for GPS Observations at Tide and Water Level Station Bench Marks”

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. Datum Offset Computation Worksheet

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

I. Data Submitted on Diskettes or CD-ROM or DVD

	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. Transmittal Letter

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

K. 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.

II. For the Project:

A. Files

	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.

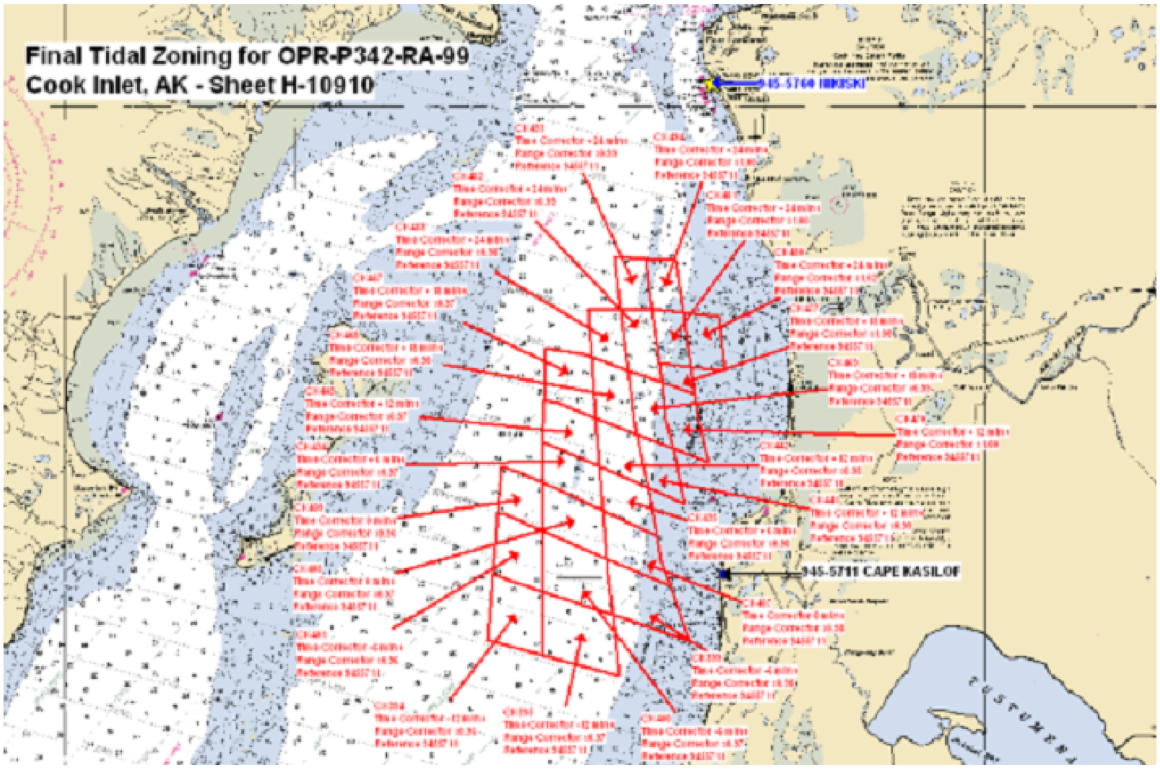
Note 2: Nikiski, AK served as datum control for subordinate tide stations and for tidal zoning in this hydrographic survey. Accepted datums for this station have been updated recently and have changed significantly from previous values.

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)

4.6.2 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 by the contractor for a period of not less than three years after the survey is completed or as stipulated in the contract, whichever is longer. 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.

4.6.3 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
1234567890123456789012345678901234567890123456789012345678901234567890123
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.

4.6.4 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 the final tidal zoning scheme digitally in either MapInfo or ArcView compatible formats and in CARIS compatible format. A 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© formats including geographical presentation of summary data and co-phase/co-range maps, if appropriate
- GIS compatible digital final zoning files
- Final tide reducer data files
- Final Tide Note
- GIS compatible survey outline

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

*If no subordinate water level station was installed, then preliminary tidal zoning may be used as final tidal zoning pending availability of verified water levels and confirmed stability during periods of survey operations at the designated control stations.

4.6.5 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, OPUS published data sheet and bench mark photos (as listed in Section 4.7), and other reports (as listed above in Section 4.6.4) as required , shall be forwarded within 15 business days of the removal of the stations/gauges. Final zoning schemes with methodological documentation shall be submitted within 45 days of the removal of the stations/gauges.

Submit a transmittal letter to the appropriate Contracting Officer's Representative (COR) 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 shall be submitted in digital format. Please refer to Section 4.6.1,4.6.2, 4.6.3, and 4.6.4 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 water level station report
5. Chartlet
6. USGS Quad map
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 4.6.2 and 4.6.3)
22. GPS data and documentation, OPUS published data sheet and 4 photos of GPS bench mark, as applicable per CO-OPS document (reference 8 in Section 4.7).
23. Contractor created summary files, final zoning, final tide reducer data, final tide note, and co-phase, co-range maps, if appropriate, etc. Zoning files must be in in GIS format with all associated metadata included. (Metadata includes but is not limited to water level stations, intervals of tide, ranges of tide, tidal datums, and any other information on which the revised zoning is based. All metadata on which the zoning scheme is based must be included.) If this information is not included, CO-OPS will not be able to validate the zoning. JPEGs, PDFs, or other simple image files are not acceptable.

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/CDROM 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 water level 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, co-phase/co-range maps

Submit one copy of all the documentation, water level data, including OPUS published data sheet and 4 photos of GPS bench mark, final tidal zoning, final tidal reducers, final tide note, etc., in required digital formats.

Submit the completed station package to:

Chief, Engineering and Development Branch
NOAA/NOS/CO-OPS/ED/EDB
SSMC 4, Station # 6507
1305 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 2897 X 190

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.

Most of these documents are available on CO-OPS web site at http://tidesandcurrents.noaa.gov/.

1. Next Generation Water Level Measurement System (NGWLMS) Site Design, P reparation, and Installation Manual, NOAA/NOS, January 1991. http://tidesandcurrents.noaa.gov/publications/NextGenerationWaterLevelMeasurementSystemMANUAL.pdf

2. User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, NOAA/NOS, dated October 1987. http://tidesandcurrents.noaa.gov/publications/users_guide_for_installation_of_Bench_Mark.pdf

3. User's Guide for Writing Bench Marks Descriptions, NOAA/NOS, Updated January 2011 http://tidesandcurrents.noaa.gov/publications/bmguide5.pdf

4. Standing Project Instructions for Coastal and Great Lakes Water Level Stations, Updated February 2011. http://tidesandcurrents.noaa.gov/publications/Standing_Project_Instructions_for_Coastal_and_Great_Lakes_Water_Level_Stations_Updated_August_2011_Final.pdf

5. User's Guide for 8200 Bubbler Gauges, NOAA/NOS, updated February 1998.http://tidesandcurrents.noaa.gov/publications/hy8200bub_manual.pdf

6. User's Guide for 8200 Acoustic Gauges, NOAA/NOS, updated August 1998. http://tidesandcurrents.noaa.gov/publications/hy8200aco_manual.pdf

7. User's Guide for 8210 Bubbler Gauges, NOAA/NOS, updated February 2001. http://tidesandcurrents.noaa.gov/publications/8210_guide.pdf

8. User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, NOAA/NOS, updated December 2009.

http://www.tidesandcurrents.noaa.gov/publications/Users_Guide_for_GPS_Observations_updated_December_2009.pdf

9. Tidal Datums and Their Applications, Special Publication No. CO-OPS 1, NOAA/NOS, June 2000.
http://tidesandcurrents.noaa.gov/publications/tidal_datums_and_their_applications.pdf

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, January 2000. http://tidesandcurrents.noaa.gov/publications/glossary2.pdf

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

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

15. 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.

16. NGWLMS GOES MESSAGE FORMATTING FOR HOURLY TRANSMISSIONS, Phil Libraro, September 2003.
http://www.tidesandcurrents.noaa.gov/publications/newgoes_format.pdf

17. Computational Techniques for Tidal Datums, NOAA Technical Report NOS CO-OPS 2, U.S. Department of Commerce, NOAA, NOS, DRAFT December 1998.
http://tidesandcurrents.noaa.gov/publications/Computational_Techniques_for_Tidal_Datums_handbook.pdf

18. Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, September 1984.
http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.htm#3.5

19. NOAA Technical Memorandum "NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3", November 1997. http://www.ngs.noaa.gov/PUBS_LIB/NGS-58.html

20. Geodetic Leveling, NOAA Manual NOS NGS 3, U.S. Department of Commerce, NOAA, National Ocean Survey, August, 1981. http://www.ngs.noaa.gov/PUBS_LIB/Geodeticleveling_nos_3.pdf

21. Sutron Xpert Operations and Maintenance Manual, October 2006.
http://www.tidesandcurrents.noaa.gov/publications/Xpert_User_Manual.pdf

22. Upgrading an Existing Water Level Station or Installing a New Water Level Station, SOP-3.2.3.5, May 2011. http://tidesandcurrents.noaa.gov/publications/Upgrading_an_Existing_Water_Level_Station_or_Installing_a_New_Water_Level_Station_05102011.pdf

5 Depth Sounding

5.1 General Standards for Depth Values

The requirements of this section shall apply to all depths included in bathymetric data products or feature attribution, regardless of source. Note that some depth sounding systems and processing techniques may produce individual measurements which do not conform to these standards. The hydrographer shall ensure that final depths delivered to NOS are compliant with these specifications.

5.1.1 Definition of Terms

For the purposes of this Section, technical terms will be used as defined in the Glossary of IHO Special Publication 44, 5th Edition.

Additional terms:

- Sounding: A measurement from the sea surface to the seafloor, regardless of method (echosounder, lidar, lead line, diver's least depth gauge, etc.). A "sounding" may be corrected for factors such as sound speed, vessel draft, and water levels, but remains the product of a single measurement sample.
- Depth: A fully processed seabed elevation value relative to an established vertical datum, portrayed in a gridded dataset or product surface of a hydrographic survey. A surveyed "depth" may be computed based on statistical analysis and uncertainty estimates from a sample set of "soundings".
- Depth Value: A generic vertical seabed elevation value, inclusive of "soundings" and "depths".

5.1.2 Units and Rounding

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

Uncertainty estimates for depth soundings and ancillary measurements shall be recorded with sufficient precision to support Total Propagated Uncertainty (TPU) estimates for depth values at centimeter precision.

Depths reported in the Descriptive Report (DR), other reports, or correspondence shall be accompanied with the associated estimate of TPU. Both depth and TPU shall be rounded to the nearest centimeter by standard arithmetic rounding ("round half up"). These values may be accompanied by the equivalent depth value in chart units with NOAA cartographic rounding (0.75 round value) applied if direct comparison with charted depths is required.

5.1.3 Uncertainty Standards

As mentioned in Section 1, these NOS Specifications are partly based on the IHO Standards for Hydrographic Surveys as outlined in Special Publication 44 (S-44), 5th Edition. IHO S-44 specifications are suggested minimum standards that member states may choose to follow. The IHO minimum standards for uncertainty 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 uncertainty of a depth value. These specifications should not be interpreted to imply that NOAA Hydrographic Surveys ”meet” a particular IHO survey order overall.

NOS standards for Total Vertical Uncertainty (TVU) in hydrographic surveys apply to general water depths and least depths 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,lidar, lead line, diver investigation, or other method.

The formula below shall be used to compute the maximum allowable TVU for depths included in bathymetric data products or feature attribution at the 95 percent confidence level, after application of correctors for all systematic and system specific errors:

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

Where:

- a represents that portion of the uncertainty that does not vary with depth

- b is a coefficient which represents that portion of the uncertainty that varies with depth

- (b x d) represents that portion of the uncertain that does vary with depth

- d is the depth

The variables a and b shall be defined as follows:

- In depths less than 100 meters, a = 0.5 meters and b = 0.013 (IHO Order 1)

- In depths greater than 100 meters, a = 1.0 meters and b = 0.023 (IHO Order 2)

The maximum allowable uncertainty in 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).

5.1.4 Resolution and Feature Detection Standards

Bathymetric data resolution and feature detection are functions of the parameters of the sounding equipment, manner in which it is operated, and processing methods. NOS defines resolution and feature detection standards for bathymetric data in terms of the requirements of the final gridded dataset (see Sections 5.2 and 5.3). Regardless of depth measurement technique, the hydrographer shall select and operate depth sounding equipment and process the resulting measurements in a manner adequate to meet these requirements.

5.2 Multibeam and Other Echosounders

Many Hydrographic Survey Project Instructions require the use of multibeam echosounders for NOS Hydrographic Surveys. However, there may be surveys which require single beam or other sonar-based techniques. Therefore, the standards included in this section will be valid for all echosounding data.

Note on Phase Measuring Bathymetric Sonars (PMBS): NOAA's extensive investigation of PMBS systems (also known as interferometric sonars, or Phase Differencing Bathymetric Sonars) has shown that the discrete soundings generated by these systems have unacceptably high uncertainty for use in nautical charting and that available systems are incapable of resolving features to the standards required in this manual. NOAA has also found that statistical processing of these raw data to a gridded depth product is not currently practical due to the exceptionally high sounding density and lack of a validated uncertainty model. Therefore, bathymetry generated from PMBS systems shall not be utilized in products intended to support nautical charts unless specifically authorized by the Chief, NOS Office of Coast Survey Hydrographic Surveys Division.

5.2.1 Gridded Data Specifications

5.2.1.1 Background In the Navigation Surface approach, survey data are archived as a certified digital terrain model rather than as a set of verified soundings. HSD has determined that the highest resolution the data can support 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 other users without needlessly burdening NOAA field units and contractors. The 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 estimate. This requires robust, verified error models for all systems which contribute measurements to the final depth solution. These include not only echosounders, but positioning system, heave, pitch, and roll sensors, sound speed instruments, tide gauges, static and dynamic draft measurements, and anything else that contributes to the calculation of a depth value. Once this comprehensive error model is assembled, the uncertainties in each measurement be propagated from the measurement platform to each individual sounding. Only when each sounding has an associated Total Propagated Uncertainty can we combine the soundings into a Navigation Surface with depth and uncertainty attributes for each node.

The open source Bathymetric Attributed Grid (BAG) format was developed as 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`.

5.2.1.2 General Requirement Management of Multiple Grids

This section defines grid resolution, feature detection, and coverage specifications as a function of depth and survey requirement. Many surveys will cover a sufficiently wide range of depths and echosounder properties to require bathymetric data at several different resolutions. Currently, the BAG standard supports only single-resolution grids. The CARIS Bathymetry with Associated Statistical Error (BASE) surface has variable-resolution functionality; however, it is not presently approved for NOAA surveys. Therefore, the hydrographer is required to create and manage individual grids for each required depth/resolution band.

The hydrographer will adjust the extents and number of grids based on the bathymetry of the survey area, feature detection requirements, the type of echosounder 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.

Multiple Echosounding Sources in a Single or Multiple Grids

In cases where multiple echosounding sources (e.g., vertical beam and multibeam) are used to cover a survey area, the NOAA processing branches generally expect that different grids will be created for different system types (i.e. vertical beam echosounders or multibeam echosounders). The exception to this is for crossline data; where main scheme and cross line system types differ, the resulting data will be submitted in a single grid provided doing so will not reduce the resolution of the strictest resolution requirement. In those cases where there is vast disparity between the coverage type and/or resolution of the different sounding sources (e.g., vertical beam main scheme soundings with scattered high resolution multibeam feature developments, or a mix of multibeam echosounders with varying specifications), multiple device-specific grids may be required. See Section 5.2.2.3 for additional guidance, and consult with the Operations Branch or COR if necessary.

Feature Detection and Designated Soundings

The hydrographer shall choose grid resolution(s) adequate to capture and portray the minimum required feature size as given in Section 5.2.2. This requires that the hydrographer conduct a pre-survey assessment of the survey area to determine the characteristic size of the navigationally significant features likely to be encountered and select grid resolution(s) accordingly. A grid must sample the seafloor at a spatial period of at least half the characteristic size of the smallest feature required to appear in the grid (e.g., detection and portrayal of a 2 meter cube would require a grid with resolution no coarser than 1 meter).

The hydrographer has the responsibility to review the surface and ensure that it truly reflects the conditions in the survey area. Even in cases where the appropriate resolution was selected, it is possible that the grid may fail to portray some navigationally significant depths. In some survey areas, the hydrographer may also detect navigationally significant features (e.g., submerged piles or wrecks in high traffic waters) which fall below the minimum detection threshold established by the Hydrographic Survey Project Instructions and Section 5.2.2. An experienced hydrographer must, therefore, review the data and may occasionally select “designated” soundings which override the gridded surface and force the model to recognize the shoal sounding.

The following criteria shall guide the selection of designated soundings:

- Depth 20 meters and less: A designated sounding may be selected when the difference between the gridded surface and reliable shoaler sounding(s) is more than one-half the maximum allowable TVU at that depth.
- Depths greater than 20 meters: A designated sounding may be selected when the difference between the gridded surface and reliable shoaler sounding(s) is more than the maximum allowable TVU at that depth.
- Survey Scale: When the distance between two depths is less than 2mm at the scale of survey (20m for 1:10,000 scale) then only the shoalest depth shall be designated.

The hydrographer shall always consider navigational significance before designating a sounding. For instance, a rock on a steep slope need not be designated if depths from the slope above the rock would make the rock insignificant at survey scale.

If the hydrographer finds that a large number of designated soundings are necessary to adequately portray the survey area for navigational use, a higher grid resolution may be required. The hydrographer may increase the resolution beyond that specified in Section 5.2.2 for small areas of the survey to increase grid accuracy and data processing efficiency. If large areas of higher resolution are required, the hydrographer shall consult with HSD Operations Branch (in-house surveys) or COR (contract surveys) for guidance.

Soundings on features that would not be charted with a depth shall not be designated. Examples include a pier face, a piling that is above MHW or an anchor chain in the water column for an operational buoy on station.

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 most significant shoalest features as required by the navigational use of the area and the scale of the survey.

Conversely, if noisy data, or ‘fliers’ are incorporated into the gridded solution, the surface may be shoaler than the true seafloor. If these spurious soundings cause the gridded surface to be shoaler than the reliably measured seabed by greater than the maximum allowable TVU at that depth, the noisy data shall be rejected and the surface recomputed.

Attribution

By definition each node of the grid includes not only a depth value, but other attributes. The following minimum attributes shall be associated with each grid node:

- Depth Value
- Total Vertical Uncertainty: The uncertainty value for the grid node shall be the greater of the standard deviation of the soundings contributing to the depth solution, and the a priori computed uncertainty estimate. 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.

The following additional attributes shall be included if supported by the hydrographer's data processing software:

- Shoal Depth: Depth value of the shoalest measurement which contributed to the depth solution
- Sounding Density: Number of soundings contributing to the depth solution
- Standard Deviation: Standard deviation of the depths within the capture radius of the node

5.2.2 Coverage and Resolution

In general, there are three classifications of bathymetric coverage: Object Detection Coverage, Complete Coverage and Set Line Spacing. Object Detection and Complete Coverage are 100% bathymetric bottom coverage methods, and therefore attainable only with multibeam sonars. (Note that 200% side scan sonar coverage with set line spacing bathymetry is also a valid 100% bottom coverage technique, although not full bathymetric coverage.) Set Line Spacing may be accomplished by single beam or multibeam, as specified in the Hydrographic Survey Project Instructions. The required survey coverage classification will be specified in the Hydrographic Survey Project Instructions. Field operations shall be conducted such that the accuracy requirements in Sections 5.1.3 and 5.1.4 are met for the entire coverage.

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 Hydrographic Survey 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, a separate single beam surface is required.

These requirements shall be followed by contractors unless stated otherwise in the Hydrographic Survey Project Instructions or an exemption is approved by the COR. 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 and either AHB or PHB, as appropriate. Approval for deviations shall be included in the Descriptive Report Appendices.

Specific requirements of each coverage classification are given below in Sections 5.2.2.1, 5.2.2.2, and 5.2.2.3, The experienced hydrographer will use discretion in following this guidance. If the requirements of the grid for an area do not seem appropriate, the hydrographer should notify HSD or the appropriate COR to discuss alternate gridding resolutions. This 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 may serve no purpose. Also, object detection coverage gridding specifications may not be necessary in 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 method).

5.2.2.1 Object Detection Coverage

- Detect and include in the grid bathymetry all significant features measuring at least 1m x 1m x 1m in waters up to 20 meters, and a cube measuring 5% of the depth in waters greater than 20 meters.
- Grid resolution shall be 0.5m in waters up to 20 meters, 1m in depths greater than 19 meters and not greater than 5% of the water depth in waters 40 meters and deeper.
- At least 95% of all nodes on the surface shall be populated, with at least 5 soundings.
- The maximum propagation distance shall be no more than the grid resolution divided by $\sqrt{2}$.
- For depths up to 30m no holiday spanning more than 3 nodes; for depths deeper than 30m, hydrographer’s discretion shall be used so long as no other requirements are violated, notwithstanding any violation of other coverage requirements.
- No holidays over tops of potentially significant features.
- The following grid-resolution thresholds as a function of depth range; shall be used unless an exception is approved as described in Section 5.2.2. Object detect coverage is rarely needed in depths greater than 30m. All final submitted grids shall include the grid coverage within the specified depth ranges as lsited below. In cases of steep slopes, the overlap between object detection grids of different resolutions may need to be increased to prevent gaps in their junction. In these cases, the courser resolution grid should have its shoaler extent modified to prevent this coverage gap (e.g. change 1 meter resolution depth range to 17- 40 meters).

Depth Range (m)	Resolution (m)
0-20	0.5
19-40	1

5.2.2.2 Complete Multibeam Coverage

- Detect and include in the grid bathymetry all significant features measuring 2m x 2m horizontally, and 1m vertically in waters up to 20 meters. Detect features measuring 10% of depth horizontally and approximately 5% vertically in waters deeper than 20m.

- Grid resolution shall be 1m in waters 20 meters or less, 2m in waters greater than 18 meters and not greater than 40 meters, 4m in waters greater than 36 meters and not greater than 80 meters, 8m in waters greater than 72 meters and not greater than 160 meters, 16m in waters greater than 144 meters and not greater than 320 meters, and 5% of the water depth in waters greater than 320 meters not to exceed 32m resolution.
- Courser resolutions may be warranted in certain areas due to bottom topography ”steep and deep”, or if concurrent side scan data is also collected, or other project specific reasons.
- At least 95% of all nodes on the surface shall be populated, with at least 5 soundings.
- The maximum propagation distance shall be no more than the grid resolution divided by $\sqrt{2}$.
- For depths up to 30m no holiday spanning more than 3 nodes; for depths deeper than 30m, hydrographer’s discretion shall be used so long as no other requirements are violated, 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 have designated soundings from a beam within 30 degrees of nadir unless multiple passes were made over the feature.
- The following grid-resolution thresholds as a function of depth range shall be used unless an exception is approved as described in Section 5.2.2. All final submitted grids shall include only the grid coverage within the specified depth ranges as listed below. In cases of steep slopes, the overlap between complete multibeam coverage grids of different resolutions may need to be increased to prevent gaps in their junction. In these cases, the courser resolution grid should have its shoaler extent modified to prevent this coverage gap (e.g. change 2 meter resolution depth range to 16 - 40 meters).

Depth Range (m)	Resolution (m)
0-20	1
18-40	2
36-80	4
72-160	8
144-320	16

5.2.2.3 Set Line Spacing The hydrographer shall conduct multibeam and/or single beam sounding at the line spacing specified in the Hydrographic Survey Project Instructions. For example, set line spacing may be employed in the following scenarios: (1) when acquiring bathymetry concurrently with side scan sonar operations (referred to set line spacing), where the side scan swath is wider than the bathymetric swath), or (2) when acquiring bathymetric data in areas too shallow for efficient full bottom coverage bathymetry or too hazardous for use of multibeam equipment.

Specific notes on Set Line Spacing coverage requirements:

1. Multibeam sonar Set Line Spacing coverage:

- Grid resolution shall be 2m in waters 20 meters or less deep, 4m in depths greater than 16 meters and not greater than 40 meters, and follow the resolution specifications for complete multibeam coverage for depths greater than 40 meters.
- At least 95% of all nodes on the surface shall be populated, with at least 3 soundings.
- The maximum propagation distance shall be no more than the grid resolution divided by $\sqrt{2}$.
- Continuous along-track coverage is required. No gap in the entire multibeam swath may be greater than 3 nodes along track.
- All significant shoals or features found in waters less than 30m deep shall be developed to Object Detection standards.
- The following grid-resolution thresholds as a function of depth range shall be used unless an exception is approved as described in Section 5.2.2. In cases of steep slopes, the overlap between Set Line Spacing multibeam coverage grids shall include only the grid coverage within the specified depth ranges as listed below.

Depth Range (m)	Resolution (m)
0-20	2
16-40	4

2. Single beam sonar Set Line Spacing coverage: There are three possible scenarios for delivery of single beam sonar data:

    - If the single beam data is acquired incidental to Complete or Object Detection multibeam coverage, and is not the primary sounding technique of the survey (e.g., nearshore single beam echosounding for NALL definition), the resulting soundings shall be processed and delivered as separate grids from other sounding sources (i.e. multibeam echosounder).
    - If single beam data is the primary means of bathymetric coverage for a survey (e.g. Set Line Spacing) soundings for survey specified for 200% side scan sonar coverage), single beam echosoundings shall be gridded at 4 meter resolution regardless of depth. Note that any multibeam echosounder data acquired incidental to the main scheme single beam soundings (e.g., developments of features) shall be processed, gridded, and delivered according to the appropriate full bathymetric bottom coverage specification above.if employed as general bathymetry 5.2.2.2. Or, if this multibeam echosounder data was acquired specifically for feature development, then the gridding resolution should follow the object detection specifications 5.2.2.2.
    - In rare instances, NOAA may require that single beam sounding resolution be scaled with depth. This will be specified in the Hydrographic Survey Project Instructions or other communication from the Operations Branch or COR. In these cases, grid resolution shall be between 20 and 40% of depth.

Notes on Set Line Spacing coverage with Single Beam:

- Due to the potentially sparser sounding sets produced by single beam echosounders, statistical methods for estimating depth (such as CUBE or CARIS Uncertainty Weighted Grids) yield less certain results with single beam than multibeam. Thus, NOAA requires that all single beam sounding sets be fully “cleaned” (e.g., all “fliers” and other erroneous soundings removed) prior to creation of gridded bathymetric products and that grids be computed with a “shoal” layer.

- In some cases, bathymetric coverage in a single survey may be subdivided into separate areas of single beam and multibeam coverage. In these instances, separate grids shall be delivered as discussed above. Contact the Operations Branch or COR for any clarification required.
- Splits: "Splits" are additional sounding lines run between main scheme lines in a Set Line Spacing scenario. Splits shall be acquired for both multibeam and single beam hydrography to adequately define shoals or significant deeps indicated between main scheme lines, and to verify currently-charted depths that are shoaler than any adjacent echosounder coverage. If a charted depth falls between 2 sounding lines and is shoaler than the adjacent survey depths, the field unit must "split" the lines to verify or disprove the charted sounding.

5.2.3 Corrections to Echo Soundings and Uncertainty Assessment

To meet the accuracy and resolution standards specified in Section 5.1.3, and to create a BAG that includes an accurate uncertainty layer, the hydrographer must 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. For example the error model for CARIS contains uncertainties associated with the sensor and sonar, physical offsets, latency, draft, loading, sound speed and zoned water levels (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.

An important distinction exists between such corrections to echo soundings measured relative to the in situ water level (discussed above), to that of 3-D positioning of echo soundings relative to an ellipsoid as is done in ERS hydrography (Section 9). In ERS, the KGPS height uncertainty of the survey platform encompasses the otherwise individual correctors associated with draft and heave. Additionally, the uncertainty associated with zoned water levels is replaced by uncertainties present in the vertical datum transformation.

In recognition of the possibility that some discrepancies in soundings 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.

5.2.3.1 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 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.

5.2.3.2 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 planing.

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 by the hydrographer at least once a year to at least 0.05 meter precision 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.

5.2.3.3 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 5.1.3 are met, speed of sound observations should be taken with sufficient frequency, density, and accuracy. The certainty at which the speed of sound can be determined is a complex function of the measurement of salinity, temperature and depth, or alternately, sound speed and depth.

Sound Speed values derived from Conductivity, Temperature, and Depth measurements shall be calculated using the Chen-Millero equation. Use of Wilson's equation is no longer authorized.

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 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 during the service life of the instrument while in operational support of OCS hydrographic survey operations. In addition, the instrument(s) must be recalibrated when they are removed from operations or at the end of their service life if the 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).

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 5.1.3 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.

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 8.1.4).

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 leg. Include confidence check results in Separate II, Sound Speed Profile Data (see Section 8.1.4).

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 echosounding, 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. If the surface sound speed sensor value differs by 2 m/s or more from the commensurate cast data, another sound speed cast shall be acquired. Any deviations from this requirement will be documented in the descriptive report.
- Sound speed profiles shall be acquired within the survey limits 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.

5.2.3.4 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 Kinematic GPS shall compensate for squat if attitude is not corrected for single beam.

5.2.3.5 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, 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).

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.

5.2.3.6 Uncertainty Budget Analysis for Depths The hydrographer shall discuss (in Section B.2 of the Descriptive Report) the methods used to minimize the uncertainty associated with the determination of depth (corrections to echo soundings). A sample of uncertainty components and common values are presented below. These uncertainties are inherent to hydrographic surveying and all have practical minimums that are usually achievable only under ideal circumstances or with highly specialized equipment. The survey system uncertainty components and key survey system component offsets shall then be used to calculate the depth uncertainty estimate for the soundings per the Total Propagated Uncertainty Model.

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

The uncertainty component values provided below are estimates to allow hydrographers to get a basic “feel” for the possible uncertainty values that may occur in practice. The values discussed below are at the 68% confidence level (i.e. 1 sigma).

Motion Sensor Uncertainties: These values include heave, pitch and roll measurement uncertainties and can include gyro measurement uncertainty. A common value for gyro, pitch and roll measurement uncertainty is 0.02°. A common value for heave uncertainty is 5% of the heave amplitude or 0.05m, whichever is greater.

Navigation Sensor Uncertainty: This value includes the uncertainty in the determination of the vessels position. This value will depend on the method of positioning used (C/A. DGPS, PPK/RTK) and is commonly reported at 1m.

Timing Uncertainty: These values include the uncertainty in the measurement of time stamps used in the survey system and include Navigation Sensor timing, Gyro Sensor timing, Heave Sensor timing, Pitch Sensor timing and Roll Sensor timing. A commonly reported value for this is between 0.005 and 0.01 seconds.

Vessel Offsets: These values include the uncertainty in the measurements made to determine the survey system offsets. Ranges will depend on how accurately the offsets were measured but are commonly reported between 0.001m and 0.1m.

Vessel Speed: This value includes the uncertainty in the measurement of vessel speed. It is commonly reported as 0.03m/s plus the average current in the area.

Loading: This value includes the uncertainty in draft changes throughout the survey due to factors such as fuel consumption, etc. Commonly reported values range between 1 and 30cm, depending on the vessel, fueling frequency and frequency of draft measurements.

Draft: This value includes the uncertainty in measurement of draft. Commonly reported values range between 1 and 20cm depending on how accurately the draft of the vessel can be measured.

Delta Draft: This value includes the uncertainty of the vessels dynamic draft measurements. Commonly reported values are between 1 and 3cm depending on dynamic draft measurement methodology and magnitude.

MRU Alignment: This value includes the uncertainties in the patch test determined bias measurements of yaw, roll and pitch. Commonly reported values are less than 1°.

Tides: This value includes the uncertainties in the measurement of tides and the uncertainty of the tide zone model. Tidal uncertainties have been discussed in detail in Section 4.1.6.

Sound speed: This value includes the uncertainties in the measurement of sound speed for full depth profiles and surface measurements. The factors associated with this uncertainty estimate 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. Commonly reported values range between 0.3 and 4m/s.

5.2.4 Quality Control

5.2.4.1 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 (yaw). Deviations from this order or other variations on the accepted calibration methods shall be explained in the project documentation

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 ensonified 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 (yaw) 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.

5.2.4.2 Positioning System Confidence Checks See Sections 3.2.2 for details.

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 soundings and positions. Crosslines shall be run across all planned sounding lines at angles of 45 to 90 degrees.

Crosslines shall be acquired and processed to the same accuracy and data quality standards as required for mainscheme lines, and shall be included in the grids that are submitted as the final bathymetric product of the survey.

Crossline requirements are dependent on bathymetric coverage type assigned and achieved by the field unit, Section 5.2.2.

- Set Line Spacing: Lineal mileage of crosslines shall be at least 8% of main scheme mileage in areas surveyed with set line spacing coverage using single beam or multibeam echosounders. This applies for mixed main scheme and crossline techniques, i.e. single beam main scheme with multibeam crosslines or vice versa.
- Object Detection or Complete: Lineal mileage of crosslines shall be at least 4% of main scheme mileage in areas surveyed to meet object detection or complete bathymetric coverage requirements.

The primary purpose of crosslines in a set line spacing coverage area, is to identify systematic errors and blunders in the surveying system. Discrepancies between main scheme and crossline coverage indicate potential systematic errors in offsets, biases, or correctors or the application thereof, faulty positioning or echosounder operation, or other issues. The hydrographer shall compare main scheme and crossline coverage to identify, evaluate, and rectify any such errors.

Crosslines are not the primary means of identifying systematic errors and blunders in multibeam echosounder data used to achieve 100% bathymetric bottom coverage. Most such issues are more readily and reliably identified in the bathymetric grid through examination of depth values and ancillary attributes such as uncertainty and standard deviation. However, crosslines in an object detection or complete bathymetric coverage do provide an additional semi-independent check for spatial and temporal correlation of the data set across the range of area, time, seabed relief and bottom types, survey vessels, and sonar systems represented. For this analysis to be valid, crosslines must be acquired with the same attention to accuracy and data quality as mainscheme data. Whenever possible, crosslines should be acquired under different conditions (vessel, sonar system, tide state, etc.) than main scheme data.

Two possible methods of conducting the independent analysis are beam by beam statistical analysis or 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 COR or or servicing Hydrographic Branch. Regardless of method, the comparison shall be performed at the same resolution as the final survey product as required in Section 5.3.2.

Analysis and Documentation: The hydrographer shall evaluate each area of overlapping crossline and mainscheme coverage to ensure that at least 95% of depth values from the two datasets differ by no more than the maximum allowable TVU for the depth of the comparison area (as specified in Section 5.1.3). Any deviations from this standard shall be investigated, and the source of error identified and corrected. If unexplained or excessive discrepancies persist, additional crosslines shall be re-acquired to assist in resolution of the issue.

The hydrographer shall evaluate crossline to mainscheme agreement, and discuss the method and results in Section B of the Descriptive Report. If the magnitude of any discrepancies varies widely over the survey, the hydrographer shall make a quantitative evaluation of the disagreements area by area. If differences were found to be within the allowable maximum TVU, the hydrographer shall note this. Conversely, any errors identified through crossline analysis and the means by which they were corrected shall be discussed.

5.3 Lidar

5.3.1 Accuracy and Resolution Standards

All requirements outlined in Section 5.1 to bathymetric lidar data products and feature attribution. For project specific guidance the hydrographer shall refer to the Hydrographic Survey Project Instructions

5.3.1.1 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 dependent 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 the specified spatial resolution was obtained.

5.3.1.2 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. For lidar bathymetry, the archived elevation model should 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 alternative approach may be discussed with the COR 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. Refer to Section 5.2.1 for more guidance. See also Section 8.2 for guidance on delineating and characterizing rocky seabed areas.

The data density and resulting grid resolutions created shall be discussed with the COR during the project planning phase. Any deviations from the plan, project instructions or Specifications and Deliverables shall be discussed with the COR 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 5.2.1.2 for more guidance. See also Section 8.2 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 computed uncertainty estimate. 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.

The Navigation Surface for lidar requires that each sounding have a horizontal and vertical uncertainty. 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. See Section 5.1.3 for additional guidance.

5.3.2 Coverage and Resolution

In general, there are two classifications of bathymetric lidar coverage: Complete and Reconnaissance coverage.

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

Complete Coverage requires a minimum of 200% coverage, a minimum laser spot spacing of 4 meters, and conforms to the depth accuracy standards outlined in Section 5.1. In situations where poor water clarity and related environmental factors make complete coverage impossible the COR shall be notified. In addition the hydrographer shall identify (textually and graphically) those areas where full coverage was not obtained and/or further investigation using sonar may be required.

Reconnaissance coverage refers to range of coverage overlap and laser spot spacing requirements below the minimum specified for Complete coverage. Data products and feature information produced under Reconnaissance requirements are used to obtain general bathymetry for applications other than nautical charting (e.g. navigational safety, operational planning, and research). The Hydrographic Survey Project Instructions will identify if a given surveys is for reconnaissance purposes and the hydrographer shall indicate the requirement in the Descriptive Report.

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 3.1.1 or do not meet the Vertical Uncertainty standards as defined in Section 5.1.3, 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 COR as they occur.

Attribution

By definition each node of the grid includes not only a depth value, but other attributes. The following minimum attributes shall be associated with each grid node

- Depth Value
- Total Vertical Uncertainty: The uncertainty value for the grid node shall be the greater of the standard deviation of the soundings contributing to the depth solution, and the a priori computed uncertainty estimate. 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.
- Shoal Depth: Depth value of the shoalest measurement which contributed to the depth solution.
- Sounding Density: Number of soundings contributing to the depth solution.
- Standard Deviation: Standard deviation of the depths within the capture radius of the node.

5.3.3 Corrections to Lidar Soundings

To meet the accuracy and resolution standards for measured depths specified in Section 5.2.3, and to create a Bathymetric Attributed Grid (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.

5.3.3.1 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 main scheme 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.

5.3.4 Quality Control

5.3.4.1 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, reconfigurations, 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 5.2.3.

5.3.4.2 Positioning System Confidence Checks See Sections 3.2.2 for details.

5.3.4.3 Lidar 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 soundings and positions. Crosslines shall be run across all planned sounding lines at angles of 45 to 90 degrees.

Crosslines shall be acquired and processed to the same accuracy and data quality standards as required for mainscheme lines and shall be included in the grids that are submitted as the final bathymetric product of the survey. Lineal of crosslines shall be at least 8 % of main scheme mileage in areas requiring complete coverage (refer to 5.3.4.3)

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 COR and explained in the Descriptive Report.

The hydrographer shall make a general evaluation of the lidar crossline to main scheme 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.

An independent analysis of the crossline and main scheme data shall be conducted. Although any crossline/main scheme 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 to meet object detection requirements. The use of side scan sonar to meet object detection requirements does not alleviate the responsibility of the hydrographer to investigate features or acquire splits as discussed in Sections 5.2.2.2 or 5.2.2.3. Any requirement for side scan sonar coverage in conjunction with a hydrographic survey will be specified in the Hydrographic Survey Project Instructions.

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. 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.

See Section 5.2.2.3 for information on Set Line Spacing and bathymetry.

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.

In areas with excessive bathymetry variability or when hull mounted systems are used, the hydrographer shall ensure that coverage and object detection are met. When the towfish height has exceeded the maximum threshold, either the hydrographer needs to take extra care in examining the data for contacts with reduced shadow lengths or re-acquire the data at an appropriate depth. Likewise if the minimum towfish height is not met, additional lines (or splits) may be required to meet coverage requirements.

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.

All significant contacts identified shall be developed with a multibeam echosounder using the object detection coverage grid resolution defined in Section 5.2.2.1, to determine the least depth of the feature. The least depth measurement should be determined from a beam within 30 degrees of nadir unless multiple passes were made over the feature. When a significant contact is correlated to multibeam data acquired concurrently with side scan sonar operations, the feature shall be developed further if the correlating sounding is sourced from one of the multibeam system’s outer beams.

If a significant contact must be developed by a single beam echosounder, dive investigations shall be used to determine the feature’s depth with a diver’s least depth gauge when it is practical. The shoaler depth of the two methods shall be used for feature’s reported depth. A dive investigation may be conducted to supplement data from a multibeam echosounder development.

When multiple significant contacts are located during the first 100% side scan coverage of an area, the hydrographer may determine that is more efficient to survey the area completely with the multibeam echosounder rather than survey the second 100% and develop each significant contact individually. In this case the hydrographer shall meet the requirement for object detection stated in Section 5.2.2

In areas where the water depth and the size of the area containing multiple significant contacts make this approach prohibitive an alternative gridding method may be used. Once 200% coverage has been achieved and all contacts correlated, the hydrographer may divide the area into 400 square meter investigation cells and develop the most significant contact in each investigation cell. If the developed feature's measured height off the bottom is significantly less that the contact height from the sonar record and is less than the next most significant contact height in the grid cell the hydrographer shall develop the next most significant contact.

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

The character of the bottom shall be determined for nautical charting, particularly in harbors, designated anchorages, and in all other areas where vessels may anchor. In addition to furnishing information for selecting anchorages, charted bottom characteristics assist fisherman in selecting areas where fish may be found while avoiding places where equipment may be damaged.

In general, sampling the surface sediment layer is usually adequate to define the bottom characteristics for charting. Clamshell bottom snappers or similar type grab samplers should be used to obtain as large a sample as possible. If a more detailed study of the ocean floor is required the project instructions will specify the type of sampler to use.

When a field unit is assigned to conduct bottom samples, the field unit should review the bottom sample plan provided within the Hydrographic Survey Project Instructions to the survey data acquired. The field unit should contact HSD Operations Branch or COR to discuss modifying the bottom sample plan if the data suggest more appropriate locations for the bottom samples. The survey data will often better differentiate varying bottom characteristics within the survey area when compared to the sample plan provided. This may increase or decrease the sample density but should closely maintain the same numbers of samples per survey as originally assigned.

In areas where bottom samples are not required but where the general trend of the newly surveyed depths has changed significantly since prior surveys, the field unit shall contact HSD Operations Branch or COR as appropriate to determining if bottom samples are necessary and to define the sample density.

When sampling is required, the hydrographer shall record position for each sample obtained. In addition, each sample shall be described and completely attributed in the S-57 feature file. Refer to section 8.2 for more detailed guidance on S-57 attribution of bottom samples. A complete description of a bottom sample consists of: one adjective describing the grain size or consistency; one adjective designating the color; and one noun naming the class of bottom material. If the sample consists almost entirely of one constituent, only one noun shall be used. If the sample consists of two or more constituents, the nouns for the primary constituents shall be used and arranged in order of their predominance. For example, if a sample of fine black sand contains a smaller portion of broken shells and a couple of pebbles, the bottom characteristic shall be recorded as follows:

fne bk S brk Sh

Sediments are typed according to the size of the particles. Table 1, located in Appendix J, is a general guide for classification of sands and courser particles. It is not intended that the dimension be measured. A careful estimation by eye is satisfactory. Technically there are two classes of material finer than sand. These are silt and clay. For practical purposes, silt and clay are classified under the general term of, mud.

Consistencies of bottoms determined by feeling with lead line or sounding pole (without visual examination of the material) should usually be described as “hard” or “soft”. The term “rocky” may be used only when it is known positively that the bottom is bedrock or consists of material larger than gravel, although a specimen was not obtained for examination. “Rock” is only used when solid rock or a rock ledge is visible to the hydrographer.

The return of an empty sampler is not a sufficient reason to label the bottom as “hard or “soft”. If repeated tries for a grab sample fail, negative samples still need to be addressed in the DR. They will not, however, be added to the S-57 feature file. These samples must be addressed in the DR for evidence of the attempts as assigned in the project instructions.

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 8.1.3 Danger 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 (NOAA and contractor field units) and the Field Procedures Manual (NOAA field units only).

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.

All NOAA field units (in-house and contract) shall adhere to the hydrographic survey report naming conventions. The standard naming convention for survey report digital files submitted to and handled by HSD shall be named as follows:

Descriptive Reports:

- Main Body (Sections A through D) in MS Word format:
  - Format: <Survey Registry Number>_DRBody.docx
  - Example: "H12345_DRBody.docx"
- Full Report (Cover Sheet, Title Sheet, Sections A through E, and Appendices) in Portable Document Format (PDF):
  - Format: <Survey Registry Number>_DR.pdf
  - Example: "H12345_DR.pdf"
- Separates:
  - Format: <Survey Registry Number>_Separates.pdf
  - Example: "H12345_Separates.pdf"
- Data Acquisition and Processing Reports:
  - Format: <Project Number>_DAPR.pdf
  - Example: "OPR-A123-KR-10_DAPR.pdf"
- Horizontal and Vertical Control Reports:
  - Format: <Project Number>_HVCR.pdf
  - "OPR-A123-KR-10_HVCR.pdf"

In rare instances it may be necessary for a field unit to submit a revised version on a hydrographic survey report. This occurs most often when the DAPR submitted with the first survey of a long project (as required in Section 8.1.5.1) does not include all information required for later surveys.

Field units shall take all practical steps possible to avoid revision and resubmission of reports. However, when revisions are necessary, the following guidance shall apply:

- The revised report shall fully supersede all previous versions

  - For example, if a DAPR is submitted with the first survey of a project, and subsequently revised for the second survey, the revised DAPR shall apply to both surveys and replace the original submission

- Revised reports shall be identified by inclusion of a revision number in the name as follows:
  - Format: <Report Base Name>_rev<revision number>.<suffix>
  - Examples:
    * "OPR-A123-KR-10_DAPR_rev1.pdf" (the first of the DAPR for OPR-A123-KE-10; fully supersedes "OPR-A123-KR-10_DAPR.pdf"
    * "H12345_DRBody_rev2.docx" (the second revision of the DR Body file for H12345; fully supersedes "H12345_DRBody_rev1.docx" and "H12345_DRBody.docx")

8.1.1 Progress Report

The hydrographer shall report Monthly Survey Progress digitally via email as one Excel file to progress.sketches@noaa.gov in accordance with the guidance below by the fifth day of the month following survey operations. To assist in the submission of this information, HSD Operations Branch will provide each ship and contractor with a Monthly Report Excel file with separate tabs as indicated below. See example (Figure I.1) in Appendix I. Note that the final Progress Report spreadsheet shall also be included with the final survey deliverables in Separates II of the Descriptive Report (see Section 8.1.4).

a. Survey Progress Estimate – This will be used to track estimated monthly survey progress by area within a given month. It will be a spreadsheet that consists of rows showing the vessel's current project and all associated survey sheets. Column titles are self-explanatory. For each month that data is acquired on a survey sheet (as well as sheets that are still incomplete) the cumulative percentage completed through the end of that month should be entered in the spreadsheet. Any modifications to the initial survey sheet layout must be reported.

b. Project Statistics – This will be used to track monthly statistics other than square nautical miles. Since each row of the spreadsheet represents a specific project within a given month, the field is advised to maintain one sheet for the entire fiscal year and submit the updated version every month. 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 the number of AWOIS items or newly discovered items that require extra survey time.

- “Tide Gauges Installed/Removed” and “Bottom Samples” are the only other stats needed from NOAA survey vessels.
- Contractors are still required to report Days at Sea (on site working on the project) and days (or fraction of days) lost due to weather or equipment malfunction.

c. Vessel Utilization – This is a requirement for NOAA vessels only. Refer to the OCS Field Procedures Manual, section 5.2.3.2.1 for details.

8.1.2 Survey Outline

After completion of all field work for a given survey sheet, the hydrographer shall provide a survey outline in a MapInfo compatible format, Latitude/Longitude coordinate system, NAD 83, that shows the extent of hydrography completed for the registered survey (e.g. H number). This outline shall bound the extent of continuous survey data judged by the hydrographer to be adequate to supersede the chart. Along shore, the survey outline shall be coincident with the NALL as surveyed in accordance with the Hydrographic Survey Project Instructions and Section 1 of this document.

Careful attention should be paid in the near shore area to ensure that features and bathymetry inshore of the NALL are not included. The survey outline need not include all discrete features contained in the S-57 feature file deliverable (i.e. a rocky area or ledge may extend inshore of the survey outline). Also, the Survey Outline should not inscribe high water features positioned inshore of the NALL (e.g., Aids to Navigation).

The only two exceptions to this are coverage acquired pursuant to investigation of assigned AWOIS items, which should be inscribed by the Survey Outline, and LIDAR surveys. The survey outline for a LIDAR survey shall be coincident with the MHW.

The final survey outline shall normally be a single, completely enclosed polygon bounding the final surveyed area as described above. In cases where this area includes an unsurveyed region (e.g., an island), the survey outline file will also include an interior limit (i.e., ’donut hole’) following the NALL around this area. In cases where the survey includes a detached surveyed area (e.g., an assigned AWOIS item with a search radius that does not intersect the main body of the survey), the final survey outline file shall include a separate polygon for the detached area.

The final survey outline should be compiled in ESRI Shapefile, MapInfo TAB or GML format. These files shall be attributed with the following metadata:

Attribute	Description	Examples
Survey	Registry number assigned in Project Instructions	”H12345”
Platform	NOAA Field Unit or Contractor assigned to the survey	”NRT-3” ”NOAA Ship Rainer” ”SAIC”
State	Standard two letter abbreviation of the state(s) or territory in whose waters the survey falls. For those surveys outside state waters, the state or territory most closely adjacent to the survey area.	”MD”, ”MD, VA”
Scale	Survey scale as assigned in Project Instructions	”1:10,000”
Year	Year field work is completed	
Survey Type	Lidar hydrographic survey (”Lidar”) or traditional vessel-based hydrographic survey (”Hydro”)	”Lidar”, ”Hydro”
MB cov	Completed only for surveys performed primarily with full bottom coverage multibeam sonar. Left blank for other coverage types	”MB”
SS cov	Completed only for surveys performed primarily with full bottom coverage side scan sonar. Left blank for other coverage types	”SS”

Final survey outlines shall be submitted via email survey.outlines@noaa.gov. Contract field units shall cc their assigned COR on this submission. NOAA field units shall reference Section 5.2.3.3.3 of the OCS Field Procedures Manual for additional guidance. Note that the Survey Outline shall also be included with the final survey deliverables in Separates II of the Descriptive Report (see Section 8.1.4).

The final survey 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 COR to explain the delay and provide an estimate for delivery. Any large differences (± 10%) between the total square miles reported via the Survey Progress Report for the survey and the area defined by the survey outline should be explained in the cover e-mail. Email the outline to survey.outlines@noaa.gov.

8.1.3 Danger to Navigation

As soon as practicable after discovery, the hydrographer shall submit a Danger to Navigation. 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 reported.

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 and poses an imminent danger to the mariner. 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, 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.

When surveying a USACE maintained channel, the hydrographer shall conduct a comparison of survey depths with the controlling depths, tabulated depths, reported depths, and with the DRVAL1 found in the ENC's DRGARE of all maintained channels. When survey soundings or obstructions located in the channel are found to be shoaler than the controlling depth of that channel then the hydrographer shall immediately report these results to the COR or project manager. The COR or project manager will inform the NOAA Navigation Manager, who will to address the issue with the USACE, USCG and communicate the findings to the local Pilots. The field unit shall document this correspondence in section D of the DR for the affected survey. Copies of all correspondences shall be place in DR Appendix II.

Dangers to Navigation shall be recommended 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

Note on DTONs in Uncharted Areas: If there are no charted depths in the survey area, consult with the HSD Operations Branch or COR as appropriate to develop DTON selection criteria appropriate to the navigational use of the area.

Once all dangers to navigation 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.

Dangers that are too complex to be adequately identified as discrete features shall be depicted as area features. For example, widespread shoaling would be represented as a selection of the shoalest depths with a selection interval of 3mm at the largest scale.

NOAA field units shall submit all Dangers to Navigation via e-mail directly to Marine Chart Division's (MCD) Nautical Data Branch at e-mail address ocs.ndb@noaa.gov, with courtesy copies to chief, Operations Branch and to the chief of the appropriate Processing Branch, in accordance with Section 4.4.3.6 of the OCS Field Procedures Manual.

NOAA field unit DTON recommendations shall be submitted as follows using Pydro software:

1. A PDF 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’.
    - Data shall follow the format:
        - Latitude - decimal degrees to seven decimal places (XX.XXXXXXX)
        - Longitude - decimal degrees to seven decimal places (-XX.XXXXXXX)
        - Depth - metric to three decimal places (XX.XXX)
        - Feature - Text description (e.g. 34 ft. Wreck)
        - Date and Time - YYYY MM DD HH MM
    - ASCII Format:
        - XX.XXXXXXX -XX.XXXXXXX DD.DDD Remark YYYY MM DD HH MM SS
        - e.g. 38.0740331 -76.4294391 10.412 Wreck 2010 07 03 12 38 41A chartlet showing the DTON on the largest scale chart of the area.
3. A chartlet showing the DTON on the largest scale chart of the area.
4. Screen captures of Side Scan Sonar or Multibeam image of the DTON.

Contractors shall submit all Dangers to Navigation via e-mail to the COR and ACOR at processing branch stated in the Hydrographic Survey Project Instructions.

Contractor DTON recommendations shall be submitted as follows:

1. An S-57 .000 feature file attributed in accordance with section 8.2 S-57 Soundings and Features Deliverables. In addition to the following NOAA attributes shall be populated as follows:
    (a) Special Feature Type (sftype)=DTON
    (b) Images (images) shall include associated images such as chartlets, Multibeam and side scan imagery of the danger (see AppendixF).
    (c) Primary/Secondary Flag (prmsec)=Primary

The ACOR will review the DTON .000 feature file, import the .000 file into Pydro, and create the .xml file (ACOR’s should see Section 4.4.3.6 of the OCS Field Procedures Manual for more information). A letter and .xml file will then be forwarded to the Nautical Data Branch at ocs.ndb@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. Within three days of DTON report submission, MCD’s Nautical Data Branch (NDB) will send an email to the field unit (NOAA in-house surveys) or the originating Hydrographic Branch and associated contractor and COR (contract surveys) confirming that DTON data has been received and released from NDB to the Production Team. If a DTON submission is not confirmed by NDB within one week, the hydrographer should promptly contact MCD (via an inquiry email to (ocs.ndb@noaa.gov) to verify that the report has been received and released from NDB to the Production Team. 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.

NOAA field units shall include a copy of the DTON verification e-mail from NDB (e.g. DREG registration e-mail) in Appendix II Supplemental Survey Records and Correspondence of the DR. See Descriptive Report Appendices below. DTON features shall remain in the .000 Final Feature File.

Contractors shall include the DTON features in the .000 Final Feature File.

8.1.3.1 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.

8.1.4 Descriptive Report (DR)

A Descriptive Report is required for each hydrographic survey completed, unless specified otherwise in the Hydrographic Survey Project Instructions.

NOAA field units shall submit an XML Descriptive Report in addition to the requirements below. Contractors may be required to submit XML Descriptive Reports in the future.

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.

TITLE SHEET (NOAA Form 77-28, see Figure C.1 in final Progress Report and Survey Outline)

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. The DR shall be submitted electronically in both Microsoft Word and Adobe PDF format as described below:

Microsoft Word: Submit the main body of the DR (Sections A through D) in a single Microsoft Word file.

Adobe PDF: Submit the entire Report (Cover Sheet, Title Sheet, Sections A through E, and Appendices in a single PDF file. Section E of the Report shall be digitally signed in accordance with Section 8.1.4 of the document.)

All 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
- Lineal nautical miles of multibeam only sounding lines
- Lineal nautical miles of lidar sounding lines
- Lineal nautical miles of side scan sonar only lines
- 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

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, AWOIS and newly discovered features, that required additional time/effort in the field beyond the above survey operations (these shall include dive operations and detached positions 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). Note: These dates should reflect the days of work for the referenced survey only, not the total project.

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 8.1.5.1 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 5.3.4.3for additional information.

Discuss the uncertainty values of the submitted CARIS generated surfaces (uncertainty or CUBE) and/or BAG(s). Explain and/or justify any areas that have an uncertainty greater than the IHO levels allowed as described in Section 5.3.2and 5.2.2.

Evaluate survey junctions in this section and ensure continuity in survey coverage. 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 generated surfaces (uncertainty or CUBE) 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 8.1.5 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 of the largest scale corresponding bathymetric products available (e.g. Electronic Navigational 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, edition date, dates of the most recent Local Notice to Mariners and Notice to Mariners. In addition, Notices to Mariners affecting the survey area which were issued subsequent to the date of the Hydrographic Survey Project Instructions 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.

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.

A general chart comparison between survey depths and charted soundings should be conducted. Discuss the methods used for the chart comparison in sufficient detail to demonstrate that the chart comparison was accomplished adequately. A method for accomplishing this is a comparison between the digital surfaces generated from the survey data and the largest scale 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. Charted soundings that contain the label PA, ED, PD, or Rep (see Chart No. 1 for definitions.), not specifically assigned as an Automated Wreck and Obstruction Information System (AWOIS) item shall be discussed in this section. Detailed evaluation of every charted sounding is not required.

All new and charted features not specifically assigned as an AWOIS item or addressed as a DTON, discovered or investigated in this survey, shall be documented and discussed as defined in section 8.2.

A Composite Source File (CSF), in .000 format incorporating the NOAA Extended Attributes defined in Section 8.2, shall be provided by HSD Ops along with the project instruction to assist the contractor or NOAA field unit with this requirement. The CSF will be generated from the largest scale ENC(s) covering project area and assigned surveys and will contain all S-57 features within the bounds of the project area. All features in this file should be updated based on the results of the survey. Near shore features that lie outside the assigned project area may be included in this file and assigned to the field unit to be addressed as part of the project requirements. New features should be added to this file and all features in this file shall be attributed as directed in Section 8.2. This updated file shall be submitted as the Final Feature File (FFF).

AWOIS and Maritime Boundary points may be assigned for the project. Assigned AWOIS items shall be verified or disproved following the requirements within the AWOIS item to the extent of the assigned AWOIS radius.

Briefly describe assigned AWOIS items investigated by single beam or multibeam echosounder, side scan sonar, divers, and/or other methods in this section. If any official salvage documentation is obtained by the field unit that would warrant the removal of a feature from the chart without further field investigation it shall be discussed in this section and the salvage documentation shall be place in Appendix II. Refer to any Danger to Navigation Reports submitted for this survey. A negative statement is required if no Danger to Navigation Reports were submitted.

Assigned Maritime Boundary points shall be verified by determining the existence of the furthest offshore feature that is dry at MLLW. No further verification for defining the MLLW is required once the furthest offshore feature that is dry at the MLLW is determined. The accuracy for maritime boundary points should meet the minimum horizontal position accuracy requirement set forth in Section 3. If the assigned maritime boundary point is not found or is not dry at MLLW, then the next furthest offshore feature that is dry at MLLW shall be verified. The hydrographer shall not extend their maritime boundary point search outside of their assigned survey limits. The hydrographer shall use the existing baseline points (located in the PRF) and Baseline Analysis.doc to support maritime boundary point determination.

AWOIS and Maritime Boundary real world points (e.g. rocks, wrecks, and obstructions) in the FFF shall be attributed with NOAA Extended Attribute sftype=AWOIS or Maritime Boundary respectively.

The source of the charted feature should be listed if known. Describe the condition and distinguishing characteristics of all items mentioned. 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. This information shall be provided in the NOAA attributions remarks and recommendations.

D.2 Additional Results

If specified in the Hydrographic Survey Project Instructions, 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 COR (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.

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 5.2.3.3.1 of the OCS Field Procedures Manual for additional guidance on the content of DR Appendices.

I. TIDES AND WATER LEVELS

Include the following (if applicable):

Contractors;

- Field Tide Note (see Section 4.2.2)
- Final Tide Note to include the final tidal zoning and final tide reducers used to reduce the data to chart datum
- 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 transmittal letter for project water level data submitted to CO-OPS
- Any other correspondence directly relating to tides and/or water levels

NOAA Field Units;

- Field Tide Note (see Section 4.2.2)
- Final Tide Note (see Section 4.5.3). If Final zoning and approved water levels were applied by the field unit, include the Final Tide Note in the DR Append V. The Final Tide Note is the letter provided by COOPS.
- 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

II. 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). NOAA field units shall also include the DTON verification e-mail from NDB (e.g. DREG registration e-mail). 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 shall be submitted with each survey. The Separates shall be submitted as an Adobe Acrobat file in a digital format and reside in the Separates folder as noted in Appendix L. NOAA units should refer to section 5.2.3.3.1 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. DIGITAL DATA

Crossline Comparisons

Include the summary plot analysis as a function of beam number if conducted for the main scheme/crossline intersections as required in Section 5.2.4.3 and 5.3.4.3 if applicable. Include any other crossline quality reports required by Hydrographic Survey Project Instructions.

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. SIDE SCAN CONTACT LISTING

Include the side scan contact listing of significant contacts in a manner which allows the Processing Branch to easily review and correlate specific contacts with other supporting data sets.

8.1.5 Descriptive Report Supplemental Reports

8.1.5.1 Data Acquisition and Processing Report For NOAA field units, the Data Acquisition and Processing Report (DAPR) is an annual report that shall be submitted before, or not later than, the submission of the first survey of the field season. 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. NOAA field units shall issue subsequent DAPR versions upon effecting a significant change to any item(s) retained in the report. For Contractors, the DAPR is a project-wide report that shall be submitted before, or not later than, the submission of the first survey of the project. The DAPR shall be sent to the COR and appropriate Processing Branch specified in the Hydrographic Survey Project Instructions with each survey.

The DAPR is separated into three sections: Equipment, Quality Control and Corrections to Echo Soundings. These sections shall contain a detailed discussion on the information addressed below

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

Include a cover sheet which contains the following general information:

Cover Sheet. Include the survey year, field unit/contractor, Chief of Party/Lead Hydrographer, date and version (see Figure G.1 in Appendix 7).

A. Equipment

Describe the major operational systems used to acquire survey data or control survey operations. Include the manufacturer, firmware version, model number and serial number of all equipment. Indicate how the equipment was used, as well as any operational settings. If applicable, indicate most recent calibrations and accuracy checks. Include a description of the vessel(s) used to acquire survey data.

Specifically discuss echo sounding and lidar systems and operations in this section, as well as other depth determination systems such as diver depth gauges, lead lines, sounding poles, etc. Include discussion of system specifications (e.g., range scales, number of beams, resolution and along track coverage) and indicate most recent system calibrations and accuracy checks. State whether correctors were determined and describe any nonstandard procedures used.

Discuss the computer hardware and software used for all data acquisition and processing, and provide a complete list of all software versions and dates.

B. Quality Control

Describe all data acquisition and processing methods, procedures, and parameters used.

Specifically discuss data processing routines for converting raw sounding data to the final bathymetric grid deliverables. Attach processing flow diagrams. Include a description of the methodology used to maintain data integrity, from raw sounding data to final soundings. Any methods used to derive final depths, such as cleaning filters, sounding suppression parameters, data decimation parameters, gridding parameters, and surface computation algorithms, shall be fully documented and described in this section. Discuss how the surface computation methodology (e.g., radius of propagation, uncertainty weighting, etc.) is consistent with object detection requirements.

Discuss the methods used to minimize the errors and uncertainties associated with depth determination, and provide details of how total propagated uncertainty (TPU) is computed for each sounding (see Section 5.2.3.5 (multibeam) or 5.3.1.2 for multibeam and lidar, respectively). 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 data should be noted and a description of processing procedures should be provided. Include the methods used for establishing proof of swath coverage and the criteria used for selecting contacts. Additionally, include a brief description of how the review of side scan sonar data meets object detection and accuracy requirements as per Section 6.2. 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 across track 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. 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, and layback. Include pictures or figures of the equipment as installed on board
- Static and dynamic draft measurements
- Roll, pitch and heading biases and navigation timing errors. State the manufacturer, model, accuracy, and resolution of positioning and attitude sensor(s). Discuss accuracy and alignment test procedures and results. Include copies of system alignment, accuracy and calibration reports
- All sound speed data applied to echo soundings, including sound speed profiles and surface sound speed measurements
- 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.

Data Acquisition and Processing Report Appendices. The Appendices shall be submitted as a separate Adobe Acrobat file from the DAPR and in a digital format only.

1. Vessel Reports: Include vessel offset reports, vessel layback reports, and dynamic draft reports.
2. Echosounder Reports: Include echosounder system accuracy test ("confidence check") and system alignment test ("patch test") reports. Additionally, include data processing flow diagrams. If applicable, include manufacturer calibration reports.
3. Positioning and Attitude System Reports: Include positioning and attitude sensor calibration reports (e.g. GAMS calibration report) and system configuration reports (e.g. POS/MV configuration report).
4. Sound Speed Sensor Report: Include sound speed calibration reports.

8.1.5.2 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 which contain the following general information:

- Cover Sheet - Include the type of survey(s), state, general locality, year and months, project number, 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.
- 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 Soundings and Features Deliverables

Features shall be attributed using the International Hydrographic Organization (IHO) Special Publication 57 (IHO S-57), the IHO Transfer Standard for Digital Hydrographic Data (current version is edition 3.1.2). 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`

A Composite Source File (CSF) and Project Reference File (PRF) shall be provided with the Hydrographic Survey Project Instructions. In addition, a Prior Survey Feature File (PRI) may be provided with the Project Instructions. The CSF is an S-57 attributed dataset in .000 format and compiled from the largest scale ENC and/or preliminary ENCs. All ”Assigned” (asgnmt attribute) features from HSD OPS or the COR in CSF shall be verified.

The PRF is an S-57 attributed dataset containing reference layers such as survey limits, junctions, and recommended bottom sample locations and features which are specifically targeted for investigation such as AWOIS points or Maritime Boundary points.

The PRF feature are represented by the following S-57 feature objects:

REFERENCE FEATURE	S-57 OBJECTS	DESCRIPTION
AWOIS Points	CRANES	AWOIS investigation items
AWOIS Radii	ACHBRT	AWOIS search radius
Maritime Boundary	CRANES	Maritime Boundary investigation items
Survey Limits	TESARE	Outline survey limits
Junctions Limits	TWRTPT	Outline of junction survey
Bottom Samples	SPRING	Recommended bottom sample locations
Lidar Investigation	BUAARE	Placeholder indicating features recommended for field verification
Lidar Junction Line	FNCLNE	Line denoting extent of verified Lidar coverage

The PRF features are described with the following S-57 and NOAA extended attributes:

REFERENCE FEATURES	ATTRIBUTION	DESCRIPTION
AWOIS	asgnmt	Assigned or For Info Only
	dbkyid	Record number
	invreq	Type, Item status, Search type, Technique
	radius	AWOIS radius search
	sftype	AWOIS
	TXTDSC	AWOIS History in a .txt file
Maritime Boundary	asgnmt	Assigned or For Info Only
	invreq	Description of requirements
	sftype	Maritime Boundary
Survey Limits	invreq	Survey, Priority, Name
Junctions	invreq	Survey, Platform, Year, Scale
Bottom Samples	asgnmt	Assigned
	invreq	Description of requirements

The prior survey features are provided in MapInfo and S-57 format. The prior survey features are for reference only and do not need to be verified in the field. The S-57 file (PRI) contains features such as rocks, wrecks, and obstructions. The MapInfo files contain one file with the features and one file with the soundings.

All ”Assigned” CSF features shall be delivered in a Final Feature File (FFF) in S-57 .000 format. Each FFF shall be broken down according to surveys. Only the features within the survey limits shall reside in each survey deliverable (i.e. HXXXXX.FFF.000, not the entire project feature data). The FFF shall contain attributed information on specific objects that cannot be portrayed in a simple depth grid. Features to include in the FFF include; all ”Assigned” features from the Composite Source File (CSF) and any new features found within the survey area. The FFF shall be in the WGS84 datum, unprojected and 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

The FFF shall include shoreline data only if the hydrographer conducted shoreline verification. New features and changes to the source shoreline shall be portrayed in the FFF and be as fully attributed as possible using S-57 encoding rules.

U.S. Coast Guard maintained aids to navigation shall NOT be included in the FFF. The hydrographer shall investigate all aids to navigation and report results as required in section 7.2. Privately maintained aids and/or mooring buoys shall be included in the FFF, unless they are temporary in nature or are repositioned frequently.

General soundings, contours and depth areas will NOT be included in the FFF since these objects will be derived from Caris surfaces or final BAGs during chart compilation. In rare cases, an isolated sounding may be part of the FFF if it is a navigationally significant shoal and/or needs additional attribution.Required Objects and Attribution

These Specifications and Deliverables will not attempt to include all possible S-57 objects and attribution that may be used to support hydrographic survey data. They shall identify the objects and attribution that are required for NOAA hydrographic survey data when shoreline verification is required for a project.

Listed below are all the objects and attribution that shall be populated. The hydrographer shall attempt to provide as much additional information as possible on an object to facilitate the Processing Branches in final chart compilation of the survey. The additional information shall be included with the feature in the NOAA extended attributes: description, remarks and recommendations, instead of the Descriptive Report. Images associated with a feature shall be included in the attribute ‘images’ (not PICREP). Images are used to document an individual feature (i.e. such as screen-grabs, side scan snapshots, or digital photos). Images shall be delivered in JPEG format. Multiple images shall be comma delimited and all images should be placed in the Multimedia folder with a unique name. If the hydrographer has any questions on the appropriate attribution for an object, they should contact the COR and/or the appropriate Processing Branch for clarification.

ALL FEATURE OBJECTS

ALL feature objects shall have the S-57 attributes SORDAT and SORIND populated. For features that originate from any source other than the current survey, use the SORDAT and SORIND from that source.

For features addressed by the survey:

<u>SORIND</u> (Source indication) Country code, Authority code, Source, ID code

- Country code - US
- US Authority code - US for OSC
- Source - graph
- ID code - registry number
- Ex: US,US,graph,H12345

SORDAT (Source date) The last day of survey acquisition formatted as YYYYMMDD

ALL feature objects shall have the NOAA extended attributes descrp, prmsec and remrks populated. All new features and feature disprovals shall have recomd populated and all special feature types shall have sftype populated.

descrp (Description) - Description portrays the Field Charting Action.

1. New - New features or new positions for features
2. Updates - Modification of attribution, geometry, and/or feature object class
3. Delete - Disprovals or erroneous features
4. Retain – Addressed items that are represented properly on the chart. A remark should be included for informational purposes as necessary
5. Not Addressed - For items that were ‘assigned’ by the HSD Operations Project Manager or COR but that were not addressed. Include remark describing why the feature was not addressed

prmsec (Status-Primary/Secondary) - Indicates the status of the feature. All verified real world features in the FFF must be attributed as ”primary”.

1. Primary - Principle feature that can be associated with one or more secondary features. The primary feature is always the feature with the most accurate position and least depth (if applicable). Features that have only one observation are also labeled primary.
2. Secondary - Signifies that the feature is correlated to the primary.
3. Pending - A tool used during data processing. There should be no features left as ’pending’ once a survey is complete.

remrks (Remarks) - Used to provide additional information about features that is not captured elsewhere in the digital data (e.g. S-57 attribution). For assigned features that were not verified provide a comment such as ”Retain as charted, Not investigated due to being inshore of NALL” shall be made in the remarks field.

recomd (Recommendations) - NOTE: required for new features and charted feature disprovals. Recommendations is used to provide survey data reviewers and cartographers additional information about features through the final feature file. While explicit charting recommendations are not mandatory it is important to clearly communicate all information necessary to ensure proper charting of a feature.

Do NOT include exact geographic positions (Latitude and Longitude), least depths, etc. in remarks or recommendations as they are automatically generated at the processing branches in the feature report. However, the practice of including the correlating AWOIS number (RECRD field) in the remarks is acceptable.

sftype (Sepcial Feature Type) - NOTE: required for the special feature types listed below. Indicates a feature with a special designation.

1. ATON - for all ATON investigations
2. AWOIS - for all AWOIS investigations
3. DTON - for all Dangers to Navigation
4. MARITIME BOUNDARY - for all Maritime Boundary investigations
5. CEF - for all Catographic Evaluation File investigations

DEPTHS

Depth information is delivered as SOUNDG objects with 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). Only soundings for DTONs or other significant shoals should be included in the feature file, and these should be attributed as follows.

Required Attributes:

- TECSOU (Technique of Sounding Measurement) – Individual soundings and features shall be attributed according to the following table:

Technique of Measurement for Height or Depth	**S-57 Attribute ID**
VBES (single beam) alone	‘1’ found by echo-sounder
Side Scan Sonar alone	‘2’ found by side scan sonar
Multibeam alone	‘3’ found by multibeam
Skunk Striping (full coverage SSS with partial coverage multibeam)	’3’ found by multibeam, with CATZOC reflecting lack of full coverage
Diver depth	‘4’ found by diver
LIDAR alone	‘7’ found by laser
Heights on rocks or islets using rangefinder	‘12’ found by leveling

- QUASOU (Quality of Sounding Measurement) - All sounding features that were surveyed using modern survey echosounder to NOAA/IHO standards are assumed to be QUASOU Depth Known. In these cases QUASOU should be left un-attributed. Attribute QUASOU only in the cases outlined below:
  - Depth Unknown: Use this category for obstruction area objects, such as foul areas, where “Unknown” is used for VALSOU and WATLEV.
  - Least Depth Known: Shall be populated with point objects (i.e. wrecks, rocks, and obstructions) under these circumstances:

        * Developments using Multibeam Echosounder (MBES) System
        * Developments using Side Scan Sonar (SSS) System in conjunction with VBES or MBES
        * Developments using Vertical Beam Echo Sounder (VBES)
        * Diver investigation using Diver Least Depth Gauge (DLDG)
        * Manual Depth Measurement Equipment using lead line or sounding poles
        * Sounding “designated” from the Surface
    - Value Reported (not surveyed): Use this category for Side Scan Sonar contacts in which a sonar depth is not acquired and which the side scan contact has not been investigated.

FEATURES

All features should be attributed as fully as possible. Several common features are listed below followed by their mandatory attributes and other attributes that may be required or desirable. For all sounding-based features, see instructions for populating TECSOU and QUASOU attributes under DEPTHS, above.

<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)

Required Attributes:

- CATWRK (Category of Wreck)
- WATLEV (Water Level Effect) - The attribute ‘water level effect’ encodes the effect of the surrounding water on an object (IHO S-57 Appendix A Chapter 2 – Attributes).
- VALSOU (Value of sounding) - The value of the measurement of a sounding relative to the chart datum (IHO S-57 Appendix A Chapter 2 – Attributes). Should be left blank if depth not available.
- TECSOU
- QUASOU

<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)

Required Attributes:

- WATLEV (Water Level Effect) - The attribute ‘water level effect’ encodes the effect of the surrounding water on an object (IHO S-57 Appendix A Chapter 2 – Attributes).
- VALSOU - The value of the measurement of a sounding relative to the chart datum (IHO S-57 Appendix A Chapter 2 – Attributes). Should be left blank if depth not available.
- TECSOU

- QUASOU

OBSTRN (Obstruction) - In marine navigation, anything that hinders or prevents movement, particularly any¬thing 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)

Required Attributes for OBSTRN objects:

- WATLEV (Water Level Effect) - The attribute ‘water level effect’ encodes the effect of the surrounding water on an object (IHO S-57 Appendix A Chapter 2 – Attributes).
  - For line or area objects - If VALSOU is not known, use WATLEV = “Unknown”. If a VALSOU least depth is given, use WATLEV = Covers and Uncovers, Awash or Always Submerged.
- VALSOU - The value of the measurement of a sounding relative to the chart datum (IHO S-57 Appendix A Chapter 2 – Attributes). Should be left blank if depth not available.
  - For line or area objects - VALSOU should represent the shoalest depth representing the feature or within the area obstruction and should match either the shoalest grid node or designated data point. VALSOU should be left blank if depth not available.
- TECSOU
- QUASOU
- CATOBS (Category of Obstruction) - Conditional if known.
- NATSUR (Nature of surface) - Define the nature of surface. Conditional if known.

SBDARE (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). Where SBDARE is used to describe bottom characteristics obtained through bottom sampling.

Required Attributes for SBDARE Point Objects (Bottom Characteristics):

- NATSUR
- NATQUA (Nature of Surface, Qualifying Terms)
- COLOUR (Color)

Bottom characteristic objects will have NATSUR encoded and may also have NATQUA encoded depending on the nature of the surface sampled. If a bottom sample was attempted but no sample was recovered the NATSUR will be categorized as Unknown. Multiple characteristics, colors and qualifiers may be used. The constituents should be comma separated in order of predominance using the S-57 ID number. See Appendix J for further details on encoding bottom samples.

Example: For fine sand, green mud and broken shells where sand is the major constituent, followed by mud, then shells:

- NATSUR = sand, mud, shells (4,1,17)
- COLOUR=green (-,4,-)
- NATQUA= fine,,broken (1,-,4)

SBDARE line or area objects may be used to characterize areas with numerous discrete submerged rocks (rather than encoding individual rock features) and/or areas of the seafloor that are rocky in nature. 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. (See Section 5.3.1.2 for additional details regarding these areas.) 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”.

Required Attributes for SBDARE Line and Area Objects (Ledges, Reefs and Rocky Seabed Areas)

- NATQUA = Rock
- WATLEV - Mandatory for reefs and ledges and for rocky seabed areas (with exceptions for those rocky seabed areas that extend to shore).

(NOTE: Do not use the NATQUA “hard” attribute for rocky seabed areas or rocky foul areas.)

SHORELINE

Shoreline information, if required by project, should be encoded in S-57 using the following feature objects and attributes.

COALNE (Coastline) - COALNE is attributed with CATCOA (Category of Coastline), if known. ELEVAT should not be attributed for this object.

LNDARE (Land area) - LNDARE point, line or area objects may be used to characterize islets. LNDARE objects should be accompanied by LNDELV point or line object, denoting the highest point of the feature. See Rock Attribution Figure H.1 in Appendix 8 for vertical height requirements by geographic area. The minimum horizontal requirements for charting an islet as an area object are 0.65 mm by 0.5 mm at the largest scale chart of the area.

LNDELV (Land elevation) - Elevation for islets is encoded using the object LNDELV, with attribute ELEVAT, which is given relative to the MHW datum.

META-OBJECTS

Meta-Objects provide metadata and additional information for large areas of the survey, or to attribute the entire survey area. The mandatory meta-objects with their mandatory attributes are listed below.

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. M_COVR may be used for the survey outline. See Section 8.1.2 for further details.

Required Attributes:

- 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.)
- INFORM (Information) - Contains the Following String:
  - Registry Number, Project Number, Platform or Contractor Name, State, Scale, Year, Survey Type, Coverage Type (MB, SS or VB).
  - Example: H12345, OPR-Q904-11, World Surveys Inc., AK, 2011, Hydro, MB

The optional Meta-Objects are listed below:

M_QUAL (Quality of Data) - A geographic area within which a uniform assessment of the quality of the data exists.

Required attribute:

- CATZOC (Category of zone of confidence in data)
  - Areas of different coverage types should be separated and attributed 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.

- INFORM - Vessel(s) or aircraft name
- POSACC (Positional Accuracy, in meters) – For USCG beacons or other modern Differential GPS systems
- SURSTA (Start date of survey) - Enter the start date of the field operations in format, CCYYMMDD
- SUREND (End date of survey) - Enter the end date of the field operations in format, CCYYMMDD.

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 8.4.3).

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 COR 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 COR 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 degrees) 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 Multimedia folder. 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 field units should refer to Chapter 5 of the OCS Field Procedures Manual for other guidance pertaining to survey deliverables.

8.4.1 Media

Digital data shall be submitted on USB hard drives following the data directory structure in Figure L in Appendix 12. Each registered survey shall be submitted on a separate USB drive unless prior agreement is obtained from the COR or Processing Branch. Survey data shall be accompanied by NOAA Form 61-29 Letter Transmitting Data. See Figure K in Appendix 11. The hydrographer shall work with NOAA to ensure no compatibility problems exist after data submission.

Prior to submitting digital data to NGDC, the field unit shall verify that all files are present and none have become corrupt during transfer to a portable media. A check sum shall be submitted by the field unit and generate a UNIX/LINUX hexadecimal formatted MD-5 hash of the content of the entire directory structure and include it in the digital data submission. The relative directory data structure must be used to allow verification at the processing branch.

8.4.2 Bathymetric Data

The hydrographer's bathymetric 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" 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 Echosounding Data

The hydrographer shall submit full resolution echosounding data in a format readable by CARIS HIPS. Full resolution echosounding 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.

Alternately, non-CARIS HIPS users may submit 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 Lidar Data

The contractor shall submit the full resolution lidar data in CARIS compatible format. 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, with resolution and attribution as described in Section 5.2, and/or the Hydrographic Survey Project Instructions. The hydrographer must take steps to ensure that all data has been correctly processed and that appropriate designated soundings have been selected (see Section 5.2.1.2, 5.2.2 and 5.3.1.2). The collection of grids representing the final reviewed results of the hydrographic survey shall be submitted as CARIS BASE or BAG surfaces. For surveys conducted as ERS (Section 9), two sets of surfaces shall be submitted: one referenced to the ellipsoid, and the other referenced to chart datum. 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. CARIS users shall include the version, service pack and hotfix numbers used during the creation of the surfaces in the Comments section during Step 1 of the BASE Surface Creation Wizard. Non-CARIS users may submit their Navigation Surfaces as a Bathymetric Attributed Grid (BAG).

All BAGS must adhere to the following naming convention: <Survey registry number>_<units of resolution>_<vertical datum>_<BAG file number>of<total number of BAGS files for survey>.bag

Example: H11000_5m_NAD83CORS96_1of6.bag

Example: H11000_50cm_MLLW_1of6.bag

Multibeam Calibration 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.

Other Bathymetric Data

Bathymetry from other sources (e.g., diver's least depth gauge, lead line, sounding pole, etc.) shall be submitted in a format readily understood and compatible with CARIS HIPS. As with other sources of bathymetric data, these soundings shall be delivered fully corrected for all offsets, biases, sound speed, and other factors, with corresponding uncertainty estimates. These data shall also be included in the final grids as necessary and appropriate.

8.4.3 Side Scan Sonar Data

The hydrographer shall submit digital side scan data in a format readable by CARIS SIPS. 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.

8.4.4 ERS Data Deliverables

Unless specified otherwise in the Hydrographic Survey Project Instructions, the following deliverables are required for surveys conducted as ERS:

- Raw rover observed dual frequency GPS and inertial data used to produce the IAPPK 3D vessel position
- Base Station Files in native format, if native format is other than RINEX
- Base Station Files in RINEX version 2.11+
  - Including navigation (.yyN) as well as observation files (.yyO)
  - RINEX files must include all types of dual-frequency observations, including manufacturers SNRs: C1, L1, L2, P2, P1, S1, and S2
  - RINEX header shall include at a minimum: station / marker name, receiver type / S/N, antenna type / S/N and antenna height
  - May use Compact RINEX (Hatanaka)
- Ephemerides used in IAPPK 3D vessel position
- Weekly user maintained base station OPUS reports and QC check reports as described in Section 3.4
- IAPPK 3D vessel position solution files in ASCII format to contain at a minimum:
  - Data rate
  - Time
  - Horizontal Position and uncertainty
  - Ellipsoidal Height and uncertainty
  - Heave
  - Roll, Pitch and Heading uncertainty
  - North, East and Down Velocity uncertainty
  - Number of SV's

- PDOP
- Baseline length (M)
- KGPS processing mode

- All processing log files integral to the IAPPK 3D position quality
- Separation model file if not the one provided in one of the following two formats:
  - Comma separated values: decimal lat, decimal long, separation in meters
  - NGS GEOID BIN format
- Sounding data referenced to the ellipsoid

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 Section 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 8.4.2 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.

9 Ellipsoidally-Referenced Surveys

This chapter covers the requirements for determining areas suitable for conducting three-dimensional ellipsoidally-referenced surveys (ERS), requirements for operationally conducting ERS, and requirements for vertical datum transformation and evaluating ERS survey results.

9.1 ERS Planning and Operational Requirements

Survey planning and review by NOAA's Office of Coast Survey (OCS) Hydrographic Surveys Division Operations Branch (N/CS31) shall include a component dedicated to the evaluation of specific regions for ERS.

The three principal factors which determine survey project ERS-eligibility pertain to the capabilities and infrastructure for:

1. Centimeter-level Global Navigational Satellite System (GNSS) kinematic positioning
2. Field unit capability
3. Ellipsoid-to-chart vertical datum (mean lower low water, MLLW) transformation

9.1.1 GPS Positioning

A post-processed GPS positioning methodology is preferred for reasons of quality control (QC). The required technique for NOAA ERS vessel positioning to obtain centimeter level 3D accuracy is tightly-coupled inertially-aided post-processed kinematic GPS (IAPPK). Limits to operational parameters expressed below represent conditions most favorable to achieve horizontal and vertical position uncertainty requirements.

9.1.1.1 Reference Station Infrastructure

Baseline Limits

Centimeter level accuracy in carrier-phase differential GNSS positioning restricts the length between reference station and survey vessel. For planning purposes, a nominal maximum-baseline length of 20 km is used for the pair-wise, vessel-to-single reference station configuration. A combination of National Continuously Operating Reference Station (CORS) sites, field-installed temporary shore stations, and other approved stations are used to satisfy the nominal maximum-baseline constraint. The maximum-baseline length may be extended to 70 km when a network of at least 4 reference stations are used to create a virtual reference station, and the separation between adjacent stations does not exceed 100 km. The option to use single reference station(s) or virtual reference stations will be determined during the survey planning process and identified in the Hydrographic Survey Project Instructions.

Data Rate

The nominal maximum required data rate for reference station data is equal to that of the vessel (rover) data: 1 Hz. Reference station data rates as low as 30 seconds are permitted when carrier-phase interpolation methods are used in IAPPK software.

Data Links

Field internet, radio-modem, and other data-link connectivity and bandwidth capabilities are important to the ERS planning and review process. Dual-frequency, all-in-view GPS data for each reference station must be transferred to the mobile field unit's processing center day-to-day. At the nominal high-end data rate of 1-Hz (see section above), dual-frequency all-in-view GPS receiver binary or otherwise compact/compressed ASCII data equates to just under 20 MB per day. Reliable data link infrastructure must then be capable of timely download of up to 20 MB multiplied by the number of reference stations involved in the ERS (single base or networked bases).

Additionally, precise orbit and clock data must be transferred to the field unit; however, ephemerides data are orders of magnitude smaller than carrier-phase observable data and can be downloaded with a basic internet connection.

Access to online NGS infrastructure, including the Online Positioning User Service (OPUS) and NGS Datasheets are also required.

9.1.2 Field Unit Infrastructure

ERS capability shall be included in the Hydrographic Systems Readiness Review (HSRR) or contractor quality assurance plan. Some general items that affect the broad notions of ERS suitability criteria and procedures planning are listed below.

Hardware

At a minimum, inertially-aided GPS hardware present on survey vessels must be capable of logging dual-frequency, all-in-view, GPS code and carrier phase data, as well as high-rate inertial data.

Requirements for temporary reference stations are per that discussed above. The field unit must have a sufficient mix of CORS and/or GPS receivers for base stations in hand which can satisfy the reference station infrastructure (maximum baseline length) requirements.

Software

Tightly-coupled inertially-aided GNSS positioning software capable of reading data as logged by the inertial and GPS hardware for IAPPK solutions is required. There must be sufficient licenses or “keys” with the field unit in order to sustain the processing required to support the number of surveys to be conducted as ERS.

Personnel and Training

There must be sufficient personnel with the field unit with the knowledge, skills, and abilities required to conduct the aspects of ERS which differ from, or are in addition to, traditional tide-controlled hydrographic surveys. This includes, but is not limited to, establishing and maintaining base stations, establishing geodetic control when required, post-processing of kinematic GPS data, and application of 3D ellipsoidal navigation solutions to hydrographic data.

9.2 ERS Datum Transformation Requirements

The standard method for the ellipsoid-to-chart datum transformation is to utilize the National VDatum transformation framework and software developed and published by NOAA. However, certain ERS projects may proceed in areas lacking VDatum coverage using one of the alternative ellipsoid-to-chart datum separation (SEP) models described below. The method of datum transformation to be used will be prescribed in the Hydrographic Survey Project Instructions.

9.2.1 VDatum

VDatum software is developed jointly by the NOS Tri-Office VDatum Team. VDatum transformations utilize a combination of stepwise transformations between ellipsoidal, orthometric, and tidal datums, leveraging the best available hydrodynamic models and historical tidal and geodetic data at each step. At present time, uncertainties for VDatum are known only at the shore stations used for separation model creation and are still not fully assessed away from these shore stations for all VDatum models. Therefore, the sole use of VDatum without additional validation requirements and QC checks will be limited to instances in which there is confidence in the uncertainty of the separation model throughout the entire survey area.

VDatum QC Requirements

At the discretion of HSD, after reviewing the a priori uncertainty associated with the particular VDatum region, certain additional QC requirements for VDatum evaluation may be required. These steps will be determined by HSD and will be specified in the Hydrographic Survey Project Instructions. Final determination of the method to be used to reduce data to chart datum resides with HSD after evaluation of these QC checks and may be based on a recommendation from the Chief of Party.

1. Point-wise Ellipsoid-MLLW SEP QC
   - True validation of the accuracy of a VDatum ellipsoidal SEP value (e.g., ellipsoid-MLLW) is achieved by obtaining a GPS height observation at a point wherein the tidal datum is known. Presumably data from all tidal bench marks with historical datums are already incorporated into VDatum and QC requirements represent points/areas "far" from those nodal locations
   - Traditional water level observations tied to the ellipsoid, acquired for 30 days or more, provide an accurate point-check on the SEP. Such ellipsoid tidal datum observations may be conducted using an ellipsoidally-referenced radar gauge or a GPS tide buoy. Less accurate checks using water level observations of less than 30 days may be employed using the ERS vessel as a "tide buoy" or water level "altimeter", followed by traditional comparison to water levels from a primary NWLON station
2. ERS / Zoned Hydrography Comparisons
   - A basic test methodology that includes the acquisition and processing of sounding data in the "traditional" manner (i.e. reduction to MLLW using water levels, discrete zoning, and/or TCARI), and then compared to ellipsoidally-referenced data. Such VDatum verification survey lines should be conducted according to the following basic guidelines:
     - Line spacing is such that the high-frequency character of the overall SEP surface is sampled. These specific line spacing requirements are detailed in the PI and SOW and are dictated by the local geoid and topography of the sea surface (TSS)
     - Spatial sampling should be adequate with respect to the zoned model; satisfying guideline “a.” typically satisfies this guideline as well

In order for HSD to approve the use of VDatum as the method to transform final survey data to vertical chart datum, QC checks should reveal that the uncertainty in this transformation is equal to, or better than, utilizing traditional observed water level methods. The typical contribution of the error for tides and water levels to the total survey error budget falls between 0.20 m and 0.45 m (refer to Section 5.2.3.5), therefore these QC methods should show that using VDatum achieves results equal to or better than these values, while ensuring that data do not exceed total allowable vertical uncertainty limits (Section 5.1.3).

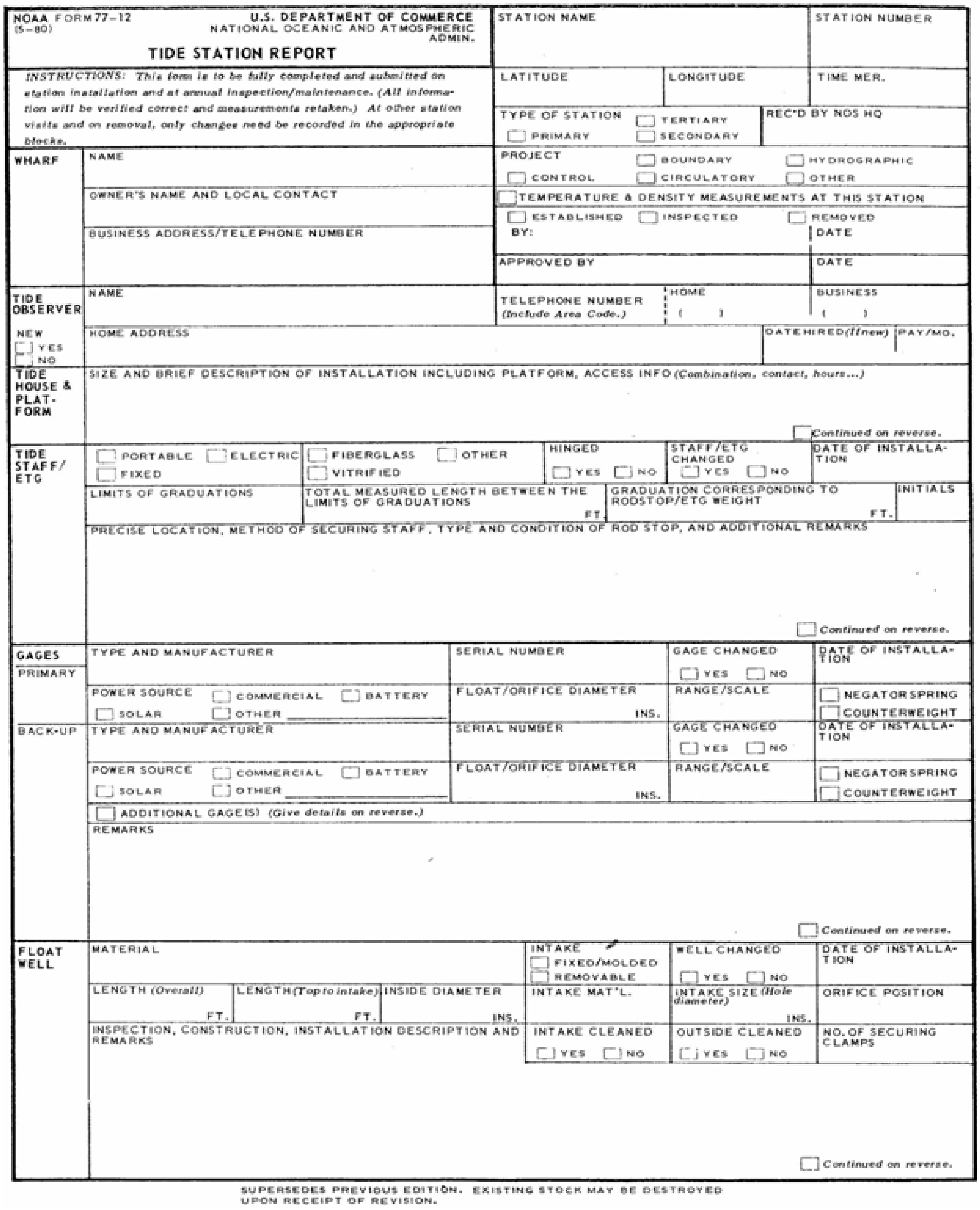
9.2.2 Ellipsoidally-Referenced Zoned Tides (ERZT)

An alternative option in areas lacking a published VDatum model is to relate "traditional" zoned water levels to the ellipsoid. This is done by measuring the height of the GPS antenna to the water line. Then a SEP is created by adding this ellipsoidally-referenced water line measurement to the zoned water level “corrector.” The SEP is then applied to the ellipsodially-referenced hydrography to reference it to chart datum. ERS-ERZT data may be readjusted at a later date when VDatum coverage becomes available.

9.2.3 Constant Value Separation Model

At the discretion of HSD, a constant SEP value for "small" survey areas in close proximity to known ellipsoid-to-chart datum SEP points may be used. Certain additional QC requirements for constant value SEP model may be required. These steps will be determined by HSD and will be specified in the Hydrographic Survey Project Instructions.

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

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.

STATION NAME | STATION NUMBER

LATITUDE | LONGITUDE | TIME MER.

TYPE OF STATION: ☐ PRIMARY ☐ TERTIARY ☐ SECONDARY | REC'D BY NOS HQ

PROJECT: ☐ CONTROL ☐ BOUNDARY ☐ CIRCULATORY ☐ HYDROGRAPHIC ☐ OTHER

☐ TEMPERATURE & DENSITY MEASUREMENTS AT THIS STATION

☐ ESTABLISHED ☐ INSPECTED ☐ REMOVED
BY: | DATE

APPROVED BY | DATE

WHARF
NAME
OWNER'S NAME AND LOCAL CONTACT
BUSINESS ADDRESS/TELEPHONE NUMBER

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.*

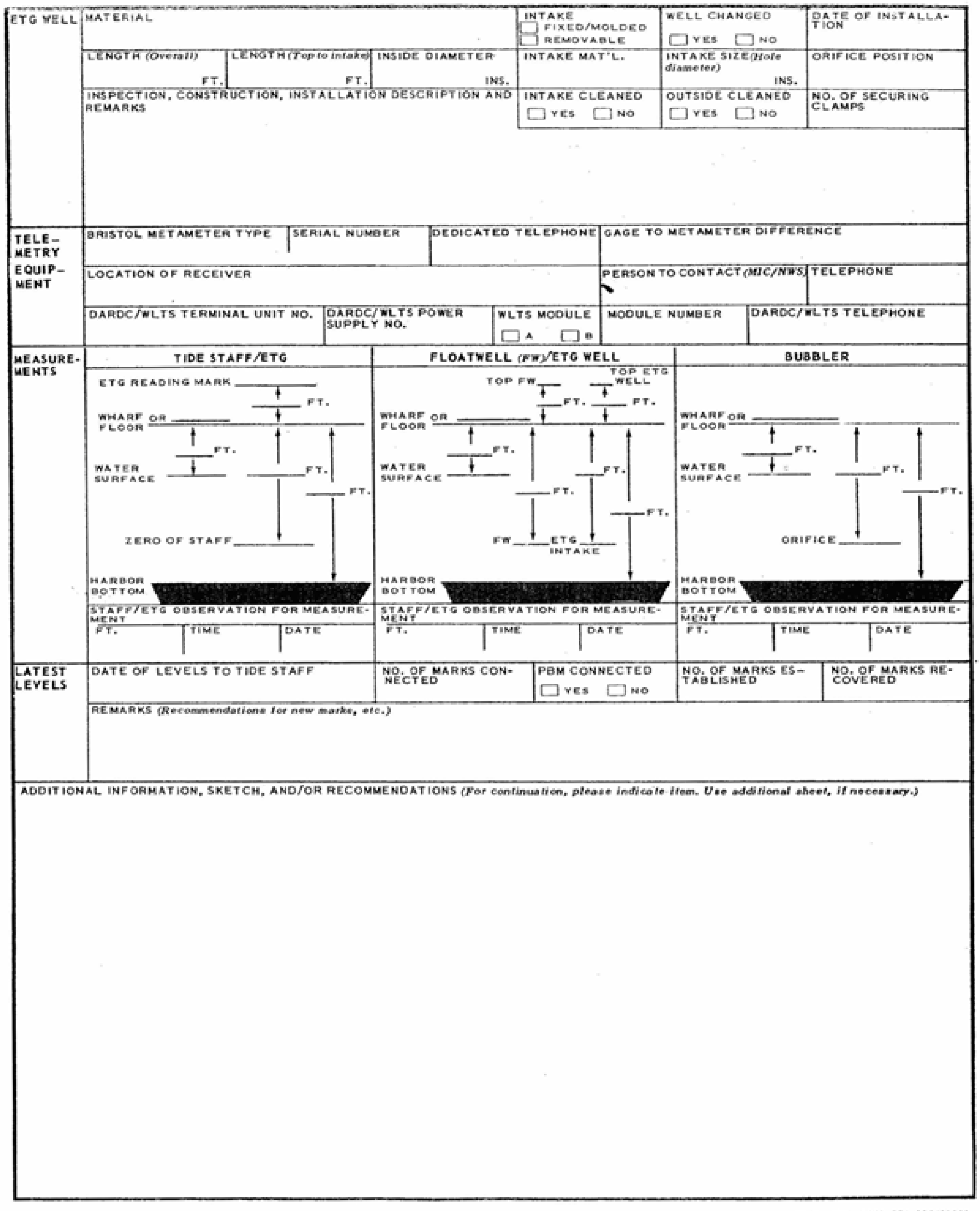
TIDE STAFF/ETG
☐ PORTABLE ☐ ELECTRIC ☐ FIXED | ☐ FIBERGLASS ☐ OTHER ☐ VITRIFIED | HINGED ☐ YES ☐ NO | STAFF/ETG CHANGED ☐ YES ☐ NO | DATE OF INSTALLATION
LIMITS OF GRADUATIONS | TOTAL MEASURED LENGTH BETWEEN THE LIMITS OF GRADUATIONS FT. | GRADUATION CORRESPONDING TO RODSTOP/ETG WEIGHT FT. | INITIALS
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

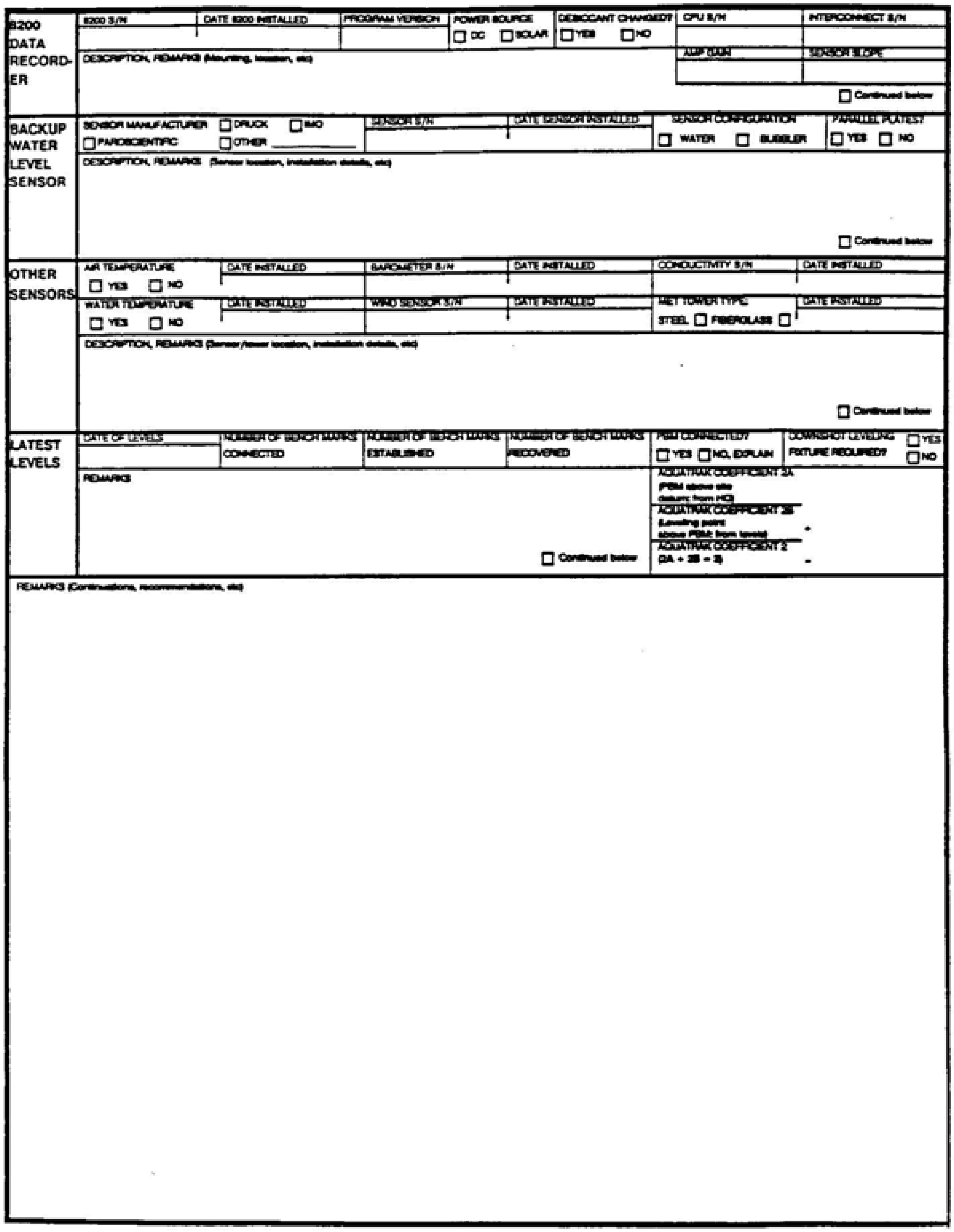


ETG WELL	MATERIAL			INTAKE ☐ FIXED/MOLDED ☐ REMOVABLE	WELL CHANGED ☐ YES ☐ NO	DATE OF INSTALLATION
	LENGTH *(Overall)* FT.	LENGTH *(Top to intake)* FT.	INSIDE DIAMETER INS.	INTAKE MAT'L.	INTAKE SIZE *(Hole diameter)* INS.	ORIFICE POSITION
	INSPECTION, CONSTRUCTION, INSTALLATION DESCRIPTION AND REMARKS			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		FLOATWELL *(FW)*/ETG WELL		BUBBLER	
	STAFF/ETG OBSERVATION FOR MEASUREMENT: FT. / TIME / DATE		STAFF/ETG OBSERVATION FOR MEASUREMENT: FT. / TIME / DATE		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	DESICCANT CHANGED?	CPU S/N	INTERCONNECT S/N
			☐ DC ☐ SOLAR	☐ YES ☐ NO		

DESCRIPTION, REMARKS (Mounting, location, etc)

AMP 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

☐ Continued below

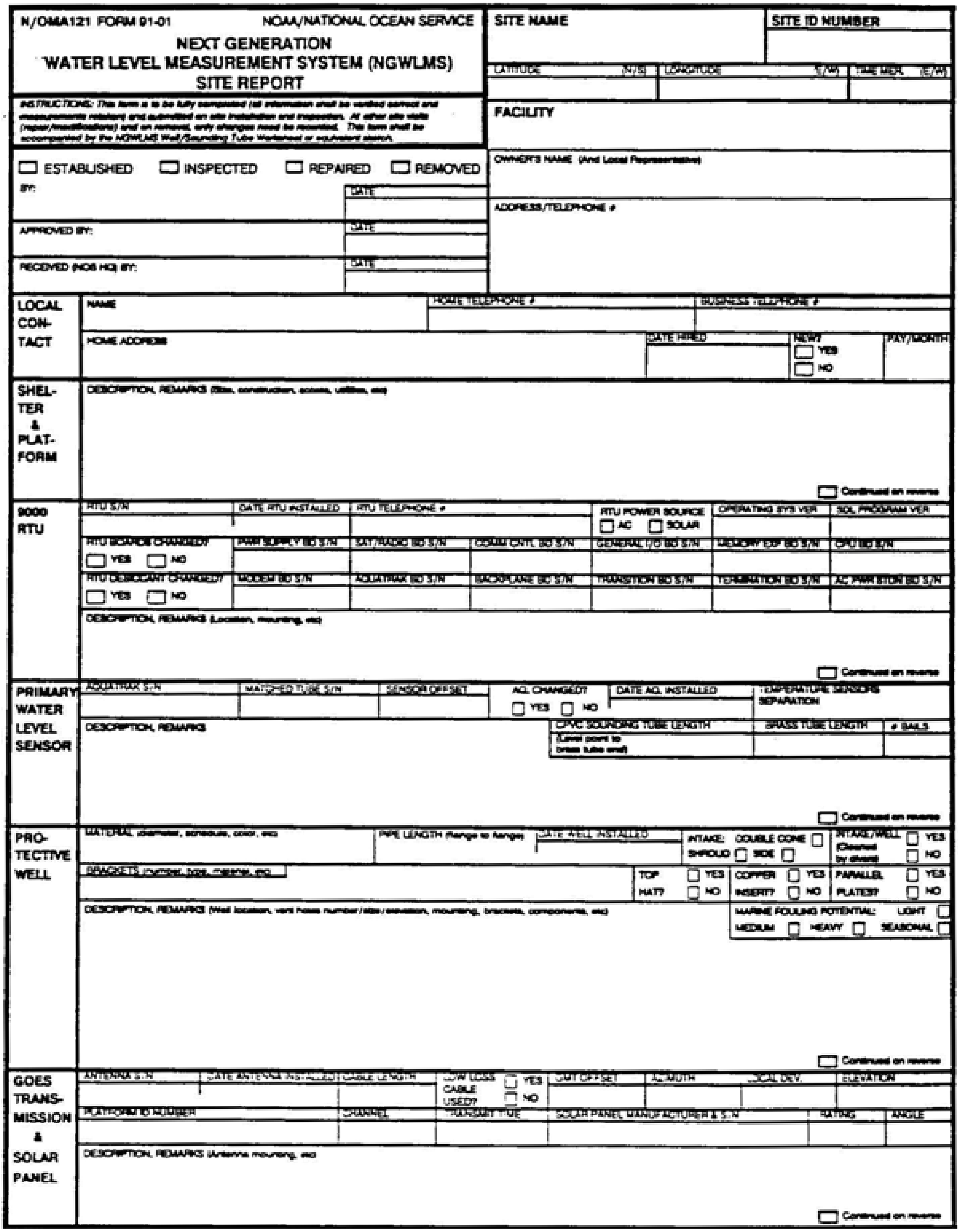
AQUATRAK COEFFICIENT 2A (PBM above site datum: from HC)

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)

INSTRUCTIONS: This form is to be fully completed (all information shall be verified correct and measurements rel[illegible]) and submitted on site installation and inspection. At other site visits (repair/modifications) and on removal, only changes need be recorded. This form shall be accompanied by the NGWLMS Well/Sounding Tube Worksheet or equivalent sketch.

FACILITY

☐ ESTABLISHED ☐ INSPECTED ☐ REPAIRED ☐ REMOVED

BY: | DATE

APPROVED BY: | DATE

RECEIVED (NOS HQ) BY: | DATE

OWNER'S NAME (And Local Representative)

ADDRESS/TELEPHONE #

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

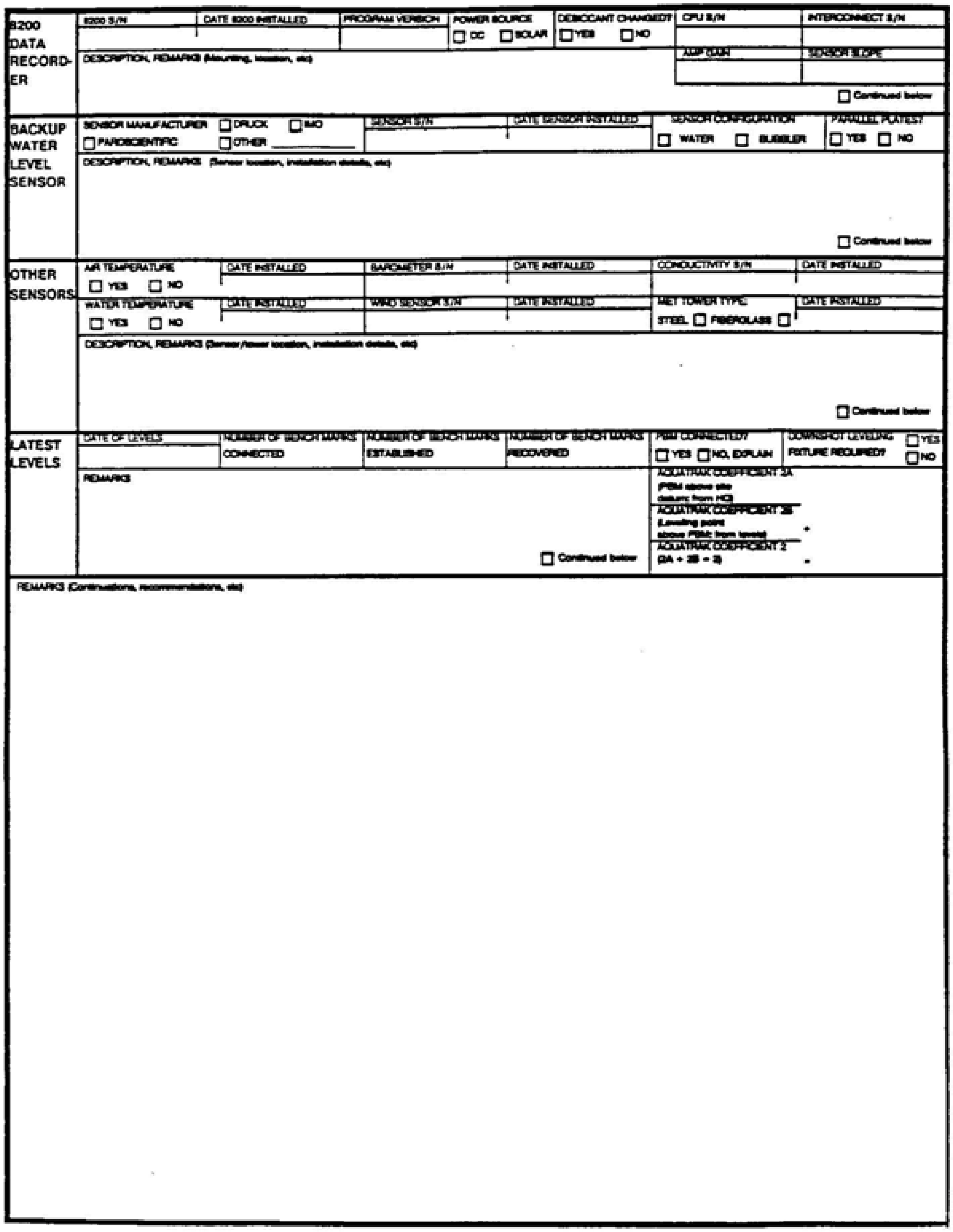
9000 RTU
RTU S/N | DATE RTU INSTALLED | RTU TELEPHONE # | RTU POWER SOURCE ☐ AC ☐ SOLAR | OPERATING SYS VER | SDL PROGRAM VER
RTU BOARDS CHANGED? ☐ YES ☐ NO | PWR SUPPLY BD S/N | SAT/RADIO BD S/N | COMM CNTL BD S/N | GENERAL I/O BD S/N | MEMORY EXP BD S/N | CPU BD S/N
RTU DESICCANT CHANGED? ☐ YES ☐ NO | MODEM BD S/N | AQUATRAK BD S/N | BACKPLANE BD S/N | TRANSITION BD S/N | TERMINATION BD S/N | AC PWR STOR 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 hole 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 | UNIT 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)

AMP 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

☐ Continued below

AQUATRAK COEFFICIENT 2A (PBM above site datum; from HO)

AQUATRAK COEFFICIENT 2B (Leveling point above PBM; from levels) +

AQUATRAK COEFFICIENT 2 (2A + 2B = 2) =

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

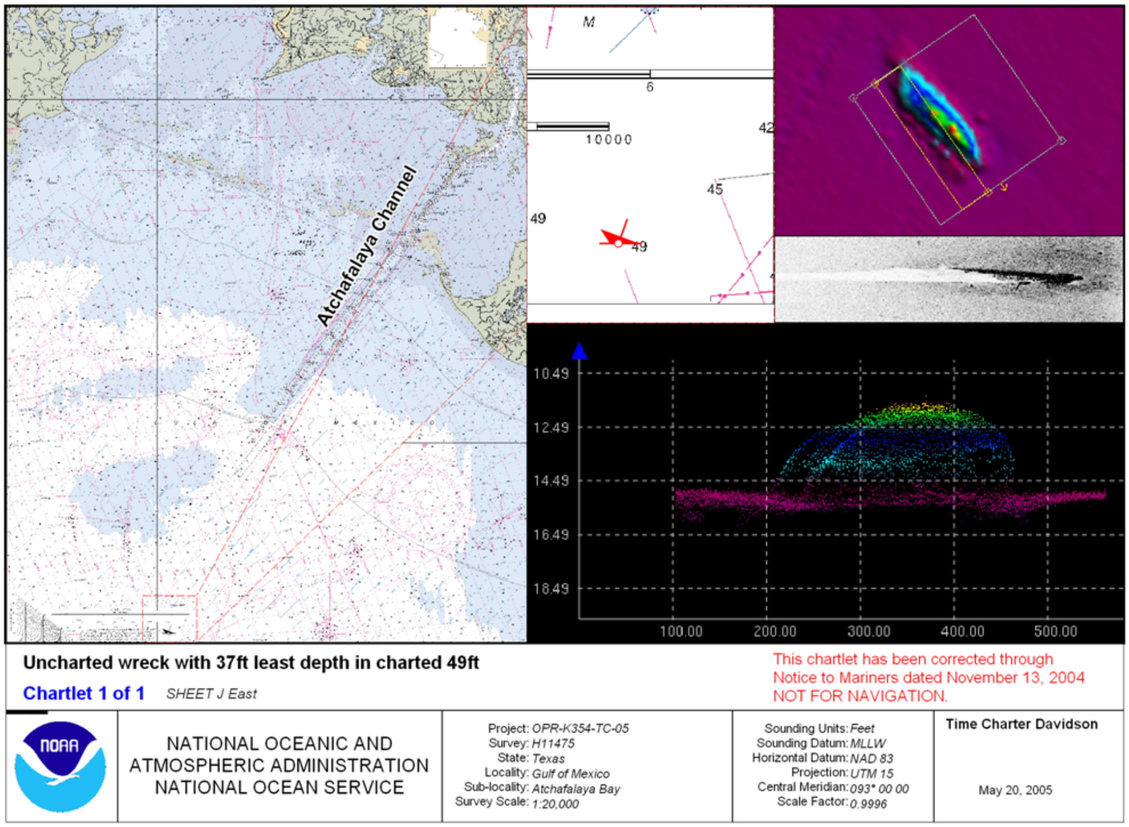


Figure F.2: Example of Chartlet to Accompany Danger to Navigation Report

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: Feature 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

NOAA Extended Attributes

NOAA Required Attribution

In addition to S-57 Attribution, NOAA requires customized attribution to support H-Cell (preliminary ENC) compilation by the cartographers and to highlight features (i.e. DTON, AWOIS).

The following is a list of required NOAA extended attributes for new, updated, and disproved features:

I.) descrp – Description from Field Charting Action

1. New - For new features or new positions for features
2. Updates - For modification of attribution, geometry, and/or feature object class
3. Delete - For disprovals or incorrect features, including all LIDAR or other investigation items that have been disproved.
4. Retain - For an item that was fully addressed or investigated, and found to be represented properly on the chart, with no edits or additions to attribution required. A remark should be included for informational purposes as necessary
5. Not Addressed - For items that were assigned but that were not addressed. Include a remark describing why the feature was not addressed

II) prmsec - Status-Primary/Secondary – Indicates the status of the feature and is particularly helpful during side scan sonar processing. All real world features in the Final Feature File shall be '1-Primary'. If prmsec is populated with '2-Secondary' prkyid must also be populated. See item 'VI' below under NOAA Discretionary Attribution.

1. Primary – principal feature. May be associated with one or more secondary features. The primary feature is always the feature with the most accurate position and least depth (if applicable). Features that have only one observation are also labeled primary.
2. Secondary - Signifies that the feature is correlated to the primary.
3. Pending – a tool used during data processing. There should be no features left as pending once a survey is complete.

III) remrks – Remarks – Used to provide survey data reviewers and cartographers additional information about features. The hydrographer's feature remarks should include techniques used to identify the feature, what the feature is and additional information that is not captured elsewhere in the digital data (e.g. S-57 attribution, etc.).

IV) recomd - Recommendations – **NOTE: only required for new features and charted feature disprovals.** Recommendations is used to provide survey data reviewers and cartographers additional information about features. Recommendations shall be populated for those features that require further clarification than the standard S-57 attributes.

V.) sftype - Special Feature Type - **NOTE: only required for the special feature types listed below.** Indicates a feature with a special designation.

1. ATON – for all ATON investigations
2. AWOIS- for all AWOIS investigations
3. DTON – for all Dangers to Navigation
4. MARITIME BOUNDARY - for all Maritime Boundary investigations
5. CEF - for all Cartographic Evaluation File investigations

Do NOT include exact geographic positions (Latitude and Longitude), least depths, etc. in Remarks or Recommendations. However, the practice of including the correlating AWOIS number (RECRD field) in the remarks is acceptable.

NOAA Discretionary Attribution

The following is a list of additional NOAA customized attributes that are not required but may be helpful:

I.) asgnmt - Assignment Flag – Internal NOAA attribute that indicates items delivered to the field unit as 'assigned' by the project manager or COR from HSD Operations. These must either be addressed or flagged as "Not Addressed" in the descrp attribute.

1. Unassigned
2. Assigned
3. For Info Only

II.) images – Image(s) associated with a feature. The attribute is a uniquely identifying filename including the file extension. Multiple images should be comma delimited. The image format shall be JPEG or PNG and the images shall be delivered in the Multimedia folder.

III.) keywrd – user customized keyword to be used for processing or querying data. Example: Lidar Investigation

IV.) acqsts – Acquisition Status.

1. Investigate
2. Resolved

This is a tracking tool used during data processing that ensures features are fully investigated as necessary. For example, a feature found using side scan sonar may need additional information to get a least depth. This attribute allows the feature to be identified for further investigation, reminding the survey manager that further investigation is required.

V.) invreq – Investigation requirements. The COR or project manager at HSD OPS uses this field to deliver information and define specific investigation requirements for the field. For example, the survey limit feature (TESARE) includes the H number, Priority, and Sheet Name. In addition, there may be specific requests from customers about particular features, or questionable features that may warrant extra attention.

VI.) prkyid – Primary Key ID. The primary key ID shall be populated for secondary features with the primary feature's Database key ID (i.e. when prmsec = secondary). This is a means for manual correlation in CARIS to associate the secondary feature with the appropriate primary feature.

NOAA Extended Attributes Schema

NOAA has created extended attributes in the acquisition and processing software to provide further flexibility than can be obtained via the S-57attribute standards. The following extended attributes are global to all S-57 object classes.

Acronym	Name	Description	ISO8211 ID	Type
acqsts	Acquisition status	Status of acquisition	2007	(E)numeration
asgnmt	Assignment status	Indicates whether a feature is (un)assigned	2001	(E)numeration
cnthgt	Contact height	Contact Height	2008	(F)loat
dbkyid	Database key ID	Unique ID for use in relational database	1041	Free text (S)tring
descrp	Description	Field recommended charting action	2000	(E)numeration
images	Images	List of comma-delimited file name(s); do not include path(s)	2003	Free text (S)tring
invreq	Investigation requirements	Specific instructions for investigation requirements	2009	Free text (S)tring
keywrd	Keyword	List of comma-delimited user keyword(s)	2006	Free text (S)tring
onotes	Office notes	Office notes	2004	Free text (S)tring
prmsec	Primary / secondary correlation status	Indicates whether a feature is the primary contact or a secondary view	2002	(E)numeration
prkyid	Primary key ID	For Secondary feature(s); the Primary feature dbkyid	2010	Free text (S)tring
recomd	Recommendations	Charting recommendations	1119	Free text (S)tring
remrks	Remarks	Remarks	1118	Free text (S)tring
sftype	Special feature type	Indicates special features	2005	(E)numeration

Figure H.2: NOAA customized attributes parameters

The expected input values for the (E)numeration attributes are:

Acronym	ISO8211 Code	Enumeration ID	Meaning
descrp	2000	1	New
		2	Update
		3	Delete
		4	Retain
		5	Not Addressed
asgnmt	2001	1	Unassigned
		2	Assigned
		3	For Info Only
prmsec	2002	1	Primary
		2	Secondary
		3	Pending
sftype	2005	1	ATON
		2	AWOIS
		3	DTON
		4	MARITIME BOUNDARY
		5	CEF
acqsts	2007	1	Investigate
		2	Resolved

Table 1: Expected input values for NOAA enumeration attributes

Figure H.3: Expected input values for NOAA enumeration attributes

I Appendix 9: Survey Progress Estimate

Survey Progress Estimate -- (Month of Report)

FY 2010 Task Order Number XX

OPS					FIELD												
Project Number and Name	Sheet Identifier	Registry Number	HQ Estimated SNM	SNM Completed Survey Outline	Date Field Work Began	Date Field Work Completed	Estimated Date of Survey Submission	March Cumulative % Complete	April Cumulative % Complete	May Cumulative % Complete	June Cumulative % Complete	July Cumulative % Complete	August Cumulative % Complete	September Cumulative % Complete	October Cumulative % Complete	November Cumulative % Complete	December Cumulative % Complete
OPR-xxxx Location, State																	

Figure I.1: Survey Progress Estimate

J Appendix 10: Bottom Classification

Type	Term	Grain diameter
Clay		(mm)
	Mud	0.02-0.1
Silt		
	Fine	0.1-0.3
Sand	Medium	0.3-0.5
	Coarse	0.5-1.0
	Fine	1-2
Gravel	Medium	2-4
	Coarse	4-6
	Fine	6-10
Pebbles	Medium	10-20
	Coarse	20-50
Stones		50-250
Boulders		≥ 250

Figure J.1: Sediment Classification by Size

Encoding for Bottom Samples

Bottom characteristics are limited in usefulness for charting purposes, but other users find the information helpful for a multitude of purposes, such as geologic, fisheries or habitat studies. Only the main constituents of the bottom sample you collect will be applied to the chart. Other constituents, as well as color, and many of your qualifying terms, will be omitted for charting purposes, but archived and made available for other users.

Use the S-57 object SBDARE (Seabed Area) for classification of bottom characteristics. NATSUR (Nature of Surface) is a required attribute for all NOAA bottom samples collected. For NOAA purposes in describing bottom samples the attribute NATQUA (Nature of Surface – Qualifying Terms) may also be used in conjunction with NATSUR, but is not to be used alone. COLOUR may also be used to further describe the NATSUR term.

How to Encode Bottom Characteristics Multiple NATSUR terms may be designated, for example, sand, gravel and shells. For more detailed descriptions the attribute NATQUA may also be used as a descriptive term. For instance, the sand may be NATQUA, coarse and the shells may be NATQUA, broken. *(NOTE: S-57 permits multiple NATQUAs to be applied to any individual NATSUR term. For example, mud may be both 'sticky' and 'soft'. However, for NOAA purposes do not apply multiple NATQUAs to a single NATSUR.)* COLOUR may also be applied to the NATSUR terms. *(NOTE: S-57 limits the use of COLOUR to just the first term, but for NOAA purposes we are applying COLOUR as needed for any or all of the terms.)* See the tables on the following pages for NATSUR, NATQUA and COLOUR options.

Follow these steps for encoding bottom samples.

(1) **NATSUR**: First determine the most appropriate general description of the seabed type using one or more of the choices for attribute NATSUR. List them in order of the most predominate first, comma delimited, using the S-57 ID number.

> Example: For sand, mud and shells where sand is the major constituent, followed by mud, then shells:

NATSUR = sand,mud,shells **(4,1,17)**

(2) **NATQUA**: Next, if clearly discernible, give more specific details for the NATSUR characteristics selected using the attribute NATQUA. NATQUA attributes should be listed in the same order as the NATSUR attributes to which they are associated, and should be comma delimited. For any NATSUR that has no NATQUA qualifier, its place in the list must be left empty and held by a comma.

> Example: Fine sand with mud and broken shells; mud is the only constituent with no qualifier:

NATSUR = sand,mud,shells **(4,1,17)**; NATQUA=fine,,broken **(1,-,4)**

Where the *last* NATSUR term has no qualifier, encode a trailing comma.

> Example: fine sand and mud, (mud has no qualifier):

NATSUR=sand,mud **(4,1),** NATQUA=fine, **(1,-)**

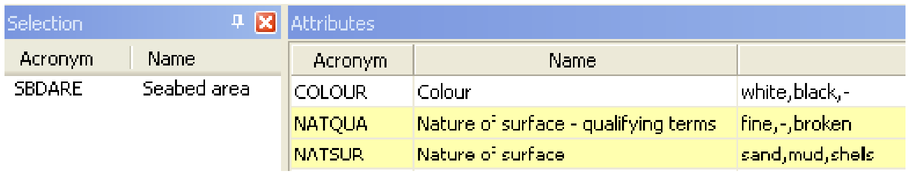
(3) **COLOUR**: Finally, if appropriate, encode COLOUR as above for NATQUA.

> Example: Fine white sand with black mud and broken shells

NATSUR = sand,mud,shells **(4,1,17)**; NATQUA=fine,,broken **(1,-,4)**; COLOUR=white,black **(1,2,)**

Figure J.2: Encoding for Bottom Samples

In ENC viewing software this is how the SBDARE and its attributes will appear for a sample encoded as 'fine white sand, black mud and broken shells'.



Many S-57 feature management software applications will automatically format the comma delimiters for NATSUR, NATQUA and COLOUR.

NATSUR (Nature of surface)

ID	Meaning	NATSUR Description
1	mud	Soft, wet earth.
2	clay	Particles of less than 0.002mm; stiff, sticky earth that becomes hard when baked.
3	silt	Particles of 0.002-0.0625mm; when dried on hand will rub off easily.
4	sand	Particles of 0.0625-2.0mm; tiny grains of crushed or worn rock.
5	stone	A general term for rock fragments ranging in size from pebbles and gravel to boulders or a large rock mass.
6	gravel	Particles of 2.0-4.0mm; small stones with coarse sand.
7	pebbles	Particles of 4.0-64.0mm; small stones made smooth and round by being rolled in water.
8	cobbles	Particles of 64.0-256.0mm; stones worn round and smooth by water and used for paving.
9	rock	Any formation of natural origin that constitutes an integral part of the lithosphere. The natural occurring material that forms firm, hard, and solid masses.
11	lava	The fluid or semi-fluid matter flowing from a volcano. The substance that results from the cooling of the molten rock.
14	coral	Hard calcareous skeletons of many tribes of marine polyps.
17	shells	Exoskeletons of various water dwelling animals.
18	boulder	A rounded rock with diameter of 256mm (25.6cm) or larger.

Figure J.3: Encoding for Bottom Samples

NATQUA (Nature of surface, qualifying terms)

ID	Meaning	NATQUA Description
1	fine	Falls within the smallest size continuum for a particular NATSUR term.
2	medium	Falls within the moderate size continuum for a particular NATSUR term.
3	coarse	Falls within the largest size continuum for a particular NATSUR term.
4	broken	Fractured or in pieces.
5	sticky	Having an adhesive or glue like property.
6	soft	Not hard or firm.
7	stiff	Not pliant; thick, resistant to flow.
8	volcanic	Composed of or containing material ejected from a volcano.
9	calcareous	Composed of or containing calcium or calcium carbonate.
10	hard	Firm; usually refers to an area of the sea floor not covered by unconsolidated sediment.

COLOUR

ID	Meaning
1	white
2	black
3	red
4	green
5	blue
6	yellow
7	grey
8	brown
9	amber
10	violet
11	Orange
12	Magenta
13	Pink

Figure J.4: Encoding for Bottom Samples

NATQUA NATSUR	1 Fine	2 Medium	3 Coarse	4 Broken	5 Sticky	6 Soft	7 Stiff	8 Volcanic	9 Calcareous	10 Hard
1 Mud					x	x	x	x	x	x
2 Clay					x	x	x			x
3 Silt					x	x	x			x
4 Sand	x	x	x			x		x	x	x
5 Stone								x	x	
6 Gravel								x	x	
7 Pebbles								x	x	
8 Cobbles								x	x	
9 Rock								x	x	
11 Lava								x		
14 Coral				x						
17 Shells				x					x	
18 Boulder								x	x	

Figure J.5: NATQUA/NATSUR Allowable Attribute Combination

K Appendix 11: Survey Data Submission

NOAA FORM 61-29
(12-71)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

LETTER TRANSMITTING DATA

REFERENCE NO.

DATA AS LISTED BELOW WERE FORWARDED TO YOU BY **(Check)**

☐ ORDINARY MAIL ☐ AIR MAIL
☐ REGISTERED MAIL ☐ EXPRESS
☐ GBL **(Give number)**________________

DATE FORWARDED

NUMBER OF PACKAGES

TO:

NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.

This package contains [List drive(s) with description (e.g. Seagate 500 GB) and CD number or drive name]
Containing Hydrographic Survey Data Submission "[Type of data (i.e. Field/Raw and Processed Data]":

Checksum

Survey: Hxxxxx
Project: OPR-xxxx-xx-xx
Size (bytes): 000,000,000
Files: 00,000
Name of Checksum File: Hxxxxx.md5

Survey: Hxxxxx
Project: OPR-xxxx-xx-xx
Size (bytes): 000,000,000
Files: 00,000
Name of Checksum File: Hxxxxx.md5

Survey: Hxxxxx
Project: OPR-xxxx-xx-xx
Size (bytes): 000,000,000
Files: 00,000
Name of Checksum File: Hxxxxx.md5

[Add additional comments or notes here]

FROM: (Signature)

RECEIVED THE ABOVE
(Name, Division, Date)

Return receipted copy to:

USDOC NOAA NOS
[Insert field unit address here]

NOAA FORM 61-29 SUPERCEDES FORM C AND GS 413 WHICH MAY BE USED.

• U.S. GOVERNMENT PRINTING OFFICE: 1988 - 554-006-61309

Reset

Figure K.1: Survey Data Submission for NOAA Units

NOAA FORM 61-29 (12-71) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION	REFERENCE NO.
LETTER TRANSMITTING DATA	DATA AS LISTED BELOW WERE FORWARDED TO YOU BY **(Check)** ☐ ORDINARY MAIL ☐ AIR MAIL ☐ REGISTERED MAIL ☐ EXPRESS ☐ GBL **(Give number)**________
TO: • • • •	DATE FORWARDED
	NUMBER OF PACKAGES

NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be returned as a receipt. This form should not be used for correspondence or transmitting accounting documents.

This package contains [List drive(s) with description (e.g. Seagate 500 GB) and CD number or drive name] Containing Hydrographic Survey Data Submission "[Type of data (i.e. Field/Raw and Processed Data]":

Survey: xxxxxx
Project: xxx-xxxx-xx-xx
Size (bytes): 000,000,000
Files: 00,000

Survey: xxxxxx
Project: xxx-xxxx-xx-xx
Size (bytes): 000,000,000
Files: 00,000

Survey: xxxxxx
Project: xxx-xxxx-xx-xx
Size (bytes): 000,000,000
Files: 00,000

[Add additional comments or notes here]

FROM: (Signature)	**RECEIVED THE ABOVE** (Name, Division, Date)
Return receipted copy to: • • • •	

NOAA FORM 61-29 SUPERCEDES FORM C AND GS 413 WHICH MAY BE USED. • U.S. GOVERNMENT PRINTING OFFICE: 1988 - 554-006-61309

Reset

Figure K.2: Survey Data Submission for Contractors

L Appendix 12: Data Directory Structure

Data Directory Structure for NOAA Units

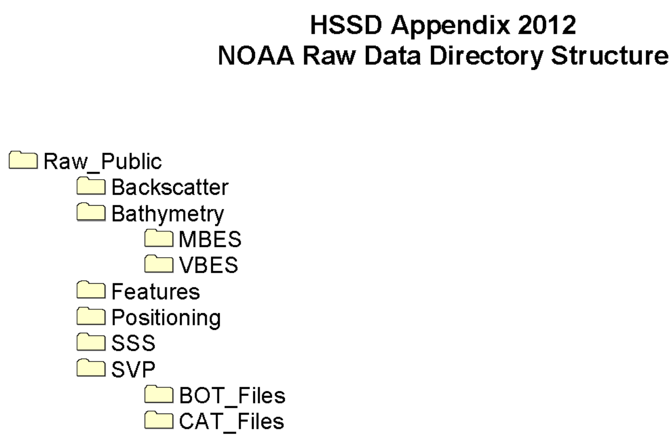


Figure L.1: Raw Data Directory Structure for NOAA Units

HSSD Appendix 2012
NOAA Data Directory Structure

- OPR-X###-XX-##_Project_Name
  - HXXXXX
    - Data
      - Processed
        - Fieldsheets
        - GNSS_Data
          - SBET
        - HDCS
        - Multimedia
        - PSS
        - S-57_Features
        - SVP
        - Tide
      - Separates
        - I_Acquisition_&_Processing_Logs
          - Acquisition_Logs
          - Detached_Positions
          - Processing_Logs
        - II_Digital_Data
          - Checkpoint_Summary_&_Crossline_Comparisons
          - Sound_Speed_Data
        - III Side_Scan_Sonar_Contact_Listing
      - Descriptive_Report
      - Public_Relations_&_Consituent_Products
  - Project_Reports
    - Coast_Pilot_Review
    - Data_Acquistion_&_Processing_Report
    - Horizontal_&_Vertical_Control_Report
      - Digital_A-Vertical_Control_Report
      - Digital_B-Horizontal_Control_Data
        - ATON_Data
        - Base_Station_Data
    - Project_Correspondence

Figure L.2: Data Directory Structure for NOAA Units

Data Directory Structure for Contractors

HSSD Appendix 2012
Contractors Data Directory Structure

- OPR-X###-XX-##_Project_Name
  - HXXXXX
    - Data
      - Preprocess
        - Backscatter
        - Bathymetry
          - MBES
          - VBES
        - Features
        - Positioning
        - SSS
        - SVP
      - Processed
        - Bathymetry_&_SSS
        - GNSS_Data
          - SBET
        - Multimedia
        - S-57_Features
        - SVP
        - Tide
      - Separates
        - I_Acquisition_&_Processing_Logs
          - Acquisition_Logs
          - Detached_Positions
          - Processing_Logs
        - II_Digital_Data
          - Checkpoint_Summary_&_Crossline_Comparisons
          - Sound_Speed_Data
        - III Side_Scan_Sonar_Contact_Listing
      - Descriptive_Report
      - Public_Relations_&_Consituent_Products
  - Project_Reports
    - Coast_Pilot_Review
    - Data_Acquistion_&_Processing_Report
    - Horizontal_&_Vertical_Control_Report
      - Digital_A-Vertical_Control_Report
      - Digital_B-Horizontal_Control_Data
        - ATON_Data
        - Base_Station_Data
    - Project_Correspondence

Figure L.3: Data Directory Structure for Contractors