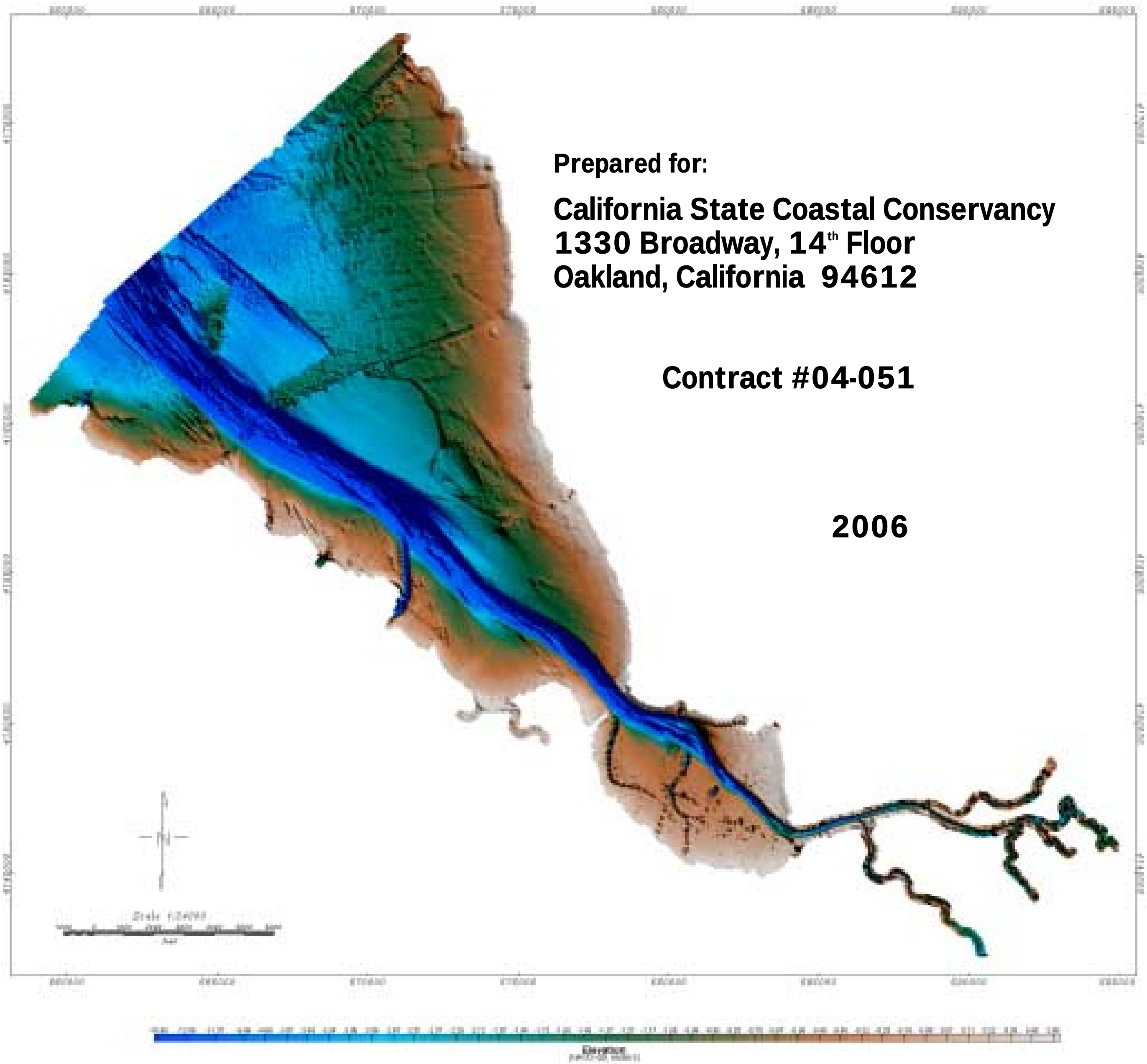
HYDROGRAPHIC SURVEY OF SOUTH SAN FRANCISCO BAY



Prepared for:

California State Coastal Conservancy
1330 Broadway, 14th Floor
Oakland, California 94612

Contract #04-051

2006

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Hydrographic Survey of South San Francisco Bay

1. INTRODUCTION

The California State Coastal Conservancy funded a Class 1 hydrographic survey of South San Francisco Bay in support of the South Bay Salt Pond Restoration (SBSPR) Project. The SBSPR Project is the largest tidal wetland restoration project on the U.S. West Coast. The soundings from the hydrographic survey will be merged with the results from an aerial topographic Light Detection and Ranging (LIDAR) survey from May 2004 (Foxgrover and Jaffe, 2005) to create a terrain model of South San Francisco Bay. An accurate terrain model is essential for developing a sediment budget useful for evaluating different strategies for Salt Pond restoration. The U.S. Geological Survey (USGS) is responsible for merging the hydrographic and LIDAR data sets, evaluating their accuracy, and developing a terrain model and sediment budget for South Bay.

The hydrographic survey, conducted in January-April 2005, is the sixth survey of South Bay. The National Ocean Service (NOS; formerly the United States Coast & Geodetic Survey) surveyed South San Francisco Bay five times, at approximate 30-year intervals, in 1858, 1898, 1931, 1956, and 1983. The USGS has already performed preliminary analyses on these historic surveys (Foxgrover, et al., 2004), and will incorporate the 2005 survey data to determine changes that have occurred within South San Francisco Bay from 1983 to 2005.

South Bay is the southern-most portion of San Francisco Bay and includes numerous sloughs and creeks. The tidally submerged lands of South San Francisco Bay cover portions of Alameda, Santa Clara, and San Mateo Counties. South San Francisco Bay has been defined as the area south of Hunter's Point (Foxgrover, et. al., 2004); however, the San Francisco Estuary Institute (SFEI) defines the northern boundary of South San Francisco Bay as being Coyote Point on the western shore and San Leandro Marina on the eastern shore (Goals Project, 1999). The California State Coastal Conservancy decided that surveying South San Francisco Bay as far north as Hunter's Point would be too costly and not necessary to accomplish the goals of the SBSPR Project. Instead, the survey of South San Francisco Bay extends as far north as the SFEI boundary line (Figure 1), defined by the following coordinates:

UTM Zone 10 North (NAD-83)		Latitude/Longitude (NAD-83)	
N 4,160,238m	E 558,523m	N 37° 35.2406'	W 122° 20.2279'
N 4,164,314m	E 561,694m	N 37° 37.4323'	W 122° 18.0524'
N 4,173,122m	E 571,415m	N 37° 42.1530'	W 122° 11.3916'

The survey area extends south of the SFEI Boundary into Coyote Creek and includes four (4) sloughs (Alviso, Artesian, Mud, and Ravenswood) at the south end of San Francisco Bay.

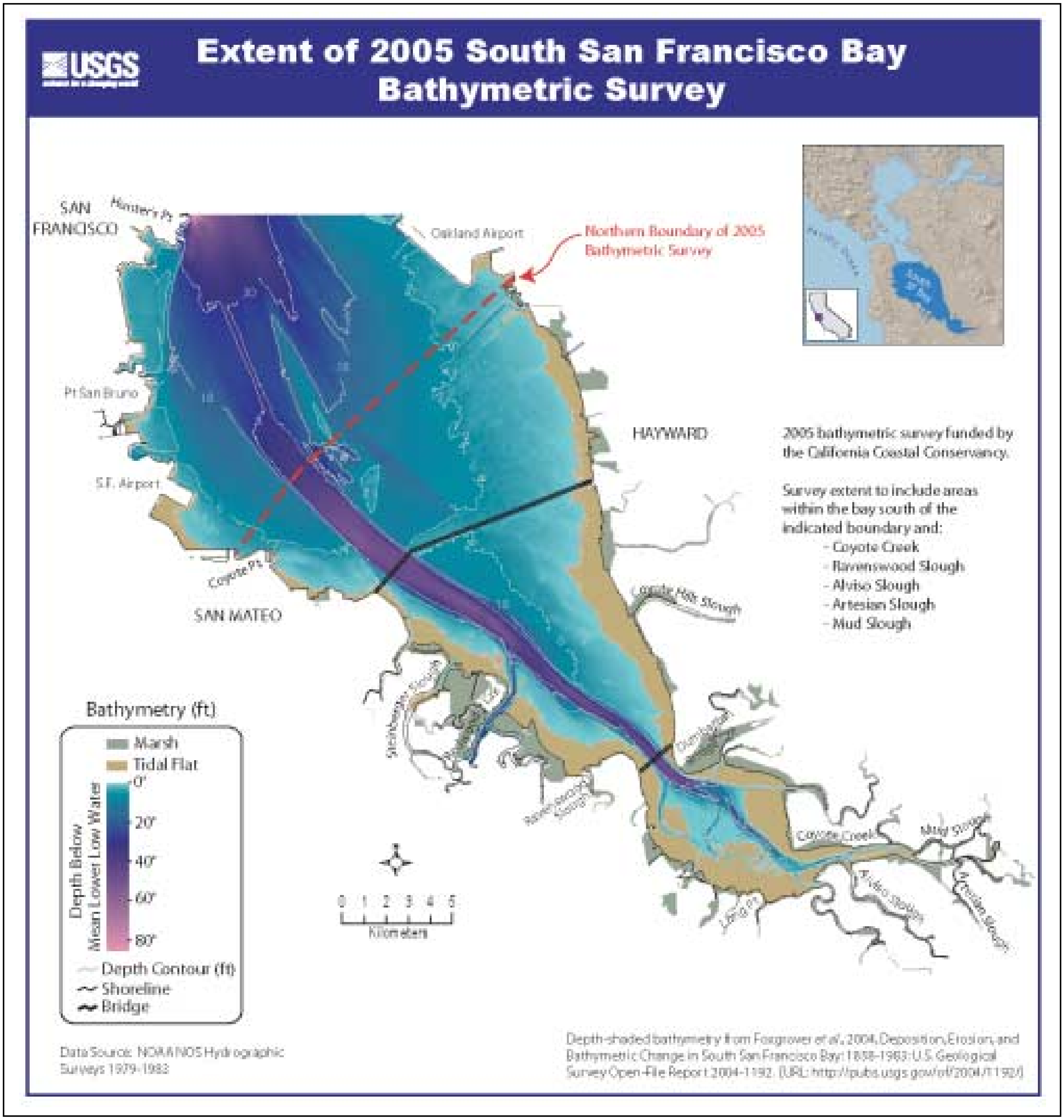

Figure 1: Extent of South San Francisco Bay Hydrographic Survey (modified from Foxgrover, et al, 2004).

2. DESCRIPTION OF WORK

The hydrographic survey was funded by the State of California, conducted by a local Contractor, and relied on the expertise, resources, and good will of many Federal Agencies, including USGS, the National Oceanic and Atmospheric Administration (NOAA), and the National Geodetic Survey (NGS).

Sea Surveyor, Inc. of Benicia, California conducted the Class 1 hydrographic survey of South San Francisco Bay under Contract #04-051 issued by the California State Coastal Conservancy on 12 October 2004. The Coastal Conservancy accepted the work performed by Sea Surveyor, Inc. on 17 November 2005 (Figure 2).

USGS prepared the scope-of-work for the hydrographic survey contract and provided technical oversight during the survey. USGS also furnished SUTRON dataloggers to record the tide data, and provided a locked shed on the Dumbarton fishing pier that safely housed a tide gauge, recorder, and satellite dish. All data was delivered to the USGS Pacific Science Center in Santa Cruz, California.

The National Oceanic and Atmospheric Administration (NOAA) provided valuable expertise and resources for measuring tides used to correct the soundings, including:

- Tides were monitored at San Leandro Marina, San Mateo Bridge, Dumbarton Bridge, and Coyote Creek using NOAA-provided air-acoustic tide gauges.
- Tide data was transmitted at 6-minute intervals directly to NOAA via the GOES satellite.
- NOAA monitored uploaded tide data continuously (24-hours/day, 7-days/week) to ensure tide gauges performed correctly.
- NOAA processed the raw tide data, computed the Mean Lower Low Water (MLLW) vertical datum, and posted the 6-minute tide data on the CO-OPS website.
- NOAA defined the tides zones used to correct the soundings.
- NOAA provided the conversions between the MLLW vertical datum and the North American Vertical Datum of 1988 (NAVD-88), based upon leveling conducted by the Contractor using methods specified by NGS.

The hydrographic survey was conducted during Winter 2005, the best season for collecting soundings in South San Francisco Bay. From October to March, South San Francisco Bay enjoys many periods of windless, flat-calm conditions that are ideal for collecting accurate soundings. Collecting accurate soundings is more difficult during Spring and Summer when strong, gusty winds and high waves prevail throughout South San Francisco Bay.

To make the soundings comparable to historical data, water depths were measured and corrected for tide using the same methods as used during the more recent of the historical surveys of South San Francisco Bay. Soundings were collected using a single-beam, survey-grade depthfinder having the same frequency and beam-width as used during the more recent of the historical surveys. Soundings were corrected to the MLLW vertical datum using tide data measured at the same location and reduced by the same organization (NOAA) as historical surveys.

Coastal Conservancy

November 17, 2005

Steve Sullivan
Sea Surveyor, Inc.
960 Grant Street, Suite C
Benicia, CA 94510

RE: South San Francisco Bay Bathymetry Survey, Contract #04-051

Dear Mr. Sullivan:

This letter serves as acceptance of the work performed by Sea Surveyor, Inc. under contract #04-051.

Sea Surveyor performed exceptional work on the bathymetry survey of South San Francisco Bay. Thanks for all of your hard work on this historic survey, your close coordination with USGS and NOAA, and for your commitment to keeping me informed of your progress. It has been a pleasure to work with you and I am very pleased with the results of the contract. The survey is already benefiting our analysis of restoration alternatives for the 15,100 acres of South Bay Salt Ponds and is destined to benefit innumerable studies of the San Francisco Bay and play a key role in our understanding of sedimentation and erosion in the Bay.

I hope we have an opportunity to work together again.

Sincerely,

Amy Hutzel
Project Manager

1330 Broadway, 11th Floor
Oakland, California 94612-2530
510·286·1015 Fax: 510·286·0470

California State Coastal Conservancy

Figure 2: Formal Letter Accepting Contractor's Work under Contract #04-051.

To increase the accuracy of the soundings, modern advances in computers, navigation, and geophysics were incorporated into the survey. High-speed computers and the Global Positioning System (GPS) replaced the sextant or LORAN-C navigation systems used for historical surveys, and the survey vessel collected soundings along straight lines instead of the arcs and radials used in some previous surveys. Recent advances in marine geophysics were also incorporated into the survey with the use of a seabed classification system that records and analyzes the acoustic properties of South Bay sediments, providing a baseline for future South Bay surveys. A heave compensator was added to remove sounding inaccuracies caused by waves.

Soundings were collected during periods of high tide in order to optimize “bank-to-bank” coverage of South Bay tidal flats, and provide maximum overlap with the aerial topographic LIDAR data collected months earlier during periods of low tide. Surveys were conducted both day and night to maximize survey efficiency and take advantage of the higher tides and calmer conditions that occur at night.

The hydrographic survey mapped 250 square kilometers (97 square miles) of tidally submerged lands in South San Francisco Bay. Soundings were collected in South Bay along a total of 2,600 km (1,618 miles) of trackline spaced at nominal 100m intervals. In addition to the South Bay survey, over 35 km (approximately 22 miles) of selected sloughs and creeks were surveyed along cross-sections spaced at nominal 100m intervals.

Soundings from the hydrographic survey are in meters referenced to two separate vertical datum, including MLLW and NAVD-88. USGS will compare soundings referenced to MLLW to historical NOS surveys of South San Francisco Bay, and merge soundings referenced to NAVD-88 with the May 2004 LIDAR topographic data to create a terrain model of existing land surface elevation and bay bathymetry.

After passing all quality control checks, the final high-frequency (200kHz) soundings were thinned to 1m intervals, grouped into zones, and delivered to the USGS Pacific Science Center in x,y,z format on CD disks referenced to Zone 10 North of the Universal Transverse Mercator (UTM) 1983 grid. Final soundings are referenced vertically to both NAVD-88 and MLLW, where possible. Other data delivered to USGS include:

- Tide data collected at 6-minute intervals by multiple pressure-sensing gauges in the sloughs and creeks of South San Francisco Bay.
- Raw (un-edited, un-corrected for tide) soundings spaced at nominal 0.15m intervals,
- Digital depthfinder records, including barcheck calibrations, in .pcx format.

Quester Tangent, the manufacturer of the seabed classification system, processed the low-frequency (50kHz) soundings and developed a map of acoustic diversity for South San Francisco Bay showing the seabed segmented into acoustically similar units. The low-frequency (50kHz) soundings were delivered to USGS in time-tagged, draft-corrected x,y,z format without correcting for tide.

The purpose of this Quality Control (QC) Report is to document the survey equipment, personnel, calibrations, analytical techniques, and QC procedures used for conducting the Class 1 hydrographic survey of South San Francisco Bay. The following sections describe the methodology, results, and QC procedures used for the survey.

3. FIELD SURVEY METHODS

The hydrographic survey of South San Francisco Bay was conducted using Class I standards, methods and accuracies outlined in the U.S. Army Corps of Engineers' *HYDROGRAPHIC SURVEYING MANUAL* (USACE, 2002) and NOAA's *HYDROGRAPHIC SURVEYS – SPECIFICATIONS AND DELIVERABLES* (NOS, 2003a). Tidal height was monitored, and soundings corrected for tide, using NOAA procedures and standards documented in the following publications:

- User's Guide for the Installation of Benchmarks and Leveling Requirements for Water Level Stations (NOS, 1987).
- Specifications and Deliverables for Installation, Operation, and Removal of Water Level Stations (NOS, 2003b).
- Summary of Procedures and Results from South San Francisco Bay Vertical Datum Determination and Conversion Study (NOAA, 2006).

The following sections describe the field survey methods, survey equipment, and personnel used to conduct the Class 1 hydrographic survey of South San Francisco Bay.

3.1 Field Survey Methodology

The survey was conducted using two 2-person field survey crews; one crew collected soundings during daylight periods of high tide, while the second crew used the same vessel and survey equipment to collect soundings during the high tides at night. Both survey crews practiced a strict regime of calibrating the survey-grade depthfinder twice per shift. At the beginning and end of each shift, the speed-of-sound calibration of the depthfinder was checked using the barcheck procedure and the transducer draft was manually-measured through the sonar well. Any discrepancies between the before-and-after or day-and-night calibrations were immediately investigated and resolved.

Soundings were collected across South San Francisco Bay along tracklines spaced at nominal 100m intervals and oriented in a northwest-southeast direction (perpendicular to the general bathymetric contour of the seafloor). Survey tracklines were divided into tide zones defined by NOAA (2006), with 100m overlap into adjacent zones. Dividing the tracklines into tide zones simplified processing the soundings and provided a QC check in the overlap area around tide zone boundaries. Unless obstructions were encountered, soundings near the shoreline extend to elevation +0.3m MLLW or higher. When practical, soundings were collected around obstructions to complete sounding lines. Overlap between survey areas and cross-lines (tie-lines) are provided for quality-control assessment of the soundings.

Soundings were collected during all stages of the tide, provided that sufficient water depth was available for safe navigation. Areas shallower than –1m MLLW were surveyed during periods of extreme high tides when the water surface elevation is +1.75m MLLW or higher. Areas deeper than –3m MLLW were surveyed during all stages of the tide (high and low), but always during periods of "neap" tides when the water surface elevation changes less than 1.25m between high and low tides. Survey lines terminated early because of shallow water during low or moderate tides were re-surveyed during extreme high tides in order to collect soundings as far upland as possible. For QC purposes, survey lines terminated early at low tide are re-surveyed at high tide with a minimum 100m overlap.

During the hydrographic survey, a written log is prepared on a standardized form for each dayshift and nightshift. The log documents the personnel, vessel, equipment, layout, and weather/sea conditions. The time that each survey line begins and ends is entered in the log, and space is provided for notes to be added to describe unusual occurrences. The speed-of-sound adjustment, transducer draft, and depth of deepest barcheck are also included in the log. The digital depthfinder record is annotated to indicate the location of each sounding line, the date and time (hour/minute) each sounding line is taken, and explanation for any line terminated early.

3.2 Survey Equipment

The Class 1 hydrographic survey of South San Francisco Bay used the following equipment:

- One of three hydrographic survey vessels of 9m, 8m, or 4m length.
- One INNERSPACE Model 455 survey-grade depthfinder with 3-degree transducer.
- One TSS DMS-05 motion sensor.
- One QUESTER TANGENT Model QTC-V seabed classification system with 50kHz transducer, SUZUKI depthfinder, and laptop computer.
- One OMNISTAR GPS receiver with differential subscription service and antennas.
- Three *CL* internal-recording, pressure-sensing tide gauges with external barometric sensors.
- Four NOAA tide gauges, including AQUATRAK Model 4100 air-acoustic water level sensors, SUTRON 8210 data loggers, and GOES satellite antennas.
- One DELL navigation computer with flat screen monitor and navigation software package for collecting and processing soundings.
- One Honda 1kW generator or 110-volt inverter.
- Six 12-volt deep-cycle batteries and one battery charger.
- One survey-grade construction level, tripod, and stadia rod.
- One barcheck with 17m (55’) stainless steel cable marked at 1.5m (5’) depths.
- Three leadlines (weighted survey tape incremented at 0.1’ intervals).
- One Chevrolet Suburban vehicle for towing vessel and trailer.
- One of three boat trailers for 9m, 8m or 4m survey vessels.

The following sections provide a detailed description of the vessels, depthfinders, navigation system, and tide gauges used for conducting the Class 1 hydrographic survey.

3.2.1 Survey Vessels

The Class 1 hydrographic survey of South San Francisco Bay was conducted using calibrated hydrographic survey vessels. These survey vessels employ a integrated system of sensors to measure and record the depth of water below the vessel at a rate of 20-times each second, three-dimensional motion of the vessel, and location of the vessel. Soundings are collected by a hull-mounted transducer located in the exact center of the vessel. A motion sensor, located directly above the transducer, records the roll/pitch/heave of the vessel and transmits changes in vessel displacement to the depthfinder as a correction to the soundings. The GPS antenna is located on the roof of the vessel directly over the transducer. Test course calibrations and squat/settlement curves are posted in each survey vessel and are incorporated in the survey computations software program, per Corps of Engineers specifications for Class 1 hydrographic surveys (USACE, 2002).

The survey vessels are calibrated to collect soundings while moving in a straight line and constant velocity. Sounding accuracy decreases when the vessel squat changes during turns and speed changes. To maximize accuracy of the sounding data, the vessels did not make abrupt turns nor alter speed until a survey line was completed, including QC overlap areas at the boundary of the tide zones. Sounding accuracy decreases when the vessel abruptly changes course and speed, which is unavoidable when collecting cross-sectional soundings in narrow sloughs and creeks.

Several times monthly, one of the survey vessels collecting soundings in South San Francisco Bay would undergo extensive calibration checks in the Port of Oakland by independent surveyors from the U.S. Army Corps of Engineers and Great Lakes Dredge & Dock. To pass these calibration checks, soundings collected along five (5) pre-selected survey lines across the Oakland ship channel had to match those collected by two independent survey vessels within ±1m horizontal and ±0.1' vertical.

The Contractor used three (3) vessels to survey South San Francisco Bay, including the 9m Minotaur, the 8m Betty Jo, and a 4m flat-bottom skiff. Each vessel has distinct advantages that are useful for surveying in various environments in South San Francisco Bay. The larger and faster Minotaur was used to survey the majority of South San Francisco Bay, while the heavier and more rugged Betty Jo surveyed the hazardous, shallow areas between the Dumbarton Bridge and Coyote Creek. The flat-bottom skiff collected soundings in the sloughs and creeks.

A description of each vessel used during the South San Francisco Bay survey is provided in the following sections.

Minotaur: The 9m (29') Minotaur is a lightweight aluminum vessel with a shallow 0.6m (2') draft that collected soundings and seabed classification data in all areas north of the Dumbarton Bridge. The Minotaur was based in San Leandro Marina during the survey. A 200hp, 4-stroke outboard motor powers the Minotaur to cruising speeds of 30-knots. The Minotaur was selected as the primary survey vessel for the hydrographic survey because its fast cruising speed minimized transit time to the various survey areas in South San Francisco Bay, and its efficient 4-stroke engine minimized fuel costs. The radar and spotlights on the roof of the Minotaur

Figure 3: 9m Survey Vessel "Minotaur"

allowed surveyors to avoid obstacles at night. The enclosed cabin, diesel-powered heater, cookstove, sink, and toilet made the Minotaur comfortable for the crew while they surveyed through the cold winter days and nights of January-February 2005.

While collecting soundings, the Minotaur maintained an over-the-ground velocity of 5.5 knots, ±0.25 knots. A 200kHz, 3-degree transducer, mounted in a sonar well through the middle of the vessel, collects 20 soundings/second. The sonar well allows the survey crew to directly measure the depth (draft) of the hull-mounted transducer, and calibrate the depthfinder for acoustic velocity using the barcheck procedure. The antenna for the differential GPS navigation is on the vessel's roof directly over the transducer in the sonar well. The 50kHz transducer for the seabed classification system is attached to an over-the-side mount on the vessel's starboard side. Test course calibration and squat/settlement curves for the Minotaur are posted in the survey vessel and are incorporated in the survey computations software program, per Corps of Engineers specifications for Class 1 hydrographic surveys (USACE, 2002).

Since the lightweight (2-ton) aluminum Minotaur is susceptible to vertical displacement (heave) by waves, a TSS DMS-05 motion sensor was installed next to the sonar well to measure and correct the soundings for heave. The motion sensor data was input directly into the survey-grade depthfinder so that the raw soundings are corrected for vessel heave.

Betty Jo: The Betty Jo is a 8m (25') *Farallon Whaleback* powered by a Chrysler-Marine 318 gas engine with single shaft-driven propeller. The Betty Jo surveyed the hazardous shallow-water area between the Dumbarton Bridge and Coyote Creek. The thick fiberglass hull of the Betty Jo protected the crew and survey equipment against frequent collisions with shallow-water obstructions. The Betty Jo is a heavy (5-ton) vessel with 1.1m (3.5') draft, which minimizes its vertical displacement (heave) by waves. A motion sensor is typically unnecessary when collecting soundings with the Betty Jo, especially in calm conditions.

Figure 4: 8m Survey Vessel "Betty Jo"

The Betty Jo maintains an over-the-ground velocity of 5.5 knots (±0.25 knots) while collecting soundings at a rate of 20 depth measurements per second. The 200kHz transducer for the survey-grade depthfinder is installed in a sonar well through the center of the vessel. The sonar well allows the draft of the transducer to be directly measured during barcheck calibrations. The antenna for the differential GPS navigation is on the vessel's roof directly over the transducer in the sonar well. The 50kHz transducer for the seabed classification system is attached to an over-the-side mount on the vessel's port side. Test course calibration and squat/settlement curves for the Betty Jo are posted in the survey vessel and are incorporated in the survey computations software program, per Corps of Engineers specifications (USACE, 2002).

The Betty Jo was based in Redwood City Marina during the survey, but was cross-calibrated to 2 other Class 1 survey vessels in the Port of Oakland several times each month. During these cross-calibrations, the Betty Jo would collect soundings along five (5) pre-selected survey lines across the Oakland ship channel. Independent inspectors provided by the U.S. Army Corps of

Engineers and Great Lakes Dredge & Dock would observe the soundings being collected, then compare the soundings against those collected immediately afterwards by the survey vessels Wildcat and Diamond Reef. The independent inspectors found little difference between the soundings collected by any of the survey vessels, and all boat-to-boat calibrations matched within ±1m horizontal and ±0.1' vertical.

Flat-bottom Skiff: A 4m (14') aluminum skiff surveyed the shallow creeks and sloughs in South San Francisco Bay. The 4m skiff is powered by an 18hp NISSAN outboard motor controlled by a steering console. Weatherproof compartments hold the survey-grade depth-finder, GPS receiver, and navigation computer. A 1kW generator provides electrical power. To reach the sloughs/creeks to be surveyed, the skiff was either launched at the unpaved boat launch ramp at the head of Artesian Slough or towed by the 25' Betty Jo from Redwood City Marina to the rail-road bridge over Coyote Creek. The skiff did not utilize a 50kHz over-the-side transducer because the sloughs and creeks are too shallow to collect seabed classification data. Test course calibration and squat/settlement curves for the skiff are incorporated in the survey computations software program, per Corps of Engineers specifications (USACE, 2002).

Figure 5: 4m Flat-Bottom Skiff shown during slough recon surveys.

Prior to conducting the hydrographic survey of each slough, a reconnaissance survey is conducted to locate the slough centerline and determine the upland extent of the survey. Reconnaissance soundings are for planning purposes only, and are not included in the final data set. After completing the reconnaissance survey of each slough, the horizontal coordinates for the slough centerline is plotted on a digital map and segmented at 100m intervals. Survey line coordinates are then programmed into the navigation computer so that cross-sectional profiles of the slough can be surveyed at 100m intervals.

During the reconnaissance surveys, the survey-grade depthfinder's narrow-beam 200kHz transducer is attached to the side of the vessel; however, during the final cross-sectional survey of the sloughs, the survey-grade depthfinder's transducer is connected to the transom of the vessel. Attaching the transducer to the transom provides better accuracy and repeatability that does a side-mounted transducer. The GPS antenna is mounted directly over the transducer, regardless if it is side-mounted or transom-mounted.

3.2.2 Survey-Grade Depthfinder

Soundings are collected using an INNERSPACE Model 455 survey-grade depthfinder with digital and graphic output. Soundings are measured in feet to the nearest 0.1-foot, but reported in meters (m) to the nearest 0.01m. The depthfinder collects 20 soundings/second, typically spaced at nominal 0.15m intervals along trackline.

The survey-grade depthfinder has a frequency of 208kHz, with a 3.5-degree cone measured at 6db point. The transducer for the depthfinder is mounted in a sonar well through the exact center of the vessel, per Corps of Engineers specifications for Class 1 hydrographic surveys (USACE, 2002). A center-mounted transducer is more accurate than a side-mounted transducer because it experiences less heave, pitch and roll. Mounting the transducer in an accessible sonar well simplifies calibrating the depthfinder and allows the depth of the transducer to be precisely measured to compensate for changes in vessel draft.

To ensure accurate soundings, the survey-grade depthfinder is calibrated twice during each survey period, and up to 4-times daily. The depthfinder must be calibrated for the acoustic velocity of the water column, which is a function of seawater density and directly related to conductivity, temperature, and depth. The strong tidal influence in South San Francisco Bay causes the acoustic velocity to vary not only vertically, but also horizontally and with time. During the hydrographic survey, the depthfinder is calibrated immediately before and after collecting soundings, and whenever the survey area changes. The calibrations are recorded so they can be reviewed for quality control.

The depthfinder is calibrated before and after each daily survey using the barcheck procedure (Figure 6). The pre-survey barcheck calibrates the depthfinder for acoustic velocity, while the post-survey barcheck demonstrates that the survey-grade depthfinder never varied more than ±0.1' at any of the 1.5m (5') calibration checks. The barcheck procedure consists of using a stainless steel cable marked at 1.5m intervals to lower a 0.5m (18") diameter steel plate through the sonar well. The steel plate serves as an acoustic target that is lowered to exact depths for calibrating the depthfinder. The depthfinder's speed-of-sound control is adjusted so that the acoustic target appears on the digital display precisely at its known depth. After the depthfinder is calibrated for the maximum practical depth, the barcheck is raised at 1.5m intervals so that any variations in the calibration can be recorded.

A TSS DMS-05 motion sensor is used to correct the soundings for vertical displacement of the vessel by waves. The motion sensor measures the roll, pitch, and heave of the survey vessel and transmits the data 10-times each second to the INNERSPACE depthfinder. The depthfinder uses the motion sensor data to correct the soundings for wave-induced displacements of the vessel. The motion sensor was installed only in the lightweight, aluminum vessel Minotaur during the hydrographic survey north of the Dumbarton Bridge; the motion sensor was not needed south of the Dumbarton Bridge because the survey was conducted during flat calm conditions when soundings collected by the heavy, fiberglass Betty Jo showed no sign of heave-induced errors.

3.2.3 Seabed Classification System

An acoustic seabed classification system manufactured by QUESTER TANGENT CORPORATION of Sidney, B.C., Canada recorded the bottom sediment acoustic characteristics during the hydrographic survey. A low-frequency 50kHz depthfinder monitored the acoustic characteristics of the seafloor across South San Francisco Bay, excluding the shallow sloughs and creeks. The acoustic signal is generated by a SUZUKI 2025 depthfinder using a 50kHz transducer with 24-degree beam width on an over-the-side mount on the survey vessel. A QTC VIEW sounder interface module records the return signal. The depthfinder was operated at 0-to-40m range with a pulse duration of 0.3ms.

The acoustic seabed classification system digitally acquires each raw echo at a rate of three soundings per second and records the waveform for later analyses. GPS navigation data is simultaneously logged as comma-delimited ASCII records which in this case was a NMEA GPGGA string. Both the full waveform and envelope data were logged by the system. The sonar data is stored in a laptop computer using a QTC proprietary format

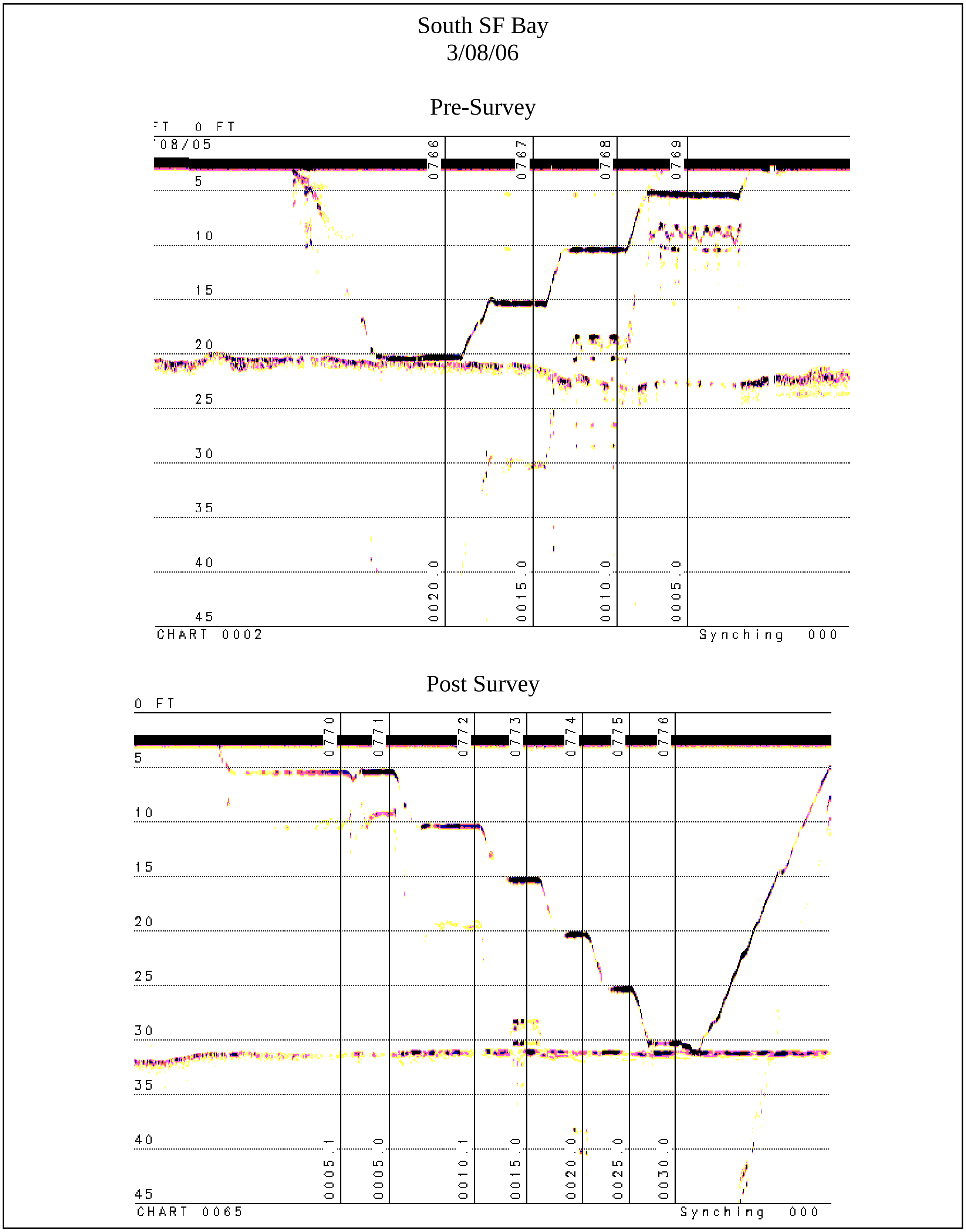

Figure 6: Typical barcheck calibration of the survey-grade depthfinder, showing daily pre- and post-survey barcheck calibrations at 1.5m (5') depth intervals.

3.2.4 Differential GPS Navigation

The soundings and all data are referenced to UTM Zone 10 North geographic coordinates, in meters, based on the Global Positioning System (GPS) with differential-corrections. Although differential GPS allows sub-meter level accuracies to be routinely obtained, horizontal accuracies achievable from a moving survey vessel are likely in the range of $\pm$3m.

The differential GPS navigation system includes a GPS receiver aboard the survey vessel, an onshore GPS base station that calculates the differential correction, and a satellite that transmits the differential correction to the survey vessel. For the South Bay survey, an OMNISTAR Model LR-8 GPS receiver with differential correction service was used to record the location of the survey vessel at 1-second intervals during the hydrographic survey. The GPS navigation antenna is mounted on the roof of the survey vessel directly above the 3-degree transducer, making correction offsets unnecessary.

Navigation and sounding data is recorded and displayed by a computer with trackline control software aboard the survey vessel. The navigation software displays the location of the survey vessel in relation to a pre-plotted line, and provides digital information useful for helming the vessel along the line. Prior to beginning the survey, pre-plots of the planned survey lines are prepared and input into the navigation computer. The navigation system uses CORPSCON, a coordinate conversion program developed by the U.S. Army Corps of Engineers, to convert between various coordinate systems and to convert NAD-27 to NAD-83.

3.2.5 Tide Measurements

Soundings are referenced to a common vertical datum by measuring and correcting for variations in tide height. During the hydrographic survey, water surface elevation was measured at seven locations in South San Francisco Bay, including:

- San Leandro Marina (NOAA Station 9414688)
- West San Mateo Bridge (NOAA Station 9414458)
- Dumbarton Bridge (NOAA Station 9414509)
- Entrance to Coyote Creek (NOAA Station 9414575)
- Railroad Bridge crossing Coyote Creek
- Top of Artesian Slough (at San Jose Wastewater Treatment Plant)
- Alviso Slough at Gold Street Bridge (NOAA Station 9414551)

Tides at San Leandro Marina, San Mateo Bridge, and Dumbarton Bridge were monitored using air-acoustic water level sensors referenced to the MLLW vertical datum. In the sloughs and creeks, tides were measured using pressure-sensing tide gauges referenced to NAVD-88. The following sections describe the methods and equipment used to measure tides for correcting soundings to a common vertical datum.

Air-Acoustic Tide Gauges: NOAA measures tides using an AQUATRAK Model 4100 air-acoustic water level sensor controlled and monitored by a SUTRON data logger. NOAA typically uses the SUTRON Model 8200 data logger to control, record and transmit data from an air-acoustic water level sensor; however, NOAA had no Model 8200 data loggers available to loan the Contractor for the South San Francisco Bay survey. Instead, USGS provided the "next generation" of data loggers, the SUTRON Model 8210. The Model 8210 is sufficiently different from the Model 8200 that the User's Guide (NOS, 1998) for installing and operating the acoustic gauge did not apply.

Since the tide gauges could not be made operational without an instruction manual, the Contractor shipped the AQUATRAK sensors and SUTRON Model 8210 data loggers to NOAA's Field Operations Division in Chesapeake, Virginia for programming and testing. The Contractor sent an electronics technician to Chesapeake, Virginia to receive training and transport the instruments back to South San Francisco Bay for installation.

While the air-acoustic tide gauges were being programmed and tested by NOAA in Chesapeake, Virginia, the Contractor installed 10cm-diameter PVC stilling wells at San Leandro Marina, San Mateo Bridge, Dumbarton Bridge, and the entrance to Coyote Creek (Figure 7). The PVC stilling wells protect the AQUATRAK air-acoustic sensor and provide a calm water surface for measuring elevation. The PVC stilling wells are 10m long, extend 6m below the water surface at low tide, and are mounted vertically on to existing structures (pier, tower, or navigation beacon).

Figure 7: Stilling wells and air-acoustic tide gauges installed at four (4) locations, including:

Beacon 14 in San Leandro Marina (upper left),

End of San Mateo Bridge Fishing Pier (upper right),

Under Dumbarton Bridge Fishing Pier (lower left), and

On the PG&E electrical tower in Coyote Creek (lower right).

The air-acoustic tide gauges at San Leandro Marina, San Mateo Bridge, and Dumbarton Bridge became operational between 31 December 2004 and 4 January 2005. The air-acoustic tide gauge installed on the electrical tower in Coyote Creek never became operational. The 3 operating tide gauges measured water surface elevation at six (6) minute intervals, with the period of the average centered at the six minute mark (i.e., :00, :06, :12, etc.). The water level data was transmitted directly to NOAA using GOES satellite antennas provided by the California Coastal Conservancy. After processing the tide data, NOAA made the tide data available on their CO-OPS website approximately 1-week later.

<u>Pressure Sensing Tide Gauges</u>: Tides in Coyote Creek, Artesian Slough, and Alviso Slough were monitored using internal-recording, pressure-sensing tide gauges provided by the Contractor. Pressure is an indirect measure of water height above the sensor. A pressure-sensing tide gauge (Figure 8) has two pressure sensors; one above-water that monitors changes in air pressure and one below-water that measures underwater pressure. Any fluctuations in the tide record caused by changes in barometric pressure are removed by subtracting the air pressure from the underwater pressure. The tide gauge filters out waves/wakes from the tide data by averaging 0.5-second samples collected for 2-minutes centered on each 6-minute interval. The manufacturer (Coastal Leasing, Inc. of Cambridge, Massachusetts) calibrated the pressure-sensing tide gauges in December 2004 immediately prior to the field survey.

Pressure-sensing tide gauges were installed at multiple locations in the sloughs and creeks of South San Francisco. Multiple tide gauges provide backup in the event of data loss from a single instrument, and provide valuable information on the long-period wave velocity as the tide ebbs and floods. The elevation of the tide gauges was determined prior to the survey, and checked again after the survey ended, by a California-registered land surveyor using nearby tidal benchmarks for reference. In addition, the accuracy of the tide readings was manually-checked multiple times on the days that soundings were collected using a weighted tape to measure the vertical distance between the water surface and nearby benchmark. After recovering the gauges, the tide data was downloaded, processed, and transmitted to NOAA and USGS for analyses.

Figure 8: Pressure-Sensing Tide Gauge with external barometric sensor on 10m cable.

3.3 Tidal Benchmarks

During the hydrographic survey, tide data was collected at key locations in South San Francisco Bay to correct the soundings for changes in the water surface elevation. Tide data and corrected soundings are referenced to the MLLW vertical datum, which is the same vertical datum used during 5 historic surveys of South San Francisco Bay conducted by NOS at approximate 30-year intervals in 1858, 1898, 1931, 1956, and 1983. The tide data collected in January-April 2005 is from the same location and reduced by the same organization (NOS) as historical surveys.

The MLLW tidal datum is useful for comparing present with historic soundings; however, soundings must be converted to the modern North American Vertical Datum of 1988 (NAVD-88) in order to be compatible and merged with topographic data to create a terrain model. Although some of the South Bay tidal benchmarks have geodetic ties to the now superseded National Geodetic Vertical Datum of 1929 (NGVD-29), few are tied to the newly adopted NAVD-88 vertical datum and conversions are not available.

Fortunately, some of the historic tidal benchmarks set by NOS in South San Francisco Bay still exist in good, stable condition and have published MLLW elevations (http://tidesandcurrents.noaa.gov) for the modern (1983-2001) tidal epoch. Coincidently, an ongoing program by the National Geodetic Service (NGS) provides GPS-derived orthometric NAVD-88 elevations for Height Modernization control points in South San Francisco Bay on the NGS website at http://www.ngs.noaa.com. Using the Height Modernization control points as reference, the NAVD-88 elevation of the historic tidal benchmarks in South San Francisco Bay can be determined using conventional land surveying techniques and/or modern GPS survey methods. Measuring the NAVD-88 elevation of the tidal benchmarks provides information from which conversions between MLLW and NAVD-88 can be derived.

A California-registered land surveyor used static GPS techniques and conventional differential leveling methods to measure the NAVD-88 elevation of the tidal benchmarks using the Height Modernization control points as reference. Determining the NAVD-88 elevation of South Bay tidal benchmarks allows datum conversions between MLLW and NAVD-88 to be developed for South San Francisco Bay.

Prior to conducting the survey, the historic tidal benchmarks that still exist were located. After a discussion with NGS, surveyors developed a plan for measuring the NAVD-88 elevation of tidal benchmarks using Height Modernization control points as reference. The survey plan included:

- Conventional survey techniques using optical leveling equipment when the tidal benchmark and Height Modernization control point are in close proximity. Differential leveling is conducted according to both NGS and NOS standards. Leveling methods meet NGS 2nd Order specifications and the optical leveling equipment, a Zeiss NI-2 automatic level with micrometer, meets NGS leveling standards. To calibrate the optical instrument to NOS standards, the survey crew performed collimation tests daily.

- When a tidal benchmark is far from the reference Height Modernization control point, the static GPS method is used. For static GPS surveys, highly-accurate Trimble 4000-SSI receivers are set simultaneously over the tidal benchmark and Height Modernization control point, and GPS data is collected at both locations for 2 sessions of 1-hour each separated by 3-hours minimum.

- If a tidal benchmark is located under a structure and far from a Height Modernization control point, the land surveyor uses static GPS to set an offset point near the tidal benchmark, and then establishes a tie to the tidal benchmark using differential leveling.

The NAVD-88 elevation of the existing NOS tidal benchmarks in South San Francisco Bay were surveyed both before (December 2004) and after (July 2005) the hydrographic survey. A description of the historic tidal benchmarks surveyed at each tide gauge location is provided below:

<u>San Leandro Marina (NOS Station 9414688)</u>: Two historic tidal benchmarks set by NOS still exist at San Leandro Marina, including Tidal BM-4, 1974 (VM-8382) and 4688-B, 1976 (VM-8386). NOS designates TIDAL BM 4, 1974 as the primary benchmark and assigns it an elevation of 5.345m above MLLW. Tidal benchmark 4688-B, 1976 is both a secondary NOS tidal benchmark and an NGS Height Modernization control point (HT2327), with an elevation of 2.809m above MLLW and 2.690m above NAVD-88.

<u>San Mateo Bridge West Fishing Pier (NOS Station 9414458)</u>: Three historic tidal benchmarks set by NOS still exist, including Brass Disk #1 (VM-8127), Brass Pin #1 (VM-8128), and Brass Pin #2 (VM-8129). NOS designates the primary benchmark as Brass Disk #1 (VM-8127) and assigns it an elevation of 5.092m MLLW. NOTE: A Height Modernization control point labeled “Guano Reset, HT0580” is located in a well near the San Mateo Bridge West Fishing Pier, but it is different than historic tidal benchmarks called “Guano Island, 1851 (HT0579)”, “Guano Island No. 6 1851 & 1967 (HT0581)”, or “Guano Island No. 7, 1851 & 1967 (HT2279)”.

<u>Dumbarton East Fishing Pier (NOS Station 9414509)</u>: Four historic tidal benchmarks still exist, and two are listed in the NGS database with NAVD-88 elevations. NOS designates the primary benchmark as U553, 1956 (VM-8150) and assigns it an elevation of 7.290m MLLW. Secondary tidal benchmarks that still exist include V553, 1956 (VM-8151), 4509K, 1996 (VM-13327), and 4509H, 1983 (VM-8154). Tidal benchmark 4509H, 1983 is Height Modernization control point DG6880.

<u>Coyote Creek Transmission Towers (NOS Station 9414575)</u>: Five tidal benchmarks set by NOS on power transmission towers still exist and three are listed in the NGS database with approximate NAVD-88 elevations using VERTCON conversions. NOS designates the primary benchmark as TIDAL BM 1, 1975 (VM-8354) and assigns it elevation 5.518m MLLW. Secondary tidal benchmarks, their VM number, and PID number (if any) include:

Tidal BM	NOS VM No.	NGS PID No.
Lag Bolt 2	VM-8356	None
D-555, 1956	VM-8357	HT1412
E-555, 1956	VM-8358	HT1413
H-555, 1956	VM-8360	HT1409

<u>Port of Redwood City (NOS Station 9414523)</u>: NOS maintains a continuously operating air-acoustic tide gauge at the Port of Redwood City, and designates the primary bench mark as Wharf 4, 1985 (VM-13856) located nearby. NOS assigns tidal benchmark Wharf 4, 1985 an elevation of 4.639m MLLW.

Oyster Point Marina (NOS Station 9414392): One benchmark, Tidal BM 12, 1975 (VM-8109), set by NOS during historical surveys of South San Francisco Bay still exists at Oyster Point Marina. NOS assigns Tidal BM 12, 1975 an elevation of 19.286m MLLW.

Alviso/Gold Street Bridge (NOS Station 9414551): One benchmark, Tidal BM 9, 1974 (VM-8347), set by NOS during historical surveys of South San Francisco Bay still exists on Gold Street Bridge in Alviso. NOS assigns Tidal BM 9, 1974 an elevation of 6.859m MLLW.

Table 1 presents the results from the tidal benchmark survey. NOS used the survey results to define the MLLW-to-NAVD88 datum conversions for all areas of South San Francisco Bay, except Artesian Slough, Upper Mud Slough and Upper Coyote Creek.

Table 1: Results from Survey of Tidal Benchmarks and Height Modernization Control Points.

	SITE	Oyster Point Marina
INFORMATION OBTAINED FROM NOS WEBSITE AT http://tidesandcurrents.noaa.gov	Tidal Benchmark	Tidal BM 12, 1975
	NOAA Number	9414392
	VM Number	8109
	MLLW Elevation	63.27 ft (19.286m)
RESULTS FROM 2005 LAND SURVEY BY TUCKER & ASSOCIATES PLS #4460	NAVD-88 Elevation	62.82 ft (19.147m)
	Latitude WGS-84	37° 39' 44" N
	Longitude WGS-84	122° 23' 13" W
	Methods	Differential leveling from nearby offset point set by 2 sessions of Static GPS of 1-hour each separated by 3-hours minimum.
	Month/Year of Survey	July 2005.
	Elevations	Session 1: 57.849' (17.632m) Session 1: 57.771' (17.609m)
HEIGHT MODERNIZATION CONTROL POINT USED AS REFERENCE (from NGS http://www.ngs.noaa.com)	Height Mod. Control Pt.	Guano Island Reset
	PID Number	HT0580
	Elevation (NAVD-88)	11.38 ft (3.468m)
	Epoch	2002.75
TIDE DATA COLLECTED AT SITE	Tide Gauge Type	None
	Data Duration	None
	Vertical Datum	None
	Data File Name(s)	None

	SITE	Alviso - Gold Street Bridge	Coyote Creek Tower #1	Coyote Creek Tower #2
INFORMATION OBTAINED FROM NOS WEBSITE AT http://tidesandcurrents. noaa.gov	Tidal Benchmark	Tidal BM 9, 1974	Tidal BM 1, 1975	E-555, 1956
	NOAA Number	9414551	9414575	9414575
	VM Number	8347	8354	8358
	MLLW Elevation	22.50 ft (6.859m)	18.10 ft (5.518m)	15.10 ft (4.603m)
RESULTS FROM 2005 LAND SURVEY BY TUCKER & ASSOCIATES PLS #4460	NAVD-88 Elevation	20.53 ft (6.258m)	16.58 ft (5.055m)	13.52 ft (4.121m)
	Latitude WGS-84	37° 25' 19.37" N	37° 27' 46" N	37° 27' 43" N
	Longitude WGS-84	121° 58' 37.89" W	122° 01' 30" W	122° 01' 32" W
	Methods	Static GPS - 2 Sessions of 1-hour each separated by 3-hours minimum.	Differential leveling from nearby offset point set by 2 sessions of Static GPS of 1-hour each separated by 3-hours minimum.	Differential leveling from nearby offset point set by 2 sessions of Static GPS of 1-hour each separated by 3-hours minimum.
	Month/Year of Survey	July 2005.	July 2005.	July 2005.
	Elevations	Session 1: 20.5316 ft (6.2580m) Session 2: 20.5321 ft (6.2582m)	Session 1: 10.7946 ft (3.2902m) Session 2: 10.7744 ft (3.2840m)	Session 1: 10.7946 ft (3.2902m) Session 2: 10.7744 ft (3.2840m)
HEIGHT MODERNIZATION CONTROL POINT USED AS REFERENCE (from NGS http://www.ngs.noaa.com)	Reference Benchmark	Z1370	Z1370	Z1370
	PID Number	HS4389	HS4389	HS4389
	Elevation (NAVD-88)	6.365 ft (1.941m)	6.365 ft (1.941m)	6.365 ft (1.941m)
	Epoch	2002.75	2002.75	2002.75
TIDE DATA COLLECTED AT SITE	Tide Gauge Type	SSI Pressure	SSI Pressure	Same as Coyote Crk Tower 1
	Data Duration	4/1/05 to 4/5/05	3/7/05 to 4/6/05	Same as Coyote Crk Tower 1
	Vertical Datum	NAVD-88	NAVD-88	Same as Coyote Crk Tower 1
	Data File Name(s)	Alvisoapril05	Coycrkearlymarch05, Coycrk latemarch05, & Coycrkapril05	Same as Coyote Crk Tower 1

TABLE 1 (continued): Results from Survey of Tidal Benchmarks and Height Modernization Control Points.

	SITE	San Leandro Marina	San Mateo Bridge West	Dumbarton Fishing Pier
INFORMATION OBTAINED FROM NOS WEBSITE AT http://tidesandcurrents.noaa.gov	Tidal Benchmark NOAA Number VM Number MLLW Elevation	Tidal BM 4, 1974 9414688 8382 17.54 ft (5.345m)	Stamping One 9414458 8127 16.71 ft (5.092m)	U 553, 1956 9414509 8150 23.92 ft (7.290m)
RESULTS FROM 2005 LAND SURVEY BY TUCKER & ASSOCIATES PLS #4460	NAVD-88 Latitude WGS-84 Longitude WGS-84	17.09 ft (5.209m) 37° 41' 43" N 122° 11' 37" W	15.96 ft (4.864m) 37° 34' 25" N 122° 15' 43" W	22.68 ft (6.913m) 37° 30' 37" N 122° 06' 40' W
	Methods	Differential leveling between Height Modernization Control Point and Tidal Benchmark.	Differential leveling between Height Modernization Control Point and Tidal Benchmark.	Differential leveling between Height Modernization Control Point and Tidal Benchmark.
	Month/Year of Survey	December 2004.	December 2004.	December 2004.
	Elevations	17.09 ft (5.209m)	15.96 ft (4.864m)	22.68 ft (6.913m)
HEIGHT MODERNIZATION CONTROL POINT USED AS REFERENCE (from NGS http://www.ngs.noaa.com)	Reference Benchmark PID Number Elevation (NAVD-88) Epoch	4688B, 1976 HT2327 8.825 ft (2.690m) 2002.75	Guano Island Reset HT0580 11.38 ft (3.468m) 2002.75	941-4509-H DG6880 9.68 ft (2.950m) 2002.75
TIDE DATA COLLECTED AT SITE	Tide Gauge Type Data Duration Vertical Datum Data File Name(s)	NOAA Air Acoustic 1/4/05 to 2/16/05 MLLW Data available at http://tidesandcurrents.noaa.gov	NOAA Air Acoustic 12/31/04 to 3/30/05 MLLW Data available at http://tides andcurrents.noaa.gov	NOAA Air Acoustic 1/1/05 to 4/5/05 MLLW Data available at http://tidesandcurrents.noaa.gov

TABLE 1 (continued): Results from Survey of Tidal Benchmarks and Height Modernization Control Points.

	SITE	Coyote Creek RR Bridge	Artesian Slough South	Redwood City
INFORMATION OBTAINED FROM NOS WEBSITE AT http://tidesandcurrents.noaa.gov	Tidal Benchmark	Top Edge of Concrete Deck	Top of I-Beam Post	Wharf 4, 1985
	NOAA Number	None	None	9414523
	VM Number	None	None	13856
	MLLW Elevation	Not Available	Not Available	15.22 ft (4.639m)
RESULTS FROM 2005 LAND SURVEY BY TUCKER & ASSOCIATES PLS #4460	NAVD-88 Elevation	11.76 ft (3.584m)	8.33 ft (2.539m)	14.15 ft (4.313m)
	Latitude WGS-84	37° 27' 36.54" N	37° 26' 26" N	37° 30' 33.87" N
	Longitude WGS-84	121° 58' 28.85" W	121° 57' 30" W	122° 12' 42.14" W
	Methods	Static GPS - 1 session of 30-minute duration.	Differential leveling from nearby offset point set by 1-session of Static GPS of 3.25-hour duration with multiple solutions.	Static GPS - 2 Sessions of 1-hour each separated by 3-hours minimum.
	Month/Year of Survey	July 2005.	July 2005.	July 2005.
	Elevations	Session 1: 11.76 ft (3.585m)	Z-1370 = 11.89 ft (3.624m) Tidal BM 9 = 11.88 ft (3.621m)	Session 1: 14.1293 ft (4.307m) Session 1: 14.1806 ft (4.322m)
HEIGHT MODERNIZATION CONTROL POINT USED AS REFERENCE (from NGS http://www.ngs.noaa.com)	Height Mod. Control Pt.	Z-1370	Z-1370	Guano Island Reset
	PID Number	HS4389	HS4380	HT0580
	Elevation (NAVD-88)	6.365 ft (1.941m)	6.365 ft (1.941m)	11.38 ft (3.468m)
	Epoch	2002.75	2002.75	2002.75
TIDE DATA COLLECTED AT SITE	Tide Gauge Type	SSI Pressure	SSI Pressure	NOAA Air Acoustic
	Data Duration	3/21/05 to 4/5/05	3/21/05 to 3/23/05	Continuous
	Vertical Datum	NAVD-88	NAVD-88	MLLW
	Data File Name(s)	RRBmarch05 & RRBapril05	Artesiansloughmar05	Data available at http://tidesandcurrents.noaa.gov

TABLE 1 (continued): Results from Survey of Tidal Benchmarks and Height Modernization Control Points.

3.4 Survey Schedule

The hydrographic survey began on 10 January 2005 and finished on 5 April 2005. Table 2 provides a summary of the survey activities, including dates, zones, calibration results and data collected. The survey collected soundings and seabed classification data day and night, during optimal tide and weather conditions. Barcheck calibration of the survey-grade depthfinder occurred twice during each survey period (day and night) to the deepest depth available in the area. The seabed classification system collected data throughout South San Francisco Bay, but not in the shallow sloughs and creeks.

TABLE 2: Summary of survey dates, calibrations, and data collected in South San Francisco Bay

Date	Shift	Tide Zone	Speed of Sound	Max. Depth of Pre- & Post-Barchecks	Soundings	Seabed Classif-ication
1/10/05	Day	SFB34	4850	10’ & 10’	X	X
1/12/05	Day	SFB34	4830	10’ & 10’	X	X
1/13/05	Day	SFB34	4840	10’ & 10’	X	X
1/14/05	Day	SFB34, SFB37	4840	10’ & 10’	X	X
1/15/05	Day	SFB34, SFB35	4840	10’ & 10’	X	X
1/15/05	Night	SFB34, SFB35	4840	10’ & 10’	X	X
1/16/05	Day	SFB37	4840	10’ & 10’	X	X
1/16/05	Night	SFB35	4840	10’ & 40’	X	X
1/17/05	Day	SFB37	4840	10’ & 35’	X	X
1/17/05	Night	SFB35, SFB33	4840	15’ & 30’	X	X
1/18/05	Day	SFB37, SFB38	4840	10’ & 10’	X	X
1/18/05	Night	SFB36	4840	25’ & 25’	X	X
1/19/05	Day	SFB31, SFB37	4840	15’ & 15’	X	X
1/19/05	Night	SFB33	4840	25’ & 40’	X	X
1/20/05	Day	SFB31, SFB37	4840	40’ & 40’	X	X
1/20/05	Night	SFB36	4840	45’ & 35’	X	X
1/21/05	Day	SFB37, SFB38	4840	40’ & 40’	X	X
1/21/05	Night	SFB36, SFB38	4840	20’ & 50’	X	X
1/22/05	Day	SFB37	4840	10’ & 10’	X	X
1/23/05	Day	SFB37, SFB38	4840	10’ & 10’	X	X
1/24/05	Day	SFB38	4840	35’ & 45’	X	X

1/25/05	Day	SFB38	4840	45’ & 45’	X	X
1/26/05	Day	SFB38, SFB39	4840	45’ & 45’	X	X
1/27/05	Day	SFB38, 39, 40	4840	45’ & 45’	X	X
1/28/05	Day	SFB38, SFB39	4840	45’ & 45’	X	X
2/02/05	Night	QC Survey Lines	4860	35’ &35’	X	X
2/03/05	Night	SFB34, 37,38,39	4860	10’, 30’, & 45’	X	X
2/04/05	Night	SFB39	4860	40’ & 40’	X	X
2/05/05	Night	SFB39	4860	25’ & 25’	X	X
2/07/05	Day	SFB40, SFB42	4860	40’ & 40’	X	X
2/08/05	Day	SFB39, SFB40	4860	40’ & 40’	X	X
2/09/05	Day	SFB40	4850	40’ & 40’	X	X
2/10/05	Day	SFB42	4860	35’ & 35’	X	X
2/11/05	Day	SFB42	4860	40’ & 40’	X	X
2/19/05	Day	SFB42, SFB43	4860	35’ & 10’	X	X
2/23/05	Day	SFB43	4860	40’ & 40’	X	X
2/24/05	Day	SFB43, SFB	4860	45’ & 45’	X	X
2/25/05	Day	SFB44	4860	15’ & 15’	X	X
2/26/05	Day	SFB44	4860	20’ & 15’	X	X
2/28/05	Day	QC lines	4880	50’ & 40’	X	X
3/07/05	Day	SFB43	4880	50’ & 45’	X	X
3/08/05	Day	SFB44, SFB46	4880	20’ & 30’	X	X
3/09/05	Day	SFB46, SFB47	4870	15’ & 30’	X	X
3/10/05	Day	SFB44	4870	15’ & 15’	X	X
3/11/05	Day	Coyote Creek	4800	15’ & 15’	X	
3/12/05	Day	Ravenswood Slough (recon)	4800	10’ & 10’	X	
3/22/05	Day	Coyote Creek & Artesian Slough	4770	10’ & 10’	X	
3/24/05	Day	Coyote Creek	4700	10’ & 10’	X	
3/25/05	Day	Mud Slough	4700	10’ & 10’	X	
3/26/05	Day	Ravenswood Slough	4700	5’ & 10’	X	
4/05/05	Day	Alviso Slough	4720	10’ & 10’	X	

TABLE 2: Summary of survey dates, calibrations, and data collected in South San Francisco Bay

3.5 Survey Personnel

The Field Survey Leader for the hydrographic survey is Mr. Steve Sullivan. Mr. Sullivan is Vice-President of Sea Surveyor, Inc. and he is responsible for overall sounding accuracy. Mr. Sullivan helmed the survey vessel at night, and inspected the depth and navigation data collected during the day to ensure pre- and post-survey calibrations are within tolerance.

Two teams comprised of two members each conducted the hydrographic survey. One team surveyed during the day, while the second team used the same boat and survey equipment to survey at night. Survey crewmembers included:

Steve Sullivan	Field Survey Leader & Vessel Operator (night shift)	25-years experience
Scott Cross	Vessel Operator (day shift)	15-years experience
James Ramber	Navigator/Sonar Operator (night shift)	40-years experience
Shawn Emard	Navigator/Sonar Operator (day shift)	7-years experience

Mr. Karl Rhynas of Quester-Tangent Corporation installed and tested the 50kHz seabed classification system aboard the survey vessel. Mr. Tom Hamel and Mr. Matt Tanner of Sea Surveyor, Inc. installed and maintained the air acoustic and pressure-sensing tide gauges. Mr. Tom Tucker, California-registered land surveyor No. 4460, used optical and GPS techniques per NOAA specifications to determine the elevation of the air acoustic and pressure-sensing tide gauges. Mr. Tucker also used GPS techniques and first-order Height Modernization benchmarks to determine the NAVD-88 elevation of NOS tidal benchmarks.

Mr. Manoj Samant managed NOAA's involvement in the South San Francisco Bay hydrographic survey. Mr. Samant coordinated the activities of the Contractor in numerous tasks to ensure results meet NOAA standards for water level measurements. Mr. Samant provided the Contractor with the location of historic tidal benchmarks and proper methods for surveying using optical and GPS methods. Mr. Samant advised the land surveyor on how to determine the elevation of the air-acoustic tide gauges, and he coordinated the loan of NOAA's air-acoustic sensors. Mr. Samant also coordinated NOAA's analytical efforts to define the MLLW vertical datum and NAVD-88 conversions for South San Francisco Bay.

Mr. Tom Mero, Chief of the CO-OPS Requirements and Development Division, reviewed the scope of work prepared by USGS for the hydrographic survey and provided specific instructions regarding the proper location of the tide monitoring stations and need to use tidal zonation for correcting the soundings. Mr. Clyde Kakazu of NOAA's Pacific Operation Branch in Seattle, Washington made a site visit with the Contractor to tide gauge locations in South San Francisco Bay and provided valuable insight into installation methods, problems, and solutions. Mr. Phil Labraro of NOAA's Field Operations Division in Chesapeake, Virginia programmed the air acoustic tide gauges and provided technical advice on proper installation and use of the instruments. NOAA's Mr. Tom Landon, and others, prepared, tested and shipped the tide gauges to the Contractor.

4. ANALYTICAL METHODS

After completing each day of the field hydrographic survey, the Contractor copied the sounding and navigation data on to a compact disk (CD) and transferred the data to their office in Benicia, California for review and processing. In the office, raw soundings are edited to remove extraneous depth and navigation spikes and tide corrections are applied to reduce the soundings to a common vertical datum. Initially, soundings in South San Francisco Bay were referenced to MLLW, while soundings in the sloughs and creeks were referenced to NAVD-88. The South Bay soundings were then converted to the NAVD-88 vertical datum, and the slough/creek soundings converted to MLLW (where available), using NOAA-provided conversions.

The following sections describe the vertical datum conversions, tide data, and tide zonation scheme used for the South San Francisco Bay hydrographic survey.

4.1 Vertical Datum Conversions

A California-registered land surveyor used fast-static GPS techniques referenced to first order Height Modernization benchmarks to determine the NAVD-88 elevation of NOAA tidal benchmarks throughout South San Francisco Bay. After evaluating the NAVD-88 elevation of South Bay tidal benchmarks, NOAA (2006) developed the datum conversions between MLLW and NAVD-88 for tide zones in South San Francisco Bay (Table 3).

Using the NOAA-provided datum conversions, South Bay soundings referenced to MLLW can be converted to NAVD-88 and the slough/creek soundings referenced to NAVD-88 can be converted to MLLW. NAVD-to-MLLW conversions are approximated for Tide Zones 51-54, which includes Artesian Slough, the upstream-most portion of Mud Slough, and the upstream-most portion of Coyote Creek. Located at the edge of tidal influence, these areas have insufficient water at low tide for gauges to operate, making defining the MLLW datum difficult.

Table 3: Vertical Datum Conversions by Tide Zone for South San Francisco Bay (NOAA, 2006).

Tidal Zone	NAVD-88 above MLLW	Control Station	Tidal Zone	NAVD-88 above MLLW	Control Station
SFB28	0.4’ (12cm)	9414688	SFB44	1.3’ (40cm)	9414509
SFB29	0.5’ (15cm)	9414688	SFB45	1.4’ (43cm)	9414509
SFB30	0.5’ (15cm)	9414688	SFB46	1.4’ (43cm)	9414509
SFB31	0.5’ (15cm)	9414688	SFB47	1.5’ (46cm)	9414509
SFB32	0.5’ (15cm)	9414688	SFB48	1.6’ (49cm)	9414509
SFB33	0.6’ (18cm)	9414688	SFB49	1.7’ (52cm)	9414509
SFB34	0.6’ (18cm)	9414688	SFB50	1.7’ (52cm)	9414509
SFB35	0.6’ (18cm)	9414688	SFB51	1.8’-2.0’ (55-61cm)	9414509
SFB36	0.6’ (18cm)	9414688	SFB52	1.8’-2.0’ (55-61cm)	9414509
SFB37	0.7’ (21cm)	9414458	SFB53	1.8’-2.0’ (55-61cm)	9414509
SFB38	0.8’ (24cm)	9414458	SFB54	1.8’-2.0’ (55-61cm)	9414509
SFB39	0.9’ (27cm)	9414458	SFB55	1.6’ (49cm)	9414509
SFB40	1.0’ (30cm)	9414523	SFB56	1.8’ (55cm)	9414509
SFB41	1.1’ (34cm)	9414523	SFB57	2.0’ (61cm)	9414509
SFB42	1.1’ (34cm)	9414523	SFB58	1.6’ (49cm)	9414509
SFB43	1.2’ (37cm)	9414509	SFB59	1.8’ (55cm)	9414509

4.2 Tide Data Analyses

Air-acoustic tide gauges measured water surface elevation at 6-minute intervals at San Leandro Marina, San Mateo Bridge, and Dumbarton Bridge and transmitted the data directly to NOAA via the GOES satellite. The air-acoustic tide data is referenced to MLLW. Tides in the sloughs and creeks were also measured at 6-minute intervals, but referenced to the NAVD-88 vertical datum. The following sections describe the analytical techniques used to correct the soundings for tide in South San Francisco Bay and the sloughs/creeks.

4.2.1 Tides in South San Francisco Bay

The tide data for San Leandro Marina, San Mateo Bridge, and Dumbarton Bridge is available in sequential or tabulated form, or can be viewed as a plot, on NOAA's CO-OPS website.

To retrieve the water level data from the CO-OPS website, select HISTORIC TIDE DATA from the PRODUCT menu and set SIX MINUTE WL for the time interval and MLLW as the datum. The tide data is available in either feet or meters, with time available in either Greenwich Mean or local standard. The tide stations and their duration of measurement include:

LOCATION	STATION NO.	BEGIN TIME/DATE	END TIME/DATE
San Leandro Marina	9414688	11:00 hrs on 1/04/05	13:54 hrs on 2/16/05
San Mateo Bridge, west side	9414458	16:00 hrs on 12/31/04	23:54 hrs on 3/30/05
Dumbarton Bridge, east side	9414509	00:00 hrs on 1/01/05	13:54 hrs on 4/05/05

NOAA processed the tide data, computed the tidal datum, and defined the tide zones (NOAA, 2006) using engineering and oceanographic practices specified in the NOS Hydrographic Survey Manual (NOS, 2003a). NOAA computed the MLLW datum for South San Francisco Bay after reviewing a minimum of 30 continuous days of tide data from San Leandro Marina, San Mateo Bridge, and Dumbarton Bridge. NOAA used tide data from their permanent gauges in Alameda (Station 9414750) and Redwood City (Station 9414523) as datum control.

After processing and reviewing the tide data, NOAA divided South San Francisco Bay into discrete "tide zones" (Figure 9). The height of tide in each zone is calculated by applying a time- and range-multiplier (Table 4) to actual tides measured at the controlling gauge. Boundary coordinates for the tide zones are listed in Table 5.

4.2.2 Tides in Sloughs and Creeks

Tides in the sloughs and creeks of South San Francisco Bay were monitored at multiple locations simultaneously during the hydrographic survey using pressure-sensing tide gauges referenced to NAVD-88.

After the internal-recorded data is downloaded from the tide gauge in the field, the barometric pressure data is subtracted from the underwater pressure data. Pressure data is then converted to water surface elevation using equations provided by the manufacturer based on sensor calibration immediately prior to beginning the hydrographic survey. The accuracy of the electronic tide data is checked against multiple manual tide measurements collected for quality control purposes during the field survey. Tides are manually measured using a weighed tape to determine the vertical distance between the water surface and a nearby benchmark.

Table 4: Time- and Range-Correctors and Controlling Tide Stations for Tide Zones in South San Francisco Bay (*modified from NOAA, 2006).

Zone	Time (min) Corrector	Range Corrector	Tide Station
SBF28	-24	x0.93	9414688
SBF29	-18	x0.95	9414688
SFB30	-12	x0.95	9414688
SBF31	-6	x0.97	9414688
SBF31A	0	x1.00	9414688
SBF32	-18	x0.97	9414688
SFB33	-18	x0.99	9414688
SFB34	-6	x0.99	9414688
SBF35	-6	x1.01	9414688
SBF36	-12	x1.01	9414688
SFB37	0	x0.98	9414458
SFB38	+6	x1.01	9414458
SFB39	+12	x1.03	9414458
SFB40	-6	x0.94	9414509
SBF41	-6	x0.95	9414509
SFB42	0	x0.97	9414509
SFB43	+6	x1.00	9414509
SFB44	+7*	x1.03	9414509
SFB46	+8*	x1.06	9414509

Figure 9: Tide Zones and Controlling Tide Stations (NOAA, 2006).

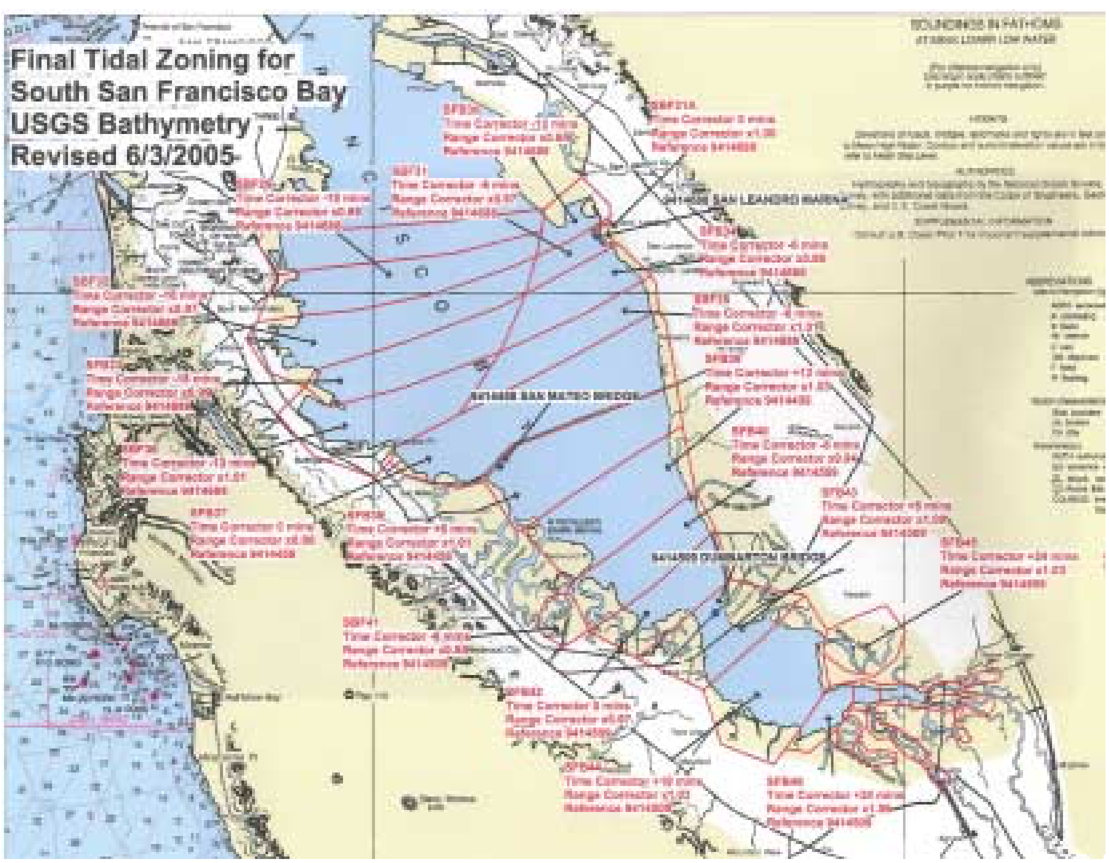

TABLE 5: Boundary Coordinates for Tide Zones in South San Francisco Bay.

Zone	Longitude	Latitude	UTM Zone 10 North	
SFB31	N 37.666447	W 122.237032	E 567,858.1m	N 4,171,148.7m
	N 37.685036	W 122.230391	E 569,740.3m	N 4,172,005.2m
	N 37.692614	W 122.208964	E 571,955.7m	N 4,173,383.2m
	N 37.704862	W 122.183702	E 571,708.5m	N 4,172,966.7m
	N 37.701128	W 122.186547	E 571,338.3m	N 4,172,700.1m
	N 37.698754	W 122.190772	E 571,075.4m	N 4,172,643.3m
	N 37.698263	W 122.193760	E 571,112.3m	N 4,172,317.8m
	N 37.695326	W 122.193373	E 571,327.1m	N 4,172,154.5m
	N 37.693838	W 122.190953	E 571,388.5m	N 4,172,155.5m
	N 37.693842	W 122.190256	E 571,573.0m	N 4,171,839.1m
	N 37.690976	W 122.188195	E 571,736.8m	N 4,171,795.0m
	N 37.690566	W 122.186341	E 571,863.3m	N 4,171,887.0m
	N 37.691385	W 122.184898	E 572,126.0m	N 4,171,971.1m
	N 37.692122	W 122.181910	E 572,403.6m	N 4,171,876.1m
	N 37.691244	W 122.178771	E 570,556.1m	N 4,170,852.4m
	N 37.682162	W 122.199823	E 567,289.3m	N 4,169,081.5m
	N 37.666447	W 122.237032	E 567,858.1m	N 4,171,148.7m
SFB33	N 37.628125	W 122.368838	E 555,963.3m	N 4,164,743.3m
	N 37.620122	W 122.374645	E 555,186.8m	N 4,163,852.0m
	N 37.609945	W 122.359816	E 556,503.1m	N 4,162,731.7m
	N 37.619515	W 122.313502	E 560,583.1m	N 4,163,822.3m
	N 37.637061	W 122.252913	E 565,914.7m	N 4,165,809.9m
	N 37.666447	W 122.237032	E 567,289.3m	N 4,169,081.5m
	N 37.660170	W 122.252151	E 565,961.5m	N 4,168,374.3m
	N 37.642223	W 122.312069	E 560,691.1m	N 4,166,342.7m
	N 37.628125	W 122.368838	E 555,963.3m	N 4,164,743.3m
SFB34	E 37.666447	W 122.237032	E 567,289.3m	N 4,169,081.5m
	E 37.682162	W 122.199823	E 570,556.1m	N 4,170,582.4m
	E 37.691244	W 122.178771	E 572,403.6m	N 4,171,876.1m
	E 37.675263	W 122.158441	E 574,211.9m	N 4,170,118.9m
	E 37.656345	W 122.199823	E 570,580.6m	N 4,167,988.0m
	E 37.637061	W 122.252913	E 565,914.7m	N 4,165,809.9m
	E 37.666447	W 122.237032	E 567,289.3m	N 4,169,081.5m
SFB35	N 37.605640	W 122.279218	E 563,602.5m	N 4,162,305.6m
	N 37.609311	W 122.275685	E 563,929.3m	N 4,162,715.3m
	N 37.637061	W 122.252913	E 565,914.7m	N 4,165,809.9m
	N 37.656345	W 122.199823	E 570,580.6m	N 4,167,988.0m
	N 37.675263	W 122.158441	E 574,211.9m	N 4,170,118.9m
	N 37.670808	W 122.155321	E 574,491.5m	N 4,169,627.1m
	N 37.658259	W 122.154111	E 574,610.8m	N 4,168,235.8m
	N 37.635781	W 122.205236	E 570,122.4m	N 4,165,702.4m

SFB36	N 37.605640	W 122.279218	E 563,602.5m	N 4,162,305.6m
	N 37.609311	W 122.275685	E 563,929.3m	N 4,162,715.3m
	N 37.637061	W 122.252913	E 565,914.7m	N 4,165,809.9m
	N 37.619515	W 122.313502	E 560,583.1m	N 4,163,822.3m
	N 37.609945	W 122.359816	E 556,503.1m	N 4,162,731.7m
	N 37.620122	W 122.374645	E 555,186.8m	N 4,163,852.0m
	N 37.606284	W 122.392370	E 553,632.5m	N 4,162,306.4m
	N 37.585377	W 122.370138	E 555,610.4m	N 4,159,999.8m
	N 37.574576	W 122.331736	E 559,009.5m	N 4,158,824.9m
	N 37.582390	W 122.322208	E 559,844.6m	N 4,159,697.9m
	N 37.589693	W 122.318244	E 560,188.7m	N 4,160,510.6m
	N 37.605640	W 122.279218	E 563,602.5m	N 4,162,305.6m
SFB37	N 37.582390	W 122.322208	E 559,844.6m	N 4,159,697.9m
	N 37.576051	W 122.313280	E 560,638.0m	N 4,159,000.3m
	N 37.569244	W 122.279517	E 563,625.1m	N 4,158,267.4m
	N 37.572467	W 122.263491	E 565,037.6m	N 4,158,636.0m
	N 37.589947	W 122.245028	E 566,652.4m	N 4,160,588.3m
	N 37.609197	W 122.180088	E 572,367.1m	N 4,162,772.1m
	N 37.621099	W 122.142525	E 575,670.4m	N 4,164,122.2m
	N 37.651755	W 122.148969	E 575,070.9m	N 4,167,518.2m
	N 37.658259	W 122.154111	E 574,610.8m	N 4,168,235.8m
	N 37.635781	W 122.205236	E 570,122.4m	N 4,165,702.4m
	N 37.605640	W 122.279218	E 574,620.5m	N 4,162,305.6m
	N 37.589693	W 122.318244	E 560,188.7m	N 4,160,510.6m
	N 37.582390	W 122.322208	E 559,844.6m	N 4,159,697.9m
SFB38	N 37.568012	W 122.259025	E 565,435.9m	N 4,158,144.8m
	N 37.548937	W 122.244749	E 566,713.6m	N 4,156,038.5m
	N 37.547887	W 122.239617	E 567,167.9m	N 4,155,925.7m
	N 37.565627	W 122.208102	E 569,935.2m	N 4,157,916.9m
	N 37.587162	W 122.166082	E 573,625.0m	N 4,160,338.2m
	N 37.600081	W 122.139024	E 576,000.8m	N 4,161,793.1m
	N 37.621099	W 122.142525	E 575,670.4m	N 4,164,122.2m
	N 37.609197	W 122.180088	E 572,367.1m	N 4,162,772.1m
	N 37.589947	W 122.245028	E 566,652.4m	N 4,160,588.3m
	N 37.572467	W 122.263491	E 565,037.6m	N 4,158,636.0m
	N 37.568012	W 122.259025	E 565,435.9m	N 4,158,144.8m
SFB39	N 37.547887	W 122.239617	E 567,167.9m	N 4,155,925.7m
	N 37.521524	W 122.208739	E 569,920.1m	N 4,153,023.3m
	N 37.539017	W 122.177542	E 572,659.9m	N 4,154,987.8m
	N 37.557772	W 122.147619	E 575,284.7m	N 4,157,092.1m
	N 37.567909	W 122.130747	E 576,764.5m	N 4,158,230.4m
	N 37.600081	W 122.139024	E 576,000.8m	N 4,161,793.1m
	N 37.587162	W 122.166082	E 573,625.0m	N 4,160,338.2m
	N 37.565627	W 122.208102	E 569,935.2m	N 4,157,916.9m
	N 37.547887	W 122.239617	E 567,167.9m	N 4,155,925.7m

SFB40	N 37.521524	W 122.208739	E 569,920.1m	N 4,153,023.3m
	N 37.516556	W 122.212021	E 569,634.7m	N 4,152,469.7m
	N 37.515136	W 122.207360	E 570,047.9m	N 4,152,315.6m
	N 37.498282	W 122.197600	E 570,926.4m	N 4,150,453.1m
	N 37.504282	W 122.184227	E 572,102.8m	N 4,151,128.9m
	N 37.519243	W 122.158443	E 574,366.9m	N 4,152,808.8m
	N 37.535469	W 122.134886	E 576,432.1m	N 4,154,627.9m
	N 37.548168	W 122.117926	E 577,917.3m	N 4,156,050.8m
	N 37.556414	W 122.123442	E 577,421.5m	N 4,156,961.1m
	N 37.567909	W 122.130747	E 576,764.5m	N 4,158,230.4m
	N 37.557772	W 122.147619	E 575,284.7m	N 4,157,092.1m
	N 37.539017	W 122.177542	E 572,659.9m	N 4,154,987.8m
	N 37.521524	W 122.208739	E 569,920.1m	N 4,153,023.3m
SFB42	N 37.498282	W 122.197600	E 570,926.4m	N 4,150,453.1m
	N 37.484174	W 122.167655	E 573,587.2m	N 4,148,910.8m
	N 37.491479	W 122.156262	E 574,587.2m	N 4,149,730.3m
	N 37.512436	W 122.124878	E 577,340.1m	N 4,152,080.7m
	N 37.523273	W 122.108187	E 578,803.8m	N 4,153,296.9m
	N 37.524174	W 122.108220	E 578,799.9m	N 4,153,396.8m
	N 37.548168	W 122.117926	E 577,917.3m	N 4,156,050.8m
	N 37.535469	W 122.134886	E 576,432.1m	N 4,154,627.9m
	N 37.519243	W 122.158443	E 574,366.9m	N 4,152,808.8m
	N 37.504282	W 122.184227	E 572,102.8m	N 4,151,128.9m
	N 37.498282	W 122.197600	E 570,926.4m	N 4,150,453.1m
SFB43	N 37.484174	W 122.167655	E 573,587.2m	N 4,148,910.8m
	N 37.468493	W 122.125785	E 577,305.2m	N 4,147,204.7m
	N 37.482373	W 122.105648	E 579,071.3m	N 4,148,761.3m
	N 37.492925	W 122.090772	E 580,375.2m	N 4,149,944.6m
	N 37.502899	W 122.077347	E 571,551.1m	N 4,151,062.7m
	N 37.515843	W 122.062839	E 582,819.2m	N 4,152,511.5m
	N 37.518187	W 122.084479	E 580,904.2m	N 4,152,752.7m
	N 37.523273	W 122.108187	E 578,803.8m	N 4,153,296.9m
	N 37.512436	W 122.124878	E 577,340.1m	N 4,152,080.7m
	N 37.491479	W 122.156262	E 574,587.2m	N 4,149,730.3m
	N 37.484174	W 122.167655	E 573,587.2m	N 4,148,910.8m
SFB44	N 37.468493	W 122.125785	E 577,305.2m	N 4,147,207.7m
	N 37.441074	W 122.114650	E 578,318.4m	N 4,144,171.9m
	N 37.431080	W 122.081994	E 581,218.1m	N 4,143,090.7m
	N 37.438937	W 122.074682	E 581,856.4m	N 4,143,968.7m
	N 37.447235	W 122.067007	E 582,526.3m	N 4,144,896.0m
	N 37.470374	W 122.047232	E 584,249.5m	N 4,147,480.7m
	N 37.486507	W 122.051379	E 583,864.8m	N 4,149,266.9m
	N 37.498010	W 122.048828	E 584,077.4m	N 4,150,545.4m
	N 37.515843	W 122.062839	E 582,819.2m	N 4,152,511.5m
	N 37.502899	W 122.077347	E 581,551.1m	N 4,151,062.7m
	N 37.492925	W 122.090772	E 580,375.2m	N 4,149,944.6m
	N 37.482373	W 122.105648	E 579,071.3m	N 4,148,761.3m

SFB46	N 37.470011	W 122.047504	E 584,249.5m	N 4,147,480.7m
	N 37.472976	W 122.030905	E 585,690.3m	N 4,147,784.1m
	N 37.458517	W 122.033082	E 585,514.3m	N 4,146,178.0m
	N 37.455360	W 122.035877	E 585,270.7m	N 4,145,825.2m
	N 37.449261	W 122.041246	E 584,802.7m	N 4,145,143.7m
	N 37.436902	W 122.059948	E 583,162.1m	N 4,143,755.9m
	N 37.438937	W 122.074682	E 581,856.4m	N 4,143,968.7m
	N 37.447235	W 122.067007	E 582,526.3m	N 4,144,896.0m
	N 37.470011	W 122.047504	E 584,249.5m	N 4,147,480.7m
SFB47	N 37.458517	W 122.033082	E 585,514.3m	N 4,146,178.0m
	N 37.458281	W 122.023516	E 586,360.6m	N 4,146,160.5m
	N 37.459315	W 122.018656	E 586,789.2m	N 4,146,279.7m
	N 37.461336	W 122.014387	E 587,164.4m	N 4,146,507.9m
	N 37.471135	W 122.015780	E 587,029.9m	N 4,147,593.8m
	N 37.473146	W 122.023226	E 586,369.1m	N 4,147,810.0m
	N 37.472976	W 122.030905	E 585,690.3m	N 4,147,784.1m
	N 37.458517	W 122.033082	E 585,514.3m	N 4,146,178.0m

Water level measurements were collected at four locations shown in Figure 10, including PG&E tower at Coyote Creek (NOAA Station 9414575), Gold Street Bridge in Alviso Slough (NOAA Station 9414551), south end of Artesian Slough (at unpaved boat ramp downstream of discharges at wastewater treatment plant), and Railroad Bridge in Coyote Creek. Tide data duration is presented below:

LOCATION	STATION	BEGIN/END DATE	FILE NAME (.tid)
PG&E Tower in Coyote Creek	9414575	3/7/05 to 3/19/05	Coycrkearlymarch05
		3/20/05 to 3/31/05	Coycrklatemarch05
		4/1/05 to 4/6/05	Coycrkapril05
Railroad Bridge over Coyote Creek	--	3/21/05 to 3/31/05	Rrbmarch05
		4/1/05 to 4/5/05	Rrbapril05
Artesian Slough boat ramp (dirt)	--	3/21/05 to 3/23/05	Artesiansloughmar05
Gold Street Bridge	9414551	4/1/05 to 4/5/05	Alvisoapril05

To determine the tide corrector to apply to cross-sectional soundings in South Bay sloughs and creeks, the tide measured by gauges upstream and downstream of the cross-section is interpolated based upon the location of the cross-section in relation to the location of the tide gauges. If an upstream gauge is not available, the tide measured by the downstream gauge is modified based upon the wave velocity and exaggeration observed in other South Bay sloughs and creeks. The following paragraphs provide a zone-by-zone description of the analytical methods used to make tide corrections for referencing the soundings collected in the sloughs and creeks to the NAVD-88 vertical datum.

Zone SFB43: Boundary coordinates provided in Table 5. Soundings referenced to MLLW using NOAA Tide Station 9414509 (Dumbarton) with time corrector of +6 minutes and range corrector of x1.00, then converted to NAVD-88 by subtracting 0.37m.

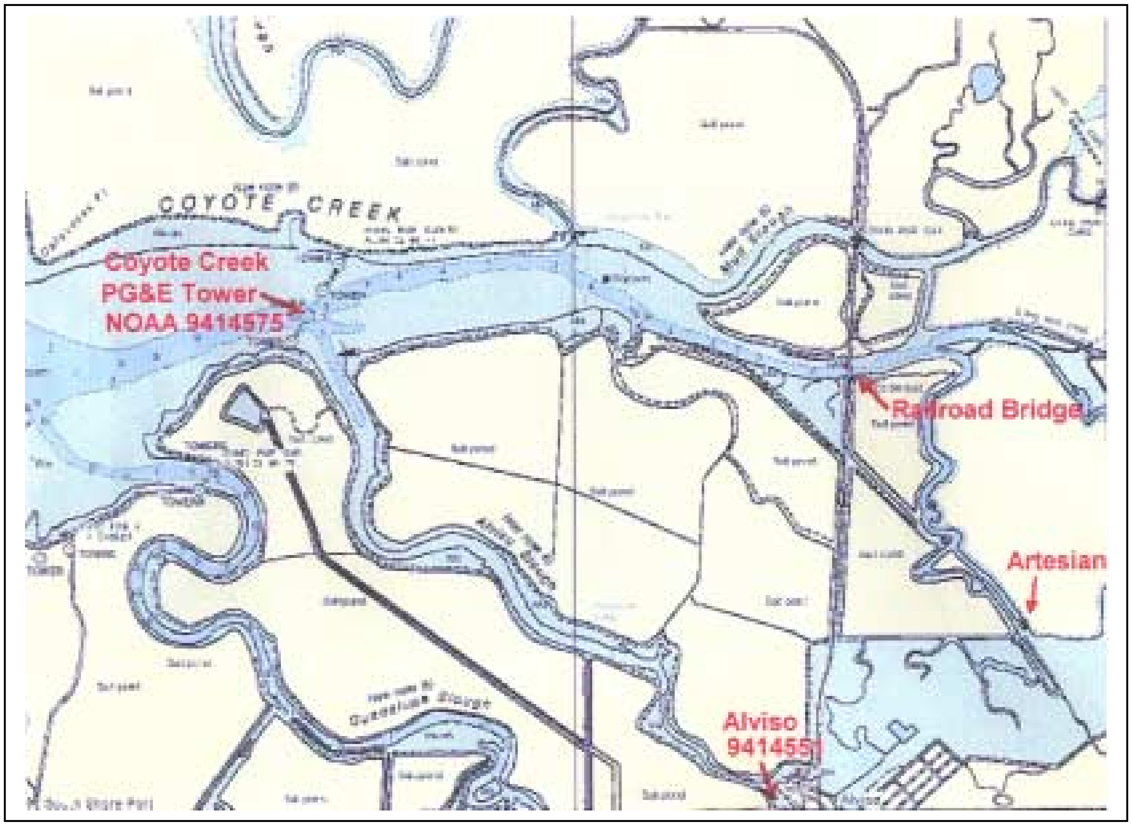

Figure 10: Location of pressure-sensing tide gauges in South Bay sloughs and creeks.

Zone SFB44: Boundary coordinates provided in Table 5. Soundings referenced to MLLW using NOAA Tide Station 9414509 (Dumbarton) with a time corrector of +7 minutes and a range corrector of x1.03, then converted to NAVD-88 by subtracting 0.4m.

Zone SFB46: Boundary coordinates provided in Table 5. Soundings referenced to MLLW using NOAA Tide Station Dumbarton with a time corrector of +8 minutes and a range corrector of x1.06, then converted to NAVD-88 by subtracting 0.43m.

Zone SFB47: Boundary coordinates provided in Table 5. March 9 and April 5 soundings referenced to NAVD88 using a pressure gauge at Coyote Creek Tower, then converted to MLLW by adding 0.46m.

Zone SFB48: Coyote Creek from east of Electrical Towers to mouth of Mud Slough. March 11 soundings referenced to NAVD88 using a pressure gauge at Coyote Creek Tower with a time corrector of +3 minutes and a range corrector of x1.01, then converted to MLLW by adding 0.49m. March 25 soundings referenced to NAVD88 using an upstream pressure gauge at the Railroad Bridge and a downstream pressure gauge at Coyote Creek Tower, then converted to MLLW by adding 0.49m.

Zone SFB49: Mouth of Mud Slough. March 25 soundings referenced to NAVD88 using an upstream pressure gauge at the Railroad Bridge and a downstream pressure gauge at Coyote Creek Tower, then converted to MLLW by adding 0.52m.

Zone SFB50: Coyote Creek, centered on Railroad Bridge. March 11 soundings referenced to NAVD88 using a pressure gauge at Coyote Creek Tower with a time corrector of +6 minutes and a range corrector of x1.02, then converted to MLLW by adding 0.52m. March 22 soundings in Coyote Creek referenced to NAVD88 using a pressure gauge at the Railroad Bridge, then converted to MLLW by adding 0.52m. March 22 soundings in Artesian Slough referenced to NAVD88 using a pressure gauge at the Railroad Bridge, then converted to MLLW by adding 0.52m. March 24 soundings in Coyote Creek referenced to NAVD88 using a pressure gauge at the Railroad Bridge, then converted to MLLW by adding 0.52m.

Zone SFB51: Upstream portion of Mud Slough. March 25 soundings in Mud Slough referenced to NAVD88 using a pressure gauge at the Railroad Bridge; no conversions yet to MLLW.

Zone SFB52: Upstream portion of Coyote Creek. March 24 soundings in Coyote Creek referenced to NAVD88 using a pressure gauge at the Railroad Bridge; no conversions yet to MLLW.

Zone SFB53: Downstream portion of Artesian Slough. March 22 soundings in Artesian Slough referenced to NAVD88 using an upstream pressure gauge in Artesian Slough and a downstream pressure gauge at the Railroad Bridge; no conversions yet to MLLW.

Zone SFB54: Upstream portion of Artesian Slough. March 22 soundings in Artesian Slough referenced to NAVD88 using an upstream pressure gauge in Artesian Slough and a downstream pressure gauge at the Railroad Bridge; no conversions yet to MLLW.

Zone SFB55: Downstream portion of Alviso Slough. April 5 soundings in Alviso Slough referenced to NAVD88 using an upstream pressure gauge in Alviso Slough and a downstream pressure gauge at the Coyote Creek Tower, then converted to MLLW by adding 0.49m.

Zone SFB56: Middle portion of Alviso Slough. April 5 soundings in Alviso Slough referenced to NAVD88 using an upstream pressure gauge in Alviso Slough and a downstream pressure gauge at the Coyote Creek Tower, then converted to MLLW by adding 0.55m.

Zone SFB57: Upstream Portion of Alviso Slough. April 5 soundings in Alviso Slough referenced to NAVD88 using an upstream pressure gauge in Alviso Slough and a downstream pressure gauge at the Coyote Creek Tower, then converted to MLLW by adding 0.61m.

The tide data collected in South San Francisco Bay sloughs and creeks is in feet, referenced to the NAVD-88 vertical datum and available in MICROSOFT EXCEL format. The tide data collected in the sloughs and creeks was also delivered in metadata format to the San Francisco District, Corps of Engineers for inclusion with their South Bay Shoreline Study.

4.3 Plotting and Checking of Tide-Corrected Soundings

The field survey was organized in a manner that simplified correcting the soundings for tide and provided a quality control check on sounding precision (repeatability). Planned survey lines were separated into individual tide zones, with the planned survey lines overlapping 100m into adjacent tide zones. Overlapping 100m into adjacent tide zones allow redundant soundings to be collected for 200m along each survey line around the boundaries of the tide zones. The 200m of overlapping soundings around the boundaries of the tide zones provide an effective tool for assessing the precision (repeatability) of soundings collected at different times, different tidal stages, and processed using different time- and range-correctors from controlling tide stations.

The soundings are edited and corrected for tide using the time- and range-corrector for the appropriate zone. After applying tide corrections, soundings are thinned in preparation for plotting. Soundings must be thinned because raw soundings, spaced at approximate 0.15m intervals, are too dense to be legible when plotted. To fit the soundings from individual tide zones on E-size paper (24" x 36") paper, soundings are thinned to a spacing of 5m intervals and plotted at scale 1:2,400 (1"=200').

After plotting, the soundings are carefully examined, especially at the intersection of "tie line" soundings collected specifically for quality control purposes along tracklines oriented perpendicular to the primary survey lines. Soundings are manually contoured at 2' depth intervals to ensure all soundings within each tide zone receive equal examination.

After the soundings in each tide zone are plotted, contoured, examined, and proven to be internally consistent, the soundings from all tide zones are combined so that overlapping soundings around the tide zone boundaries can be examined. The soundings are considered correct when overlapping soundings from adjacent tide zones match within Class 1 standards. If overlapping soundings from adjacent tide zones do not match within tolerance, the soundings from both non-agreeing tide zones undergo a rigorous quality control check. If the soundings in non-agreeing tide zones pass their respective quality control checks, then the tide corrector is likely in error and requires adjustment. For example, NOAA reviewed and modified the time- and range-correctors and controlling tide station for Tide Zones 38-42 between the San Mateo and Dumbarton Bridges after the Contractor found that the overlapping soundings from these tide zones did not match. After NOAA lowered the influence of the Redwood City station and modified the time- and range correctors for Zones 38-42, the Contractor re-applied the revised tides to the raw soundings and the overlapping soundings for these zones matched within tolerance.

4.4 Delivery of Final Soundings and Other Products

A MICROSOFT EXCEL spreadsheet was developed for each tide zone in South San Francisco Bay listing the horizontal coordinates, MLLW elevation, and NAVD-88 elevation of each sounding. After passing all quality control checks, the final high-frequency (200kHz) soundings were delivered to the USGS Pacific Science Center in Santa Cruz, California. Final soundings were thinned to 1m intervals and grouped by zone in x,y,z format on CD disks referenced to Zone 10 North of the Universal Transverse Mercator (UTM) 1983 grid. Final soundings are referenced vertically to both NAVD-88 and MLLW, where possible.

Other data delivered to USGS include:

- Tide data collected at 6-minute intervals by multiple pressure-sensing gauges in the sloughs and creeks of South San Francisco Bay.
- Raw (un-edited, un-corrected for tide) soundings spaced at nominal 0.15m intervals,
- Digital depthfinder records, including all barcheck calibrations, in .pcx format.

Quester Tangent, the manufacturer of the seabed classification system, processed the low-frequency (50kHz) data and developed a map of acoustic diversity for South San Francisco Bay showing the seabed segmented into acoustically similar units. The low-frequency (50kHz) soundings were delivered to USGS in time-tagged, draft-corrected x,y,z format without correcting for tide. Quester Tangent's report on the processing and results from the low-frequency seabed classification survey of South San Francisco Bay is presented in Section 7.

4.5 Analytical Personnel

Dr. Bruce Jaffe of the USGS Pacific Science Center prepared the scope of work for the South San Francisco Bay hydrographic survey, established the goals for the project, and served as Federal sponsor to obtain NOAA's support.

After the raw soundings are collected, Ms. Shannon Emard of Sea Surveyor, Inc. used a graphics editor to review the depth and navigation data and remove any spikes or incorrect data. Ms. Emard then used Microsoft EXCEL software to correct the soundings for tide and convert from MLLW to NAVD-88 using methods prescribed by NOAA, 2006. Mr. Shawn Emard of Sea Surveyor, Inc. conducted a second edit of the soundings to ensure that the processed data was correct. He also checked that all tide corrections and datum conversions had been properly made. Mr. Steve Sullivan, Survey Manager, conducted a final check on the soundings and prepared this QC Report.

Mr. Tom Mero, Chief of NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) Requirements and Development Division, provided specific instructions regarding analytical techniques and the tide zonation scheme to be used for correcting the soundings. Mr. Craig Martin of NOAA analyzed the tide data, defined the boundaries and time- and range-correctors for the tide zones, and posted the tide data on the CO-OPS website. Dr. James Hubbard and Mr. Gerald Hovis of NOAA computed the vertical datum conversions for South San Francisco Bay. Ms. Marti Ikehara, State Geodetic Advisor for the National Geodetic Survey (NGS), provided technical guidance regarding establishing elevations using GPS techniques, vertical datums, and subsidence in South San Francisco Bay.

Ms. Glenda Rathwell and Mr. Karl Rhynas of Quester-Tangent Corporation analyzed the seabed classification data and prepared a map of acoustic diversity for South San Francisco Bay showing the seabed segmented into acoustically similar units. Their report on seabed classification of South San Francisco Bay sediments is presented in Section 7.

Ms. Anne Sturm of the San Francisco District, U.S. Army Corps of Engineers prepared a metadata file for the tide data collected in the South San Francisco Bay sloughs and creeks. The slough/creek tide data is included as part of the Corps' South San Francisco Bay Shoreline Project. Ms. Sturm also acquired funding from the Corps to prepare a metadata file to document the results of the tidal benchmark surveys used to establish the NAVD88-to-MLLW conversions.

Final high-frequency (200kHz) soundings and low frequency (50kHz) seabed classification data were delivered to Ms. Amy Foxgrover of USGS Pacific Science Center. After Ms. Foxgrover conducts an independent quality control assessment of the data, she will compare soundings referenced to MLLW to historical surveys of South San Francisco Bay, and merge soundings referenced to NAVD-88 with the May 2004 LIDAR topographic data to create a terrain model of existing land surface elevation and bay bathymetry

5. QUALITY CONTROL RESULTS

Quality control procedures for the Class 1 hydrographic survey of South San Francisco Bay include the following checkpoints:

- Pre-survey calibration of navigation system at four (4) permanent horizontal control points surrounding the survey area (same 4 points used to reference LIDAR survey).
- Daily checks on the precision (repeatability) of the navigation system at a single point in San Leandro Marina or Redwood City Marina.
- Daily barcheck calibrations of the survey-grade depthfinder immediately before and after collecting soundings.
- Daily comparison between electronic depth measurements and depths measured manually using a weighted tape.
- Comparison of observed tides vs. predicted tides for the same location.
- Comparison of tides from adjacent gauges located upstream and downstream.
- Comparison of electronic water level measurements by pressure-sensing tide gauges vs. manual measurements of water surface elevation using a nearby benchmark as reference.
- Second and third checks of the edited soundings to ensure that all tide corrections and datum conversions are properly made.
- Comparison of soundings at the intersection of primary and perpendicular survey lines and in overlap areas around tide zone boundaries.
- Comparison of final soundings with historical NOAA surveys of the same area.

The following sections provide results from quality control checks and calibrations of the navigation system, survey-grade depthfinder, and tide gauges. The absolute precision (repeatability) of the soundings at the intersection of perpendicular tracklines and in overlapping survey areas around the tide zone boundaries is discussed.

5.1 QC Results for Differential GPS Navigation

The GPS receiver aboard the survey vessel automatically and continuously checks the quality of the geometric accuracy (called HDOP, or Horizontal Dilution of Precision) during the hydrographic survey. The GPS receiver is configured such that satellites less than ten degrees above the horizon are not used in the position computation. The navigation software automatically halts the survey if the HDOP exceeds 5.0, the Class 1 survey standard (USACE, 2002). The GPS receiver also monitors the rate of the pseudo-range correctors used in the position computation, and stops the survey collection software if the age of range corrections exceeds 3 seconds.

In December 2004, prior to beginning the hydrographic survey, the Contractor removed the differential GPS receiver from the survey vessel and calibrated it at the same four permanent horizontal control monuments around South San Francisco Bay used to reference the aerial LIDAR survey (Terrapoint, 2005). Based upon the GPS calibration at 4 locations around South San Francisco Bay, the navigation system used to collect the soundings has an absolute accuracy better than $\pm$2m. The results from the GPS calibrations are presented on the next page:

Horizontal Control Point: HS2851

Omnistar Coordinate: N37° 26' 10.050"   W121° 54' 24.900"
UTM: E596,701.5m N4,143,815.7m
NGS Coordinate: N37° 26' 10.03474"   W121° 54' 24.89490"
UTM: E596,701.6m N4,143,815.2m
LIDAR Output Coordinate: N37° 26' 10.03157"   W121° 54' 24.89230
UTM: E596,701.7m N4,143,815.1m
Difference between Omnistar and NGS Coordinate: 0.51m

Horizontal Control Point: AI7653

Omnistar Coordinate: N37° 43' 11.034"   W122° 07' 09.240"
UTM: E577,623.1m N4,175,084.4m
NGS Coordinate: N37° 43' 11.04190"   W122° 07' 09.20691"
UTM: E577,623.9m N4,175,084.7m
LIDAR Output Coordinate: N37° 43' 11.04196"   W122° 07' 09.20686"
UTM: E577,623.9m N4,175,084.7m
Difference between Omnistar and NGS Coordinate: 0.85m

Horizontal Control Point: HT0565

Omnistar Coordinate: N37° 35' 28.656"   W122° 19' 09.984"
UTM: E560,081.8m N4,160,687.4m
NGS Coordinate: N37° 35' 28.63257"   W122° 19' 09.91243"
UTM: E560,083.6m N4,160,686.7m
LIDAR Output Coordinate: N37° 35' 28.63886"   W122° 19' 09.92157"
UTM: E560,083.3m N4,160,686.9m
Difference between Omnistar and NGS Coordinate: 1.93m

Horizontal Control Point: AH7470

Omnistar Coordinate: N37° 30' 28.715"   W122° 12' 39.107"
UTM: E569,745.0m N4,151,518.7m
NGS Coordinate: N37° 30' 28.76629"   W122° 12' 39.09246"
UTM: E569,745.4m N4,151,520.3m
LIDAR Output Coordinate: N37° 30' 28.76286"   W122° 12' 39.08903
UTM: E569,745.5m N4,151,520.2m
Difference between Omnistar and NGS Coordinate: 1.65m

In addition to calibrating the absolute accuracy of the differential GPS navigation before beginning the hydrographic survey, the navigation system was checked for precision (repeatability) twice daily at a single location in either San Leandro Marina or Redwood City Marina. The results from the twice-daily check of GPS precision (repeatability) show less than ±1m drift during the 4-month hydrographic survey.

During collection of soundings along the eastern shoreline of South San Francisco Bay, an unknown microwave source (possibly radar from Oakland International Airport) occasionally disrupted the differential corrections being received aboard the survey vessel. When differential corrections were disrupted, the survey was immediately stopped and any soundings collected were discarded and re-surveyed when differential corrections were again received. The field survey crew found that placing metal shielding on the north side of the differential GPS antennae eliminated the microwave disruptions.

5.2 QC Results for Depth Measurements

The soundings were reviewed and edited in the office using a software program that allows the depth and navigation data to be displayed, checked and corrected on the computer screen against the graphical records collected in the field. Soundings were edited three-times, and the results compared, to ensure that all spikes and questionable data are removed.

Results from the barcheck calibrations conducted before and after each dayshift and nightshift during the survey were carefully reviewed in the field and during data processing. The difference between the pre- and post-survey barcheck calibrations are never greater than ±3cm (±0.1') at any of the 1.5m (5') depth intervals checked daily. Likewise, manual depth measurements collected twice daily at random locations in South San Francisco Bay matched electronic soundings within ±3cm (±0.1'), except between the Dumbarton Bridge and Coyote Creek. Between the Dumbarton Bridge and Coyote Creek, manual depth measurements are consistently deeper than electronic soundings because the 1-pound leadline used to manually measure water depths sinks into the soft, water-saturated sediments.

A review of the daily barcheck calibrations for the survey-grade depthfinder indicates that the speed-of-sound in South San Francisco Bay increased during the 3-month survey. During January 2005, barcheck calibrations measured the speed-of-sound at between 4830-4850 feet/second. The speed-of-sound increased to between 4850-4860 feet/second during February 2005, and again during March 2005 to between 4870-4880 feet/second. A lower speed-of-sound (between 4700-4720 feet/second) was measured in the sloughs and creeks of South San Francisco Bay during late March-early April 2005, probably a result of freshwater influence from winter runoff.

5.3 QC Results for Tide Measurements in Sloughs and Creeks

Water level data collected at multiple locations in the sloughs and creeks of South San Francisco Bay by pressure-sensing tide gauges was carefully reviewed and compared against:

- Manual measurements of water level surface collected during the hydrographic survey using nearby benchmarks as reference,
- Predicted tides in the sloughs and creeks, calculated by applying time- and range-multipliers to tide data from the nearest controlling NOAA tide station, as specified by NOAA (2006), and
- Tide data collected by adjacent gauges located upstream or downstream.

Manual tide measurements matched electronic water level data collected by the pressure-sensing tide gauges within ±1.5cm (±0.05') at the entrance to Coyote Creek and Artesian Slough, within ±3cm (±0.1') in Alviso Slough, and within ±6cm (±0.2') at the Railroad Bridge. The manual tide measurements matched electronic tide data best at high tide. The greatest differences between manual water level measurements and electronic tide data occurs at low tide, immediately before the water level falls below the tide gauge, exposing the underwater pressure sensor to air.

Comparing water surface elevations observed by the pressure-sensing tide gauges against predicted tides for the appropriate tide zones defined by NOAA (2006) indicates that high tide is about 8cm (0.25') higher and up to 0.5-hours earlier than NOAA predictions for South San Francisco Bay sloughs and creeks. This difference between the observed and predicted height and time of high tide in the sloughs and creeks may be caused by freshwater runoff from winter storms. Changing the controlling tide station to the air-acoustic tide gauge at Coyote Creek electrical tower (if it had been operational) might have increased the accuracy of the time- and range-multipliers in the sloughs and creeks.

5.4 Final QC Results

The hydrographic survey was conducted using standards, methods and accuracies outlined in the U.S. Army Corps of Engineers Hydrographic Manual (USACE, 2002). Soundings in South San Francisco Bay were corrected for tide and referenced to MLLW and NAVD-88 using methods described in NOAA (2006). Slough and creek soundings were referenced to NAVD-88 by applying tide corrections measured by pressure-sensing gauges, and converted to MLLW (where possible) using methods described in NOAA (2006).

Soundings were collected throughout South San Francisco Bay and five sloughs/creeks to an elevation of greater than +1m NAVD-88. A quality control review of the density of soundings collected in South San Francisco Bay shows no gaps exist in the survey coverage, except for small areas containing shipwrecks, bridges, aqueducts, or other obstructions. Aquatic vegetation did not interfere with soundings anywhere in South San Francisco Bay, except along isolated shoreline areas in the creeks and sloughs.

The vertical accuracy of the soundings is better than ±6cm (±0.2'). Daily barcheck calibrations of the survey-grade depthfinder demonstrate that electronic depth measurements are accurate to ±3cm (±0.1'), regardless of water depth. Manual measurements of water depths using a weighted tape matched electronic depth measurements within ±3cm (±0.1'). The absolute precision of the soundings is assessed where perpendicular survey lines cross or in areas of overlapping soundings. At the intersection between primary survey lines and perpendicular "tie-lines", soundings match within ±6cm (±0.2') or better. In the 200m overlap areas around tide zone boundaries, soundings collected at different times and at different tide stages match within ±6cm (±0.2') or better. Accuracy may decrease slightly in small, shallow water areas along the shoreline of South San Francisco Bay, possibly caused by freshwater runoff or small-scale variations in tide propagation not recognized by the tide zones.

Based upon GPS calibrations and examination of sounding intersections, the horizontal accuracy of soundings collected from a vessel moving at 5.5 knots is likely in the range of ±3m. Navigation inaccuracies of ±3m have little effect on sounding accuracies in the majority of South San Francisco Bay because the seafloor in the open Bay is relatively flat and featureless; however, a positioning error of ±3m in the narrow, steeply-sloping channels of sloughs and creeks has a significant effect on sounding precision (repeatability).

Soundings in the sloughs and creeks extend to the end of navigable waters. Soundings extend upstream past the point of tidal influence, where referencing elevations to tidal datums becomes suspect. Soundings collected along the centerline (or thalweg) of the creeks and sloughs match cross-sectional soundings within ±15cm (±0.5'). The lower precision (repeatability) of the slough/creek soundings compared to the open Bay soundings is caused by a number of factors, including:

- Soundings in the sloughs and creeks were collected using a 4m flat-bottom skiff, which is not as stable a platform as the larger, heavier survey boats that collected soundings in the open Bay. The quick turns and speed changes necessary for the skiff to collect cross-sectional soundings across the narrow channels of the creeks and sloughs affects the draft/squat calibrations, and lowers sounding precision.

- Navigation accuracy is a significant issue in the narrow, steeply-sloped channels of the sloughs and creeks.

- Difficulty in accurately measuring or predicting tides at intermediate locations in the sloughs and creeks, primarily because there is insufficient water depth to install highly-accurate air-acoustic tide gauges.

Obtaining higher accuracy soundings in the sloughs and creeks may not be possible from a moving boat, and may require leadline/tagline methods between two fixed shore points whose vertical and horizontal positions are accurately known from static GPS surveys. Manual (leadline) depth measurements are often more accurate than electronic soundings in the soft, water-saturated sediments at the bottom of the sloughs and creeks.

The survey equipment, data collection methods, and analytical procedures used to conduct the hydrographic survey represents the Contractor’s best effort to collect bank-to-bank soundings in South San Francisco Bay. After careful collection, processing, and review of the soundings, Sea Surveyor, Inc. is confident that all soundings meet Class 1 standards and accuracies, and the final data meets or exceeds the requirement for a Class 1 hydrographic survey. The only issue with the soundings may be that the survey line spacing (100m) is further apart than advised for Class 1 surveys. Class 1 hydrographic surveys are typically conducted along survey lines spaced at nominal 15-30m intervals. The soundings collected in South San Francisco Bay may not detect small changes in seafloor elevation that occur between survey lines.

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SECTION 7

ACOUSTIC CLASSIFICATION SURVEY FOR SOUTH SAN FRANCISCO BAY

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