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Gauging the Tide

by Mike Zieserl

Playing in the water takes on a different perspective for one team in Alaska.

Before we get to the part about the humpback whales, calving glaciers, communications satellites and General Robert E. Lee s horse, you should know that this is only a story about the tide.

In the end, the whole thing comes down to how high the sea level rises and falls each day in two bays in Kenai Fjords, Alaska. Four tides per lunar day push and pull water in and out of Aialik and Harris Bays. Flood tides rush in toward the north, swirling floes from the rapidly retreating glaciers into an icy slush. Ebb tides retreat to the south, bucking up against swells building from across the open waters of the Gulf of Alaska. LCMF Inc. of Anchorage, Alaska, was assigned the challenge of measuring this tide and determining the tidal datum in support of a hydrographic survey for the National Oceanic and Atmospheric Administration (NOAA).

An Unusual Workplace

Aialik and Harris Bays are on the south coast of the Kenai Peninsula, the first two bays west of Seward, Alaska. Scoured from granite and shale rock by glaciers from the Harding Ice Field, they are deep-water fjords bounded by mountainous peninsulas. Both Harris and Aialik Bays border active tidewater glaciers.

The original hydrographic data upon which the current large-scale nautical chart for the area is based comes from a 1928 lead line survey.* Northwestern Fjord in upper Harris Bay is not shown because it was covered in glacial ice. The glacier has retreated eight nautical miles since 1928. Furthermore, the chart has been rendered even less reliable because earthquakes and subsidence have continued to alter the tidal datum in the bays.

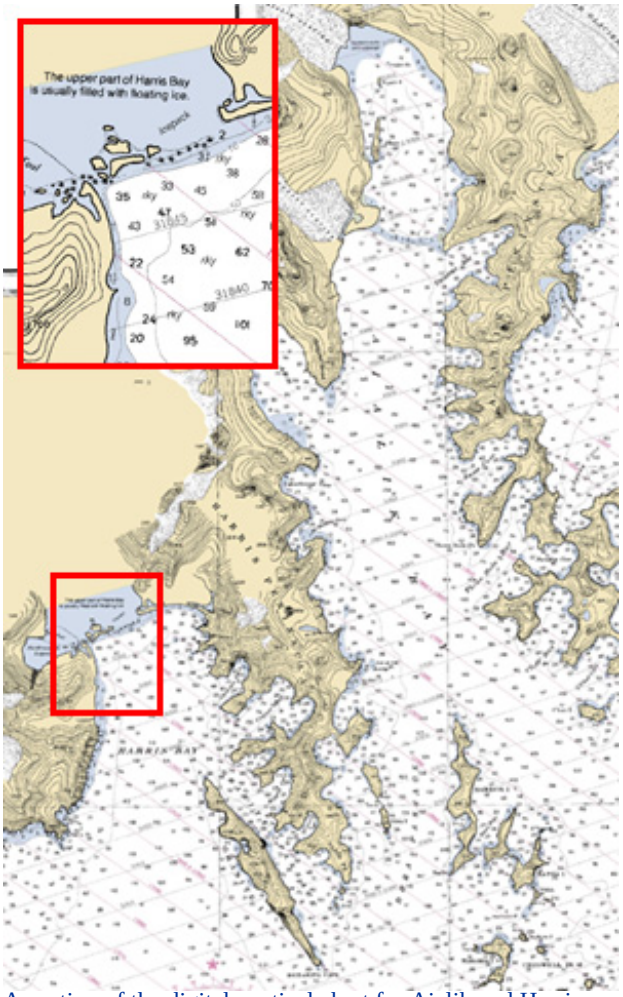
It is a place that can be difficult for navigation, where williwaws (sudden, violent cold winds) spin boats as anchorlike tops on a tight string and pinnacle rocks threaten safe navigation despite seemingly deep waters. And the number of tour boats running these unsurveyed waters continues to increase. Seward has become a cruise ship destination where over 275,000 tourists pass through this town of 4,000 every summer. Harris and Aialik Bays have become popular destinations where tourists drop $150 apiece to pound six-foot seas for eight hours to see glaciers calving, humpback whales breaching, and puffins bobbing and diving in the chilly water. The only things that drop more are the survey monuments after an earthquake.

The Tide Story

Welcome to the epicenter of a revamped effort by the NOAA Office of Coast Survey to improve the nautical charts along the Alaskan coastline through government services and private contracts. The job facing NOAA is daunting. The 231-ft NOAA hydrographic vessel Rainier is dedicated to Alaskan surveys, however, cooperative efforts by government and private contractors only reduce the backlog of critical surveys by 900 square nautical miles per year. More than 13,950 square nautical miles of Alaskan waters have been designated a critical priority for nautical charting by NOAA, as compared to 1,050 square nautical miles for the entire west coast of the United States.

Nautical charts detail water depths, shoreline, and navigational aids and hazards to the mariner. The charts are created by NOAA from hydrographic and shoreline surveys, tide measurements and geodetic data.

Despite the sophisticated charts, the hydrographer evaluating the tide forces must still grapple with the simple surveying concept of datum: the water is deep compared to what? For the purposes of nautical charting in U.S. tidal, watersdepth is relative to mean lower low water (MLLW) or the average of the lower of the two low tides each lunar day. It is the job of the tidal surveyor to determine MLLW.



A portion of the digital nautical chart for Aialik and Harris Bays. The highlighted portion of the chart notes that Upper Harris Bay is not mapped because of glacial ice. This area is open water now.

The Brave Collectors

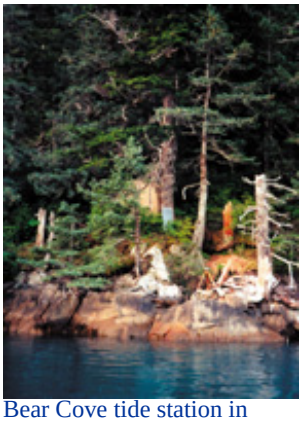
In the fall of 1998, NOAA awarded a two-year professional services contract to a team of companies comprised of prime contractor Thales (formerly Racal-Pelagos), and two Alaskan subcontractors, LCMF Inc. and Terra Surveys. In the first year of this contract the team surveyed the shipping lane approaches to Anchorage, Alaska, through upper Cook Inlet. Tide data collected by LCMF in Cook Inlet documented a tidal range between higher high and lower low tides in excess of 38 feet, the second highest range in North America.

In addition, land subsidence occurs so rapidly along the coast of Cook Inlet that the National Tidal Datum Epoch (NTDE) of 19 years was judged to have no meaning in a practical sense by NOAA s Center for Operational Oceanographic Products and Services (CO-OPS), and adjustments to the datum were made based on a shorter observation period of 1994-1998. This was necessary to ensure that the tidal datums accurately represent the existing stand of sea level. Tide ranges are still based on the 19-year NTDE. These ranges are applied to Mean Sea Level (MSL) to derive other tidal datums such as Mean High Water (MHW) and MLLW.

In 2000, this team brought its collective experience to Kenai Fjords. Thales was responsible for overall project management, data processing and mid- and deep-water hydrographic surveying. Terra Surveys covered shallow water hydrography. LCMF provided tidal data collection, tidal zoning, computation and analysis for all of the hydrographic surveying.

Unique Challenges

The team faced unique challenges in Kenai Fjords. There were no reliable NOAA tidal datums in the project vicinity, and knowledge of tidal dynamics was limited. To collect tide data, LCMF established 10 tidal datums based upon the statement of work developed by NOAA and adjusted by LCMF. Tide gauges were located to best record the change in the height and time of the tide as it moved in and out of the narrow bays. Of special concern was the tidal effect of the glacial sills, which are underwater moraines the glaciers deposited when they paused during their rapid retreat up the bays. These sills act like giant stilling wells, greatly calming the waters at the head of both bays. Historical tide data from NOAA was analyzed to determine the stability of the tides, and the necessary length of time gauges had to be run before a preliminary tidal datum could be established and applied to quality control of the hydrographic survey data.


Bear Cove tide station in Aialik Bay. A GPS unit is set over the primary bench mark. The tide gauges are in the tent in the background.

Four priorities were applied in locating the tide stations. The first was to position the gauge where it could provide the most information on the tide for the broadest area, whether covering the upper half of a bay or deep in recessed arms where the tide might differ significantly from the general curve. Second, the stations had to be located where the coastline offered some protection from the open water of the Gulf of Alaska in order to reduce surge, which creates noisy tide data. Next, the site had to allow for the tide gauge to communicate with a Geostationary Operational Environmental Satellite (GOES) operated by the National Environmental Satellite, Data and Information Service (NESDIS) using antennas aimed at a narrow window in the sky. Finally, because many of the tide stations were located on National Park Service land, equipment had to be located out of view of tourists.

Interesting Logistics

Permitting issues, transportation, and the logistics of installing equipment and housing the crew were as much a challenge as the surveying and data collection. Aialik and Harris Bays border Kenai Fjords National Park, islands under the administration of the U.S. Fish and Wildlife Service (USFWS), land owned by Alaska Native corporations, and Native Allotments owned by individuals. Obtaining permission to install tide stations from these disparate landowners and administrators often proved an interesting duty. One owner was located through word of mouth by relatives living in Chignik Lagoon near the Aleutian Islands. In order to obtain another permit, LCMF had to research historical maps and photographs to determine if Striation Island in upper Harris Bay had been covered by the glacier prior to 1980, and therefore fell under the purview of the USFWS as dictated by the Alaska National Interest Lands Act.

In order to access these remote sites, LCMF decided to purchase a boat as the main operations platform. The Traveler (after General Robert E. Lee s horse, minus one L) is an 18-ton former Bristol Bay fishing boat, built from welded aluminum with a custom-built crane on the stern deck. Bristol Bay fishing regulations are very strict on the maximum length of a fishing boat 32 feet but make no mention of width, so the Traveler had a respectable 16-foot beam. With a shallow draft of 4 feet, accommodations for a crew of four, three steering stations and plenty of hydraulics, she is a competent little ship. In her hold she packed twin 375-horsepower Detroit Diesels the equivalent of an aquatic bulldozer, which is comforting when the waves are taller than you are and the winds are blowing in excess of 60 miles per hour.

This power was also necessary for hauling the thousands of pounds of gear that had to be deployed on the rocky shores of Kenai Fjords as well as placing the heavy anchors used to secure the tide gauge sensors. A three-person crew installed each of the 10 tide stations. Seven tertiary stations, operated for a minimum of 30 days, were established during the course of the project. At tertiary sites, five tidal bench marks were drilled into rock outcroppings and third-order levels were double run through all of the marks during installation and demobilization of the station. Three zoning stations were also installed at the beginning of the project. The zoning stations were operated for one week in order to further investigate the tidal dynamics of the bays.

Gauging the Operation

Tertiary stations were operated between June 27 and Nov. 15, 2000, for at least 30 days and up to 120 days. A typical tide station consisted of a primary and backup water level measurement system, a WeatherPort tent to shelter the gauges, a GOES radio and antenna to transmit tide data and system health, and a power supply consisting of two 80-ampere-hour Optima batteries per gauge with a 75-watt solar panel for recharging.


Survey Technician Erik Oppegard levels between tidal bench marks at the tide

Tide gauge orifices were secured underwater below the level of the lowest expected tide to occur during the project. Orifices were either attached to pipe brackets and bolted to vertical rock faces that extended below water or were attached to 650-lb. anchors constructed from railroad wheels and lowered to the bottom by the hydraulic crane on the stern of the Traveler.

The tide gauges were built by Design Analysis Associates (DAA), Logan, Utah, and were comprised of the H350/H355 data logger and pressure sensor. The DAA gauges are digital bubbler gauges, meaning they determine water depth by slowly bubbling air into the water from an orifice anchored at a fixed position. The gauge determines the exact water pressure exerted and, along with the water density and the force of

gravity inputs, calculates the depth. The gauges measure pressure to 0.02 percent of the full-scale output from 0 to 30 pounds per square inch (psi), which translates to approximately 2-mm depth accuracy.

station established in Upper Northwestern Fjord in Harris Bay.

Data collection was accomplished by redundant systems to reduce turnaround time and to minimize data gaps due to system failures. The tide gauges logged water depth at six-minute intervals. The data were transmitted in three-hour blocks to a GOES satellite. This data were then downloaded by the NOAA Command and Data Acquisition Station at Wallops Island, Va., and could then be accessed through a telnet connection in the Anchorage office, or on the Traveler through a satellite phone Internet connection. The tide data were checked, processed and E-mailed to the Thales survey headquarters in Seward, providing near real-time tide data for hydrographic survey quality control. In addition, the tide gauges recorded data on 1-megabyte flash cards, which could be removed and read by a laptop computer on the Traveler. Flash card data were useful for filling occasional gaps in the GOES transmissions.

Overall, the tide gauges operated reliably and returned accurate data. Standard deviations in the measurement of water depth between the primary and backup gauges at each tide station site typically were less than 8 mms over a 24-hour period. Data from two stations showed that the anchors settled over the first three days before stabilizing. At another site, fluctuations in the apparent depth of the tide gauge orifices was attributed to faulty water density readings due to the influx of surface fresh water from a nearby stream as well as melting ice water from a nearby tidewater glacier. This problem was overcome by taking water density samples from the bottom of the bay where the salt water remained uncontaminated.

The survey crew visited the tide stations several times each week to ensure that the gauges were working properly and to perform staff shots. Staff shots, measuring the difference in elevation between a tidal bench mark and the water level, served two purposes: to check the stability of the tide gauges and to connect the tidal datum to the tidal bench marks. Readings were synchronized every six minutes to coincide with the tide gauge reading. The difference between the gauge reading and the staff shot water elevation produced a constant value, proving that the gauge orifice remained stable throughout the project.

The Resulting Datum

A preliminary MLLW datum was established for each station after two weeks of operation. This datum was computed through the NOAA method of simultaneous comparisons where the heights and times of high and low tides from the LCMF tide station were compared to the NOAA control tide station in Seward. This preliminary datum was applied to the six-minute interval data collected by the tide gauges to reduce observations to MLLW.

After the completion of the 2000 field season, a final MLLW datum was determined using several months of the data at each tide station. The revised tide correction data were used to reprocess the hydrographic survey data in order to obtain more accurate results. A report detailing methodology and final datum values was delivered to NOAA and, upon approval, the MLLW bench mark elevations will be published.

What s Next

For 2001, the Thales/LCMF/Terra team will be undertaking a hydrographic survey near Chignik along the Alaska Peninsula. Described by the U.S. Coast Pilot as home to the windiest bay in Alaska, the survey area is bordered by mountains, active volcanoes and sea lion rookeries. Sounds like just another story about the tide.

* Early hydrographic surveys were accomplished by throwing a lead-weighted line out of the boat and letting the line run out until the lead weight hit the bottom. The length of the line was the depth of the water. The position of this sounding was determined by three point sextant readings to referenced landmarks on shore.

Mike Zieserl is a tides technician and instrument man at LCMF Incorporated. He has been involved in all aspects of tide projects, including fabrication, marine navigation and data analysis.