COASTAL & NEARSHORE WATER LEVEL OBSERVATIONS IN ALASKA

Installing a tide gage near Castle Cape, Alaska – June 25, 2014
Image Credit: Personnel of NOAA Ship RAINIER (NOAA's Historic Coast & Geodetic Survey (C&GS) Collection)

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June 2016

Challenges, Assets, Gaps, and Next Steps

A Status Overview

With Meeting Notes from:
Exploring Options for an Integrated Water Level Observation Network in Alaska
May 27 – 28, 2015
Anchorage, Alaska

AOOS
Alaska Ocean Observing System

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COASTAL & NEARSHORE WATER LEVEL OBSERVATIONS IN ALASKA

CHALLENGES, ASSETS, GAPS, AND NEXT STEPS

PURPOSE

HOW HIGH DID THE WATER GET DURING THE COASTAL STORM LAST MONTH?

WHERE IS LOCAL MEAN SEA LEVEL RELATIVE TO LAND?

HOW LOW IS THE TIDE EXPECTED TO BE AT 5 PM NEXT TUESDAY?

Alaska's extensive and remote shorelines are some of the most critically under-instrumented coastal and nearshore areas in the United States. Accurate water level observations, both static and real-time, are a fundamental data requirement for flood forecasting, informed emergency response, ecosystem management, safe navigation, efficient mapping/charting, and scientific research in support of these activities. Augmentation of the existing water level instrumentation network in Alaska will require collaborative, opportunistic, and innovative instrumentation in close coordination with established monitoring strategies. This synthesis is intended to serve as a steering document for the establishment of projects and partnerships across the public, academic, and private sectors that will further the development of an integrated water level sensor network for Alaska, thus enhancing the quantity, quality, and access to these necessary baseline data.

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Introduction

For ease of use, this summary is focused on static coastal water level measurements (such as a flood elevation indicated by a strand line) and coastal and nearshore observations consisting of a series of water level measurements over some interval of time. The observation of wind waves is another outstanding data gap in the Alaska region and, while linked to water level variability at the km-scale, is not discussed within this document. Modeled water levels are only minimally described, except where they have been used to assist in identifying data gap priorities.

Many Applications: A Broad User Base for Water Level Records

Consumers of Alaska water level data form a highly diverse group, and each user brings varying levels of experience, different data formatting/delivery requirements, preferred frequency/accuracy standards and disparate geographic priorities to the type of water level information that is central to their mission or task.

The following is a non-comprehensive list of regular applications for different types of water level data in the Alaska region.

- Promote safe navigation in tidally-influenced areas
- Document peak water levels for storm surge model validation and flood mapping
- Provide tsunami warnings, watches, and advisories
- Inform environmental incident planning and response to minimize resource damage
- Support ocean search and rescue operations
- Establish tidal datums, standardized vertical reference surfaces for use in coastal engineering, shoreline and flood zone mapping, and regulatory boundary definitions
- Quantify long-term relative sea level trends arising from climate change and spatially variable patterns of tectonic uplift and subsidence
- Analyze temporal trends in coastal storm frequency, magnitude, and duration
- Guide the prioritization of coastal and cultural resource management actions
- Facilitate intertidal habitat mapping, coastal ecosystem research, and waterfowl/fisheries management decisions
- Derive tidal constituents for use in ocean hindcast/forecast modelling and improvements to total water level predictions
- Correct bathymetric and shoreline survey measurements, including those necessary for boundary definitions and land management
- Ensure locally-relevant data for science education and outreach in schools

Changes in Alaska's economy, evolving approaches to coastal management, and emerging environmental trends continue to shape priorities and considerations for new water level instrumentation activities. An expanding tourism and cruise ship industry, increased traffic in Arctic shipping corridors, shifts in oil drilling lease activities, the possible development of an Arctic deep water port, and changes in coastal storm patterns all influence both gap prioritization and available funding opportunities. Continued coastal and maritime activities without increased access to reliable water level information pose a threat to human life, property, and the coastal environment.

Water Level Instrumentation Options

There are many different types of water level sensors, data collection/retrieval approaches, and installation/leveling strategies (Figure 1). In generic terms, the sensors themselves may be grouped into three very broad categories: (1) position-based, (2) in-situ/pressure, and (3) range-finder.

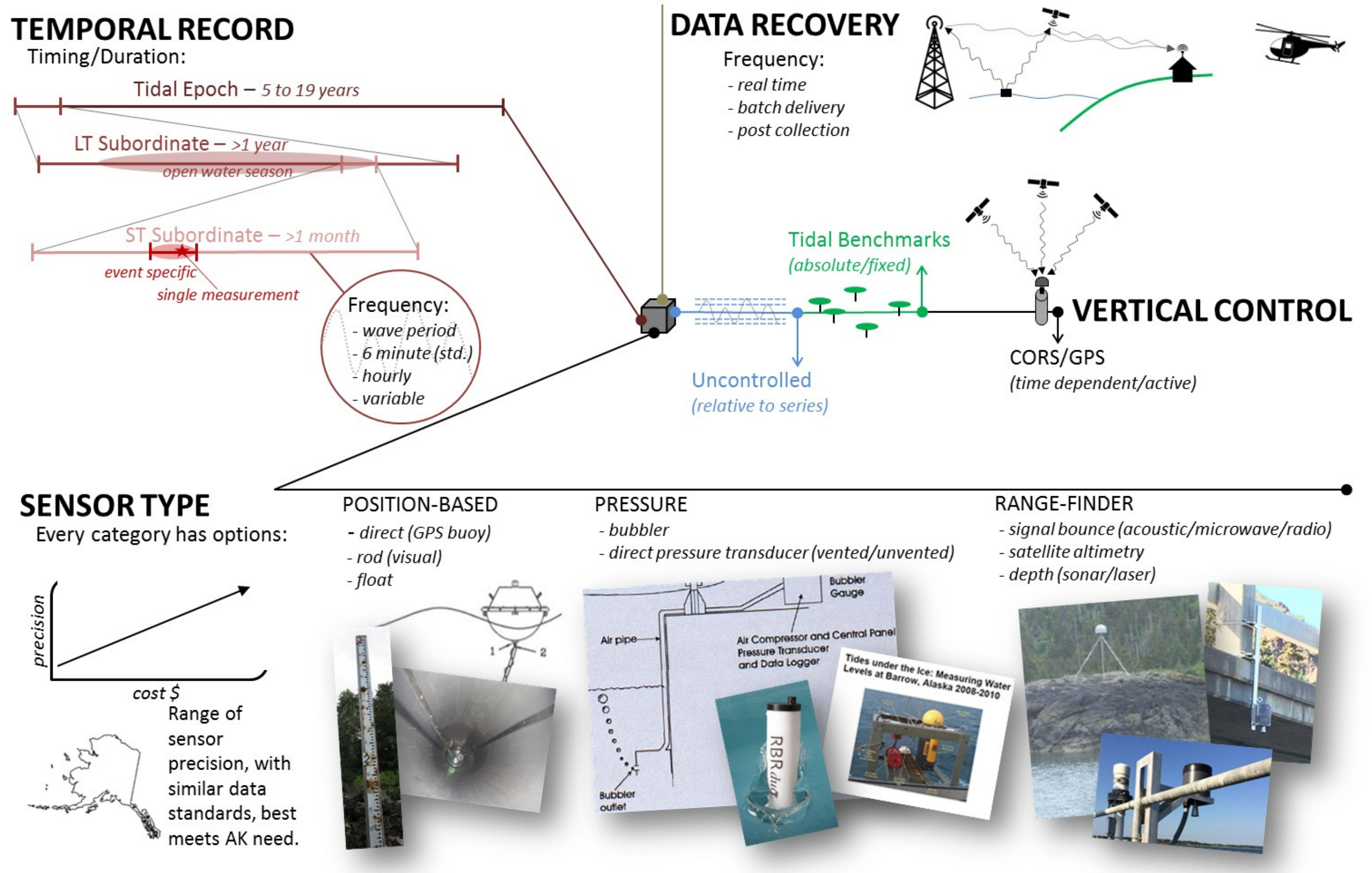

Figure 1. Graphical summary of the many attributes of a water level instrument that must be taken into consideration when selecting an option that best suits the local conditions, project parameters, and broader community needs.

Temporal Record Options

The **duration** of a water level observation record may vary from an isolated instantaneous measurement, to a permanent and continuous series. Standard practice for the reduction of water levels for datum analysis (after NOAA, 2001) is to classify water level series into a 3-level hierarchy based on record duration. In this scheme, a *Primary* series is typically a 19-year record (a full metonic cycle) comprising a complete Tidal Epoch, however in tectonically active places such as SE Alaska, a Primary series may be as short as 5-years, a Modified Tidal Epoch. A *Secondary* series, corresponding to a Long-Term Subordinate tide station, is longer than one year but less than a Tidal Epoch. A *Tertiary* series, corresponding to a Short-Term Subordinate tide station is greater than one month but less than a year. For sensors that store measurements locally, the data storage capacity may be a limiting factor in the duration of the record, although sensors operated by NOAA send their data back in near real-time.

Timing of discontinuous observations may be adjusted to align with a discrete extreme event, or be optimally scheduled to coincide with favorable conditions for install, operation and removal. Due to sea ice in Alaska, many types of water level sensors must be removed in the winter months to avoid damage, unless they reside in permanent structures with measures taken to avoid the ice damage.

The **Frequency** determines the temporal spacing of individual measurements. At very high frequencies (e.g. 1 Hz, or once per second) it is possible to collect observations of wind-generated waves. Standard practice for most NOAA and international tide gauges is to collect a measurement on a 1-minute or 6-minute interval. Longer intervals of hourly or even monthly may be appropriate in certain applications and if data storage or available power limit higher frequencies. Some sensors can be pre-programmed revert to a higher frequency during unusual conditions, such as extreme water levels, or tsunamis, or it may be possible to manually or remotely adjust the collection frequency for different circumstances.

Data Recovery Options

The most basic type of water level sensors log records on local storage devices and the data must be manually retrieved on site or after the sensor has been removed and returned to an office or lab (**post collection**).

Real time sensors are capable of relaying data from the active remote sensor to centrally accessible storage. This communication process (telemetry), which is typically automated, transmits the measurements for continuous monitoring. The most common telemetry options in Alaska include satellite, cellular, radio, telephone/acoustic modem, or some combination of these options. To account for power and network continuity limitations that are common to Alaska, non-NOAA telemetered transmissions will frequently consist of **batch deliveries** (hourly, for example).

Vertical Control Options

If a water level series is collected independent of any leveling, the data are not vertically controlled and the water level measurements are only significant with regard to their **relative positions** within the series.

Water level measurements, high water marks, and other survey elevations may be collected relative to a local or arbitrary datum established at the time of the sensor install or measurement collection- for a tide gauge this is typically referred to as the *Station Datum*. By leveling a sensor into a local network of **tidal benchmarks**, fixed or passive positional control is established. This passive control is critical to ensure sensor stability, allows for consistency in a discontinuous water level series, and provides known reference points for the establishment of local tidal datums. A local station datum or tidal datums may be linked to absolute geodetic control at tidal benchmarks with published orthometric heights (such as NAVD88).

The most comprehensive type of vertical control is to link a water level station to a near-by continuous GNSS station (or Continually Operating Reference Station, **CORS**) on land (Gill and others, 2015). Leveling tide stations to an active GNSS/GPS control station on land allows water level measurements to be linked to time-dependent measurements of vertical land motion using the same geodetic reference system, thereby providing more reliable estimates of both absolute and relative sea level variability.

Sensor Types

There are many options available for measuring coastal and nearshore water levels and specific technologies are more or less appropriate for different environmental settings or data collection priorities; the cost of a sensor typically increases with increased measurement precision. In the broadest sense, most water level sensors may be grouped into three general categories: position-based, pressure, and range-finder.

Position-Based

Position based sensors are the oldest type of water level sensor, this category is defined by any technique or technology based on a direct physical measurement of the position of the water surface. Examples include visual tide staffs (rods), a float-type gauge in a stilling well, or a GPS buoy (for a GPS buoy example see the Hydrolevel system described in Riley and others, 2014).

Figure 2. Automatic tide gauge at Port Protection, Prince of Wales Island, Alaska, 1915. Image credit: NOAA Photo Library.

Most of Alaska's original tide stations were established using position-based techniques (either tide staffs or floats in combination with a rotating paper drum; see Figure 2). Today, many opportunities exist for low-cost community-based observations of extreme water levels to be collected in this manner, and tide staffs are a regularly installed in tandem with other sensors or as aids to navigation in rivers.

Pressure

Pressure-type sensors are widely employed at many tide stations in the United States, and this category of sensors is the primary technology used in most of the Arctic tide gauges in Alaska. The most precise pressure-type water level gauges are bubbler systems that exploit basic hydrostatic principles to measure water levels; a steady low flow of gas is fed to a pressure point located below the lowest low water level and pressure in the air line is maintained as proportional to the weight of the water column through the release of excess gas at the pressure point. Bubbler systems are part of many NOAA-operated tide gauges (most frequently as the back-up sensor), but pose unique operational challenges in Alaska where it is difficult to site superstructures and protected wells that prevent the gas tube from damage by ice, and an absence of ocean infrastructure may require unstable line distances (in excess of 200 m) in low grade environments to capture the full tidal range.

Direct pressure transducers may be vented to the atmosphere to measure differential pressure, or they may measure the ambient pressure at the bottom of a water column and require post processing to remove the atmospheric pressure component and correct for water density. Direct pressure transducers (examples include *Onset Hobo data loggers* and *Solinst Leveloggers*) have been widely employed by researchers in Alaska to collect water level measurements at sites lacking long-term instrumentation due to their low cost (<$500 for an unvented sensor) and ease of install. More robust pressure sensors have also been used by CO-OPS to collected year-round measurements of water levels below the ice in an experimental project at Barrow, Alaska (Sprenke and others, 2011)

All direct pressure sensors require barometric pressure corrections and a known density profile of the water column to obtain the most precise measurements possible; areas that experience density gradients due to variations in temperature, the presence of sea ice, or salinity (such as in estuaries) are likely to suffer from reduced measurement precision. Co-located CTD sensors may help to reduce errors associated with direct pressure water level sensors in some settings.

Range-Finder

Range-finder type technologies employ an indirect measurement of the water surface position by bouncing some type of signal off of the air/water interface. Common sensor types for local installations in this category encompass airborne ultrasonic acoustic and microwave radar transducers. The majority of NOAA-operated tide stations nationwide presently operate with a primary acoustic sensor. Microwave water level (often abbreviated MWWL) sensors are less affected by air temperature differences and hydraulic pressure effects, and are therefore being increasingly used in place of acoustic sounding tubes at many NOAA tide gauges in the United States, including in Adak, Alaska (Park and others, 2014). Minimally corrected, low-cost range-finder sensors are widely used in Alaska by the NWS River Forecast Center (iGages, for example, see Kinsman and others 2016). However, most range-finder type sensors presently on the market require an orthogonal geometry, or downward-looking installation that requires ocean or coastal infrastructure to serve as a platform so existing areas with marine facilities is a limiting factor in expanding the use of these technologies.

Satellite altimetry also operates using a range-finder type approach, but these measurements are typically of too low a precision for most coast and nearshore water level observation requirements and additional noise in the signal along coastlines makes this a more useful technique for offshore areas.

CHALLENGES

The primary challenges associated with instrumenting Alaska's coastal waterways are the vastness of the region, site remoteness, limited existing infrastructure, and harsh environmental conditions. The paradox of Alaska water level observing is that the highest priority gaps are coincident with the places and times of the year with the greatest barriers to instrumentation. In an effort to meet isolated objectives, many different types of non-standard water level sensors are used in Alaska projects each year in an uncoordinated manner; this *ad hoc* approach minimizes the opportunity to share and re-use data and results in high net observation costs.

TECHNOLOGY GAP

There are many tried and tested water level sensor options available on the market, but these options frequently require non-standard modifications to operate properly in Alaska waters. More specialized custom sensors are also available; these typically require extensive assembly as well as calibration and verification of the sensor technology to align with project specifications.

One of the reasons for a lack of sensors that are appropriate for Alaska is a development lag in the technology. This lag is the dual result of equipment, services, and techniques not yet existing in many parts of Alaska (such as high-speed internet), and simply not yet existing at all (such as low-power options). The latter lag is compounded by the fact that, in many cases, the development of an ice-resistant housing, for example, is a niche requirement and the lack of such innovation is not as noticeable in other regions where the need is already being met or does not exist.

BARRIERS TO OPERATION

Work that requires field operations is notoriously expensive to conduct in Alaska as a result of the region's vastness, a limited transportation network, and finite favorable weather windows. For water gauges, this expense continues post-install as routine and emergency operation and maintenance also requires access to remote locations.

Alaska's coastline is largely undeveloped and lacks the coastal engineering structures that are widely used in other parts of the United States as platforms for water level gauges, such as docks, piers, jetties, or bridges. Since the install requirements in Alaska typically require custom mounts or specialized engineering designs, extensive site reconnaissance is critical for most new deployments. Power and telecommunication options may also be limited in many areas; remote power options such as solar may require larger battery banks for operation during sun-limited winter months and most reliable telemetry requires satellite transmission.

The timing of short-term sensor install, operation, and removal requires careful monitoring of ice conditions in the Arctic, and travel during the spring and fall may be regularly prolonged by weather complications, so extra time must be allowed to ensure site access. Many of the large coastal storms that have the potential to cause damages occur in the late fall, from October to November. Seasonal gauges that are not designed to withstand ice have typically been removed by the time these events occur, and valuable records of these extreme events have therefore been lacking in the historical record.

The siting of new gauges and interpretation of water levels is complicated by the limited mapping of Alaska's coastline and coastal processes. Unknown patterns of erosion, sedimentation, and shoreline change make it challenging to select secure equipment sites, particularly for extended periods of time. Poorly constrained or unknown inland discharge rates can make water level records at estuaries or river mouths difficult to interpret for the purposes of ocean process observations.

DATA SHARING

To date, the supplemental installation of coastal and water level stations in Alaska by numerous entities, has not been carried out in a systematic manner, these uncoordinated efforts have resulted in a multitude of data formats, the production of water level time series lacking appropriate metadata, and disparate data storage and sharing mechanisms. Those interested in historical water level measurements, such as for use in model hindcasting, are typically unable to gather all of the available measurements with ease, and it is not uncommon for researchers or engineers to miss data sets or even re-collect measurements in areas where they were unable to find existing records. Additional drawbacks stemming from a lack of standardization or centralized data sharing location include: missed cost-sharing opportunities, a lack of data continuity or compatibility; and opportunity costs associated with duplicative efforts in data collection, management and curation, or analysis. Coordination of water level instrumentation activities in coastal and nearshore Alaska would open the door to value-added projects, leveraging opportunities, and would help to alleviate issues associated with variable funding flow for the maintenance of long-term gauges.

Existing Assets

All of the assets described in this section are up-to-date as of January, 2016.

NOAA's National Water Level Observation Network

The National Water Level Observation Network (NWLON) is the backbone of a comprehensive system for observing, communicating, and assessing the impact of changing water levels nationwide. NWLON stations set the standard for archival-quality, authoritative water levels in the United States; the network is characterized by rigorous specifications and standards for water level measurement precision, redundancy, and data archival in support of a primary mission to provide (1) control for tide and water level datum determination, (2) tide predictions and (3) long-term sea level variations.

The NWLON network in Alaska presently consists of 26 active sensors, and two additional sensors (one in Unalakleet, AK and one in Snug Harbor, AK) are planned for installation in summer 2016 (see red stars in Figure 3).

Other Assets

Additional active coastal and nearshore water level sensors are presently of limited number in Alaska (see red circles in Figure 3). The National Tsunami Warning System operates nine shore-based sensors in the southern part of the state (Shemya Stn., Amukta, Adak, Atka, Akutan, Chignik, Old Harbor, Craig, and Ketchikan). The River Forecast Center, in cooperation with the Alaska Ocean Observing System and the Alaska Division of Geological & Geophysical Surveys, operate five acoustic sensors on bridges and other coastal structures in western Alaska (Kotzebue, Wales, Unalakleet, Tununak, and Platinum).

In addition to these active assets, there are several programs and partners that occasionally operate short-term water level stations in different parts of the state. Assorted intermittent, annual offshore moorings equipped with pressure sensors are part of several University of Alaska Fairbanks research efforts; typical deployment areas for these assets include Chukchi (S. Danielson), Beaufort (J. Kasper, T. Weingartner, and/or S. Okonnen) and occasional project-based areas in southeast/southcentral Alaska. Estuarine, bottom-mounted pressure transducers that are not telemetered have also been installed in Chukchi/Beaufort coastal areas (Pt Hope, Pt Lay, Wainwright, Barrow, and Kaktovik) with funding from the Bureau of Ocean Energy Management and University of Alaska Fairbanks.

Other water level assets in the State are typically installed and operated in support of project or engineering requirements. Examples include project-specific sensors established by United State Army Corps of Engineers, stations sub-contracted by the State of Alaska, short-term stations operated by NOAA in support of hydrographic surveys, and assets owned by private sector oil development/exploration companies.

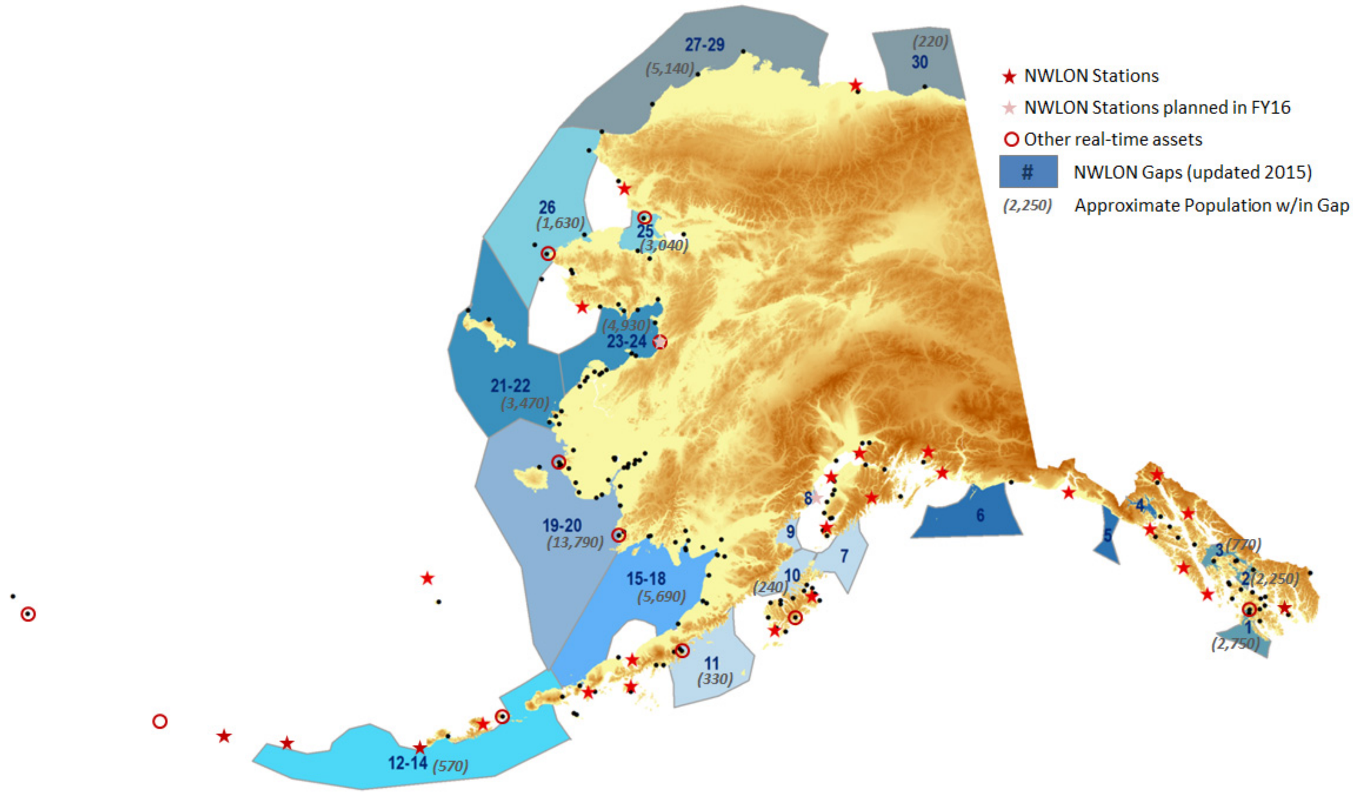

Figure 3. Map of existing and upcoming active water level assets in Alaska overlain on the known NWLON Gaps with their associated reference numbers and approximate coastal populations.

Known Gaps

The water level data applications that motivate the priorities for gap-filling vary regionally. Statewide there is a need for data in support of spill response, search and rescue, ecosystem management, navigation and engineering/ports. In northern Alaska, sea ice and oil and gas exploration are additional factors. In western Alaska, there is enhanced need for data in support of coastal flood forecasting, shipping, subsistence activities, fishing, and Relative Sea Level trend analysis. In southern Alaska the need for data to support Tsunami warnings, navigation and tourism-related activities takes a priority.

A Statewide Review of Gap Priorities

Following the format of the May 2015 "Exploring Options for an Integrated Water Level Observation Network in Alaska" workshop discussion, this summary has been framed around the NWLON Gap Analysis (NOAA, 2008). The identified gaps (shown in Figure 3) are based on GIS-derived polygons of areas lacking in the coverage minimally required for the fundamental determination of tidal and water level datums (tide control) to an uncertainty level that would meet most user requirements (0.12 ft at a 95% confidence interval). While the NWLON gaps are not comprehensive of all observational requirements or applications, they do provide an overview of the priority regions for further discussion. Land ownership is shown on the statewide gaps summary for the purposes of identifying partnerships for water level monitoring, all priorities are based on feedback associated with the May 2015 water level workshop in Anchorage, Alaska (Appendix I).

Figure 4. Permafrost-rich bluff west of Prudhoe Bay. Image credit: Shore Zone.

Region 1 of 9: North Slope

NWLON gaps 27-30.

Notable features, needs and challenges

This region is micro-tidal (<2 meter tidal range) and experiences a limited open water season. The predominant coastal landforms include permafrost-rich bluffs and barrier island systems (Figure 4). The permafrost-rich landscape makes this coastal region highly susceptible to climate change, it hosts some of the highest rates of coastal erosion in the United States (Gibbs and Richmond, 2015), has rapidly evolving drainage patterns, and there are salt water intrusion concerns. Oil and gas service activities have a strong presence in the region.

Region-wide there is a need for water level data in support of coastal flood and spill response, and, for navigation purposes, Barrow, Wainwright and Point Lay are priority areas for instrumentation; Kaktovik and Barrow are additional priorities for coastal research (Figure 5). This area also includes several coastal sites owned by the Dept. of Defense that are at risk to flooding and erosion, and there is interest in how changes in relative sea levels are altering arctic barrier island dynamics.

Partners conducting active water level work in this region include, but are not limited to: USGS Changing Arctic Ecosystems Initiative, USGS Pacific Coastal and Marine Science Center, IARPC Marine Arctic Ecosystem Study, NSF-funded academic research, gas pipeline routing studies (Alaska DNR), the Bureau of Ocean Energy Management, and Canada.

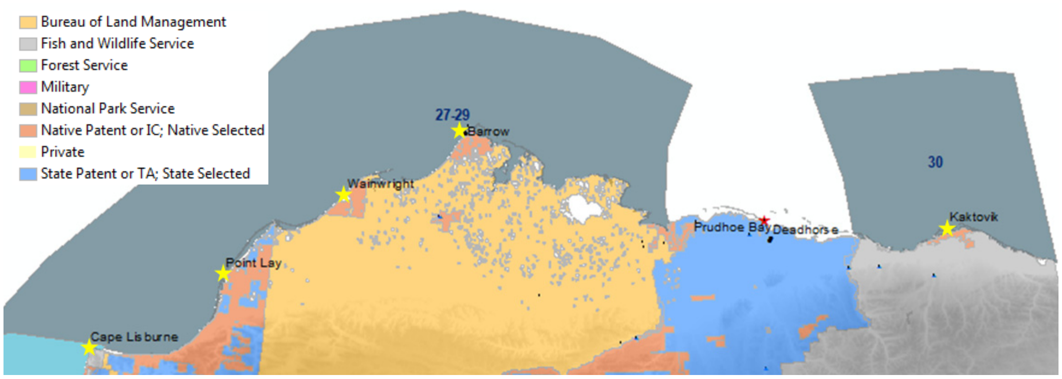

Figure 5. Map of the North Slope region with named priority locations highlighted by a yellow star.

Region 2 of 9: Northwest/Chukchi

NWLON gaps 25-26.

Notable features, needs and challenges

This region experiences a limited open water season and ice push events (ivus) are common. Significant coastal storm surge events regularly affect communities in this region. The predominant coastal landforms include low-lying permafrost-rich bluffs, rocky headlands, and barrier island systems.

Region-wide there is a need for water level data in support of coastal flood and spill response, particularly given the region's close proximity to an international shipping corridor that is experiencing annual increases in traffic. This part of the Chukchi Sea has also been the focus of recent discussions to develop a deep water port in the Arctic. The region has a high level of subsistence use activities and there is significant exposure of cultural and natural resources to extreme water levels. Areas with very high flood risk are an NWS priority for water level instrumentation (Kotzebue and Shishmaref), the National Park Service has a vested interest in water level instrumentation on its lands (Cape Krusenstern and Bering Land Bridge), and local barge operators have voiced an interest in additional observations in support of navigation in Diomede (Figure 6).

Partners with a vested interest in water level observation in this region include, but are not limited to: Northwest Arctic Borough, Red Dog Mine, National Park Service, and local barge and shipping companies.

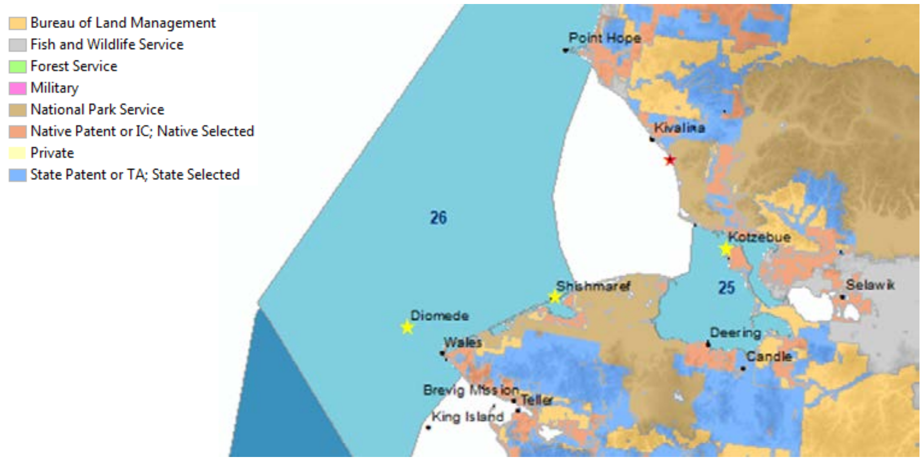

Figure 6. Map of the Northwest/Chukchi region with named priority locations highlighted by a yellow star.

Region 3 of 9: Norton Sound

NWLON gaps 21-24. **This region was identified as a very top priority** due to coastal flooding.

Notable features, needs and challenges

This region experiences a limited open water season and, due to the broad and shallow shelf combined with a west-facing orientation, is home to some of the largest coastal storm surges in Alaska. The predominant coastal landforms include permafrost-rich bluffs, barrier island systems, rocky headlands, and low-lying estuarine tundra.

Region-wide there is a need for water level data in support of coastal flood and spill response, particularly given the region's close proximity to an international shipping corridor that is experiencing annual increases in traffic. The region has a high level of subsistence use activities and there is significant exposure of cultural and natural resources to extreme water levels. Numerous locations in the region are at very high risk to coastal flooding, and these are NWS priorities for water level instrumentation (Shaktoolik, St. Michael, Kotlik, Emmonak, Sheldon Point/Nunam Iqua, and Hooper Bay). Research activities require additional water level instrumentation in Golovin, Hooper Bay, and near Saint Lawrence Island; and commercial fisheries and local barge operators have voiced an interest in additional observations in support of navigation throughout the region (Figure 7).

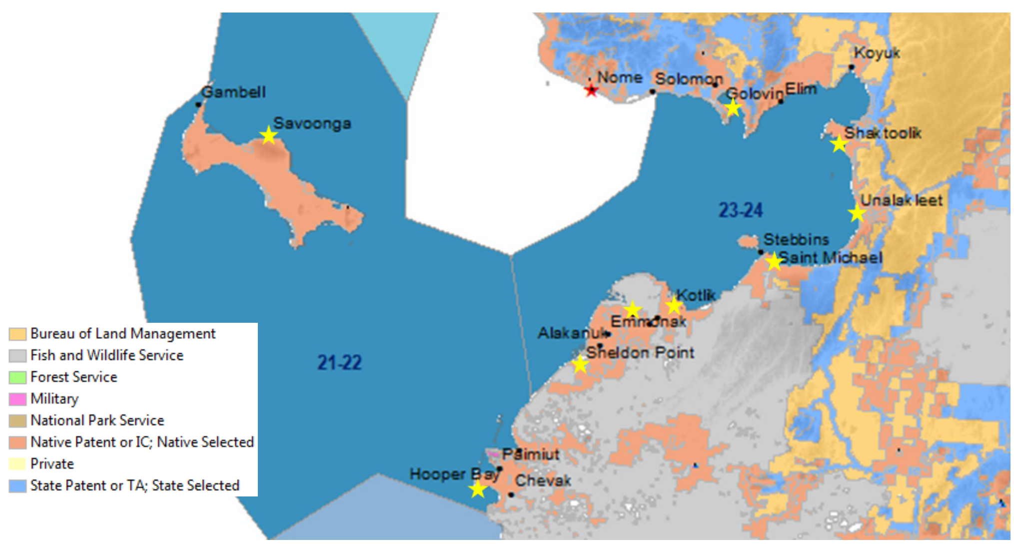

Figure 7. Map of the Norton Sound region with named priority locations highlighted by a yellow star.

Partners conducting active water level work, or with a vested interest in new observations in this region include, but are not limited to: the Alaska Ocean Observing System (wave buoy), Norton Sound Economic Development Corporation, the Western Alaska landscape Conservation Cooperative, Bering Straits Native Corporation, United States Army Corps of Engineers (deep draft port study), the Coastal Hazards Program at the Alaska Division of Geological & Geophysical Surveys, the USGS Alaska Science Center and Pacific Coastal & Marine Science Center, the Alaska Department of Transportation & Public Facilities, the Arctic Domain Awareness Center at the University of Alaska Anchorage, University of Alaska and other researchers.

Region 4 of 9: Kuskokwim

NWLON gaps 19-20. **This region was identified as a very top priority** due to navigational requirements and also coastal flooding.

Notable features, needs and challenges

This region experiences a variable open water season and large coastal storm surges. The predominant coastal landforms include very low-lying estuarine tundra, with limited bedrock (except on Nunavik and Nelson Islands). Due to the low-lying and deltaic nature of this coastline, this area is particularly vulnerable to sea level rise and there is significant interest in the relative sea level trends throughout the region. The shoreline is very poorly mapped in this part of the state.

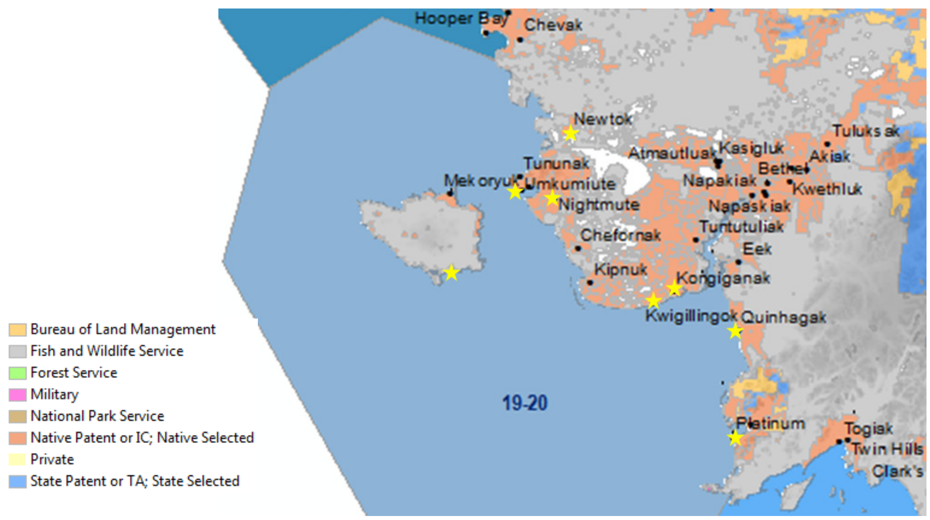

Figure 8. Map of the Kuskokwim region with named priority locations highlighted by a yellow star.

Region-wide there is a need for water level data in support of coastal flood and spill response. The region has a high level of subsistence use activities and there is significant exposure of cultural and natural resources to extreme water levels. A NWS priority for water level instrumentation due to coastal flood risk is Newtok, the United States Army Corps of Engineers is interested in water levels in Toksook Bay, and there are numerous priorities from a river and coastal navigational standpoint due to the strong metrological effects on water levels in the rivers (Nightmute, Kongiganak, Kwigillingok, Quinhagak, and Goodnews Bay), there is also interest in a water level station for navigational purposes on the South side of Nunivak Island as this area is used as a port of refuge during storms (Figure 8).

Partners conducting active water level work, or with a vested interest in new observations in this region include, but are not limited to: the United States Coast Guard (buoys), Coastal Resources, Alaska Village Electric Cooperative, the Western Alaska landscape Conservation Cooperative, the Coastal Hazards program at the Alaska Division of Geological & Geophysical Surveys, the USGS Alaska Science Center and Pacific Coastal & Marine Science Center, the Arctic Domain Awareness Center at the University of Alaska Anchorage, and other researchers at both the University of Alaska Anchorage and the University of Alaska Fairbanks.

Region 5 of 9: Bristol Bay

NWLON gaps 15-18.

Notable features, needs and challenges

This region is far enough south that portions of it remain ice-free year-round; the tidal range is also greater than to the north (meso-tidal; 2-4 meters). The region is home to some of the largest commercial fisheries in the State (salmon, crab, pollock), and very heavy weather events coupled with abundant maritime activity result in water level needs in support of search and rescue activities for this part of Alaska. The predominant coastal landforms include barrier islands, estuaries and numerous river mouths. Critical ecosystems in this region, such as migratory bird wetlands and eelgrass beds, are vulnerable to changes in sea level.

Region-wide there is a need for water level data in support of coastal flood and spill response. The region has a high level of subsistence use activities and there is significant exposure of cultural and natural resources to extreme water levels. River and coastal navigational priorities include Naknek and river mouths and there may be need for water levels in conjunction with potential resource development activities (Figure 9).

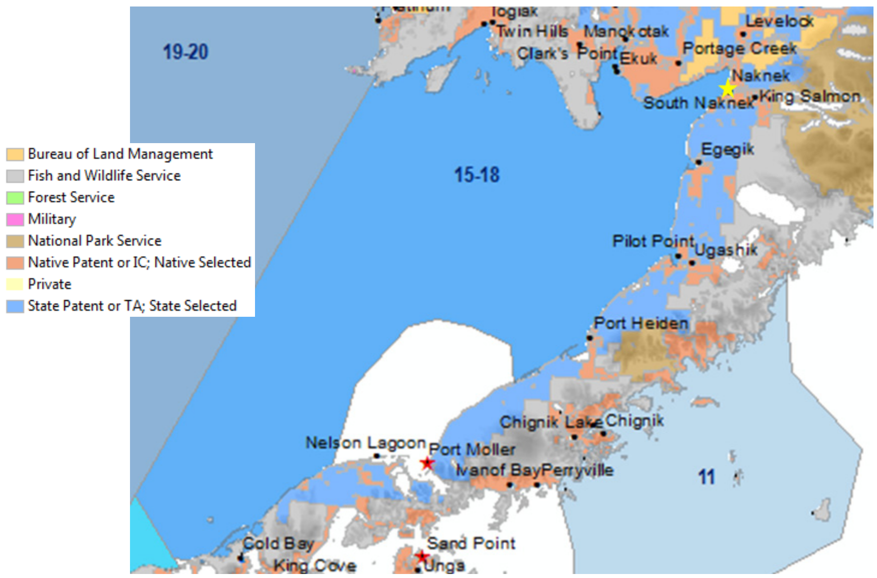

Figure 9. Map of the Bristol Bay region with a named priority location highlighted by a yellow star.

Partners with a vested interest in new observations in this region include, but are not limited to: private fishing fleets and seafood processors, Bristol Bay Economic Development Corporation, Bristol Bay Native Association, Bristol Bay Native Corporation, Togiak, Alaska Peninsula/Becharof, and Izembek National Wildlife Refuges, Coastal Hazards Program at the Alaska Division of Geological & Geophysical Surveys, and NOAA national Marine Fisheries Habitat areas.

Region 6 of 9: Aleutians

NWLON gaps 12-14.

Notable features, needs and challenges

This region is home to some of the largest commercial fisheries in the State (salmon, crab, pollock), and very heavy weather events coupled with abundant maritime activity result in water level needs in support of search and rescue activities for this part of Alaska. The predominant coastal landforms include rocky cliffs on volcanic islands. Critical ecosystems in this region, such as seabird and marine mammal rookeries, are vulnerable to changes in sea level at many timescales. This region is also at risk to Tsunamis.

Region-wide there is a need for water level data in support of navigation and spill response, particularly in light of increasing international vessel traffic through the Aleutian Islands, named priorities include Unimak, Akutan, Attu, Amchitka, Ft. Glenn, and the Islands of Four Mountains (Figure 10).

Partners with a vested interest in new observations in this region include, but are not limited to: private fishing fleets and seafood processors, shipping companies, Alaska Maritime Agencies, the USGS paleotsunami research, academic partners investigating alternative energy such as the National Renewable Energy Laboratory, Aleutian and Bering Sea Islands landscape Conservation Cooperative, Aleutian Pribilof Islands Community Development Association for renewable energy, and the Aleutian Islands Risk Assessment Project.

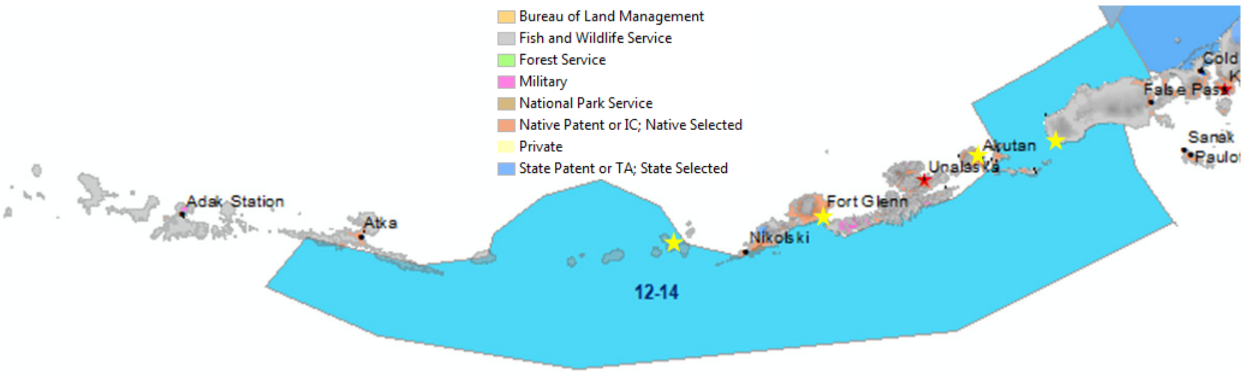

Figure 10. Map of the Aleutian region with named priority locations highlighted by a yellow star, Attu and Amchitka fall west of the area shown.

Region 7 of 9: Southern Alaska Peninsula

NWLON gaps 7-11.

Notable features, needs and challenges

This region experiences the largest tidal ranges in the state (marco-tidal; >4 meter tidal range), has the highest coastal population, and is vulnerable to tsunamis. The predominant coastal landforms include bluffs, rocky cliffs, and fjords.

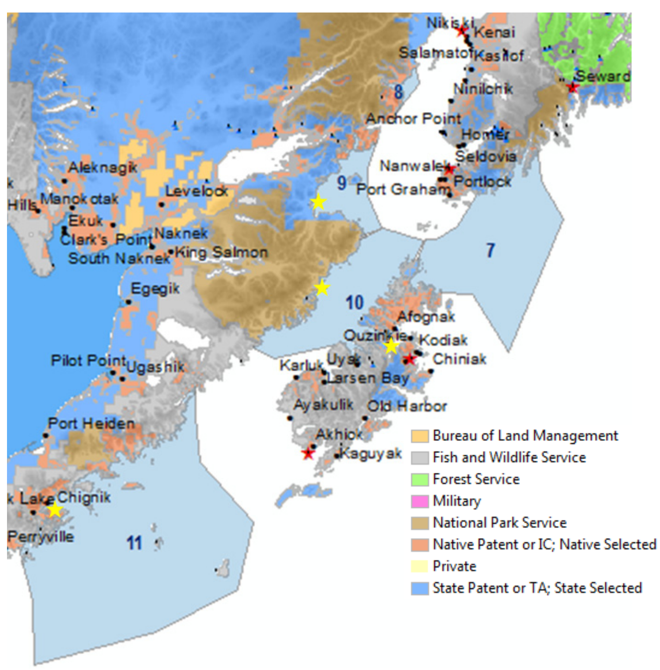

Figure 11. Map of the Southern Alaska Peninsula region with named priority locations highlighted by a yellow star.

Region-wide there is a need for water level data in support of navigation and spill response, particularly in Cook Inlet, which has the highest level of commercial vessel traffic. Additional water level considerations in this part of Alaska include increased recreational use of coastal areas and tourism, this region is also home to the majority of the state's coastal engineering projects, and has clamming and commercial fishing activities. NWLON gap 8 should be closed with the establishment of a NWS-sponsored tide station in Snug Harbor in 2016. NWLON gap 10 encompasses Shelikof Straight and Katmai, where there is a known need for improved water levels in support of navigational safety; additional areas of concern include Port Lions, Chignik, and Kamishak Bay (Figure 11).

This region benefits from many opportunities to partner to improve the density of water level observations. Active opportunities to partner in this region include, but are not limited to: National Park Service (Kenai Fjords, Lake Clark, Katmai and Aniakchak), Fish and Wildlife Service National Wildlife Refuges (Alaska Peninsula/Becharof, Kodiak, and Alaska Maritime), gas pipeline terminal and other industrial development projects, assorted oil and gas activities, commercial air taxis and tourist cruises, the Alaska Ocean Observing System and active ocean modeling research, the Cook Inlet Regional Citizens Advisory Council, Tribes and native Regional Associations, and local communities.

REGION 8 OF 9: PRINCE WILLIAM SOUND, GLACIER BAY AND THE LOST COAST

NWLON gaps 4-6.

NOTABLE FEATURES, NEEDS AND CHALLENGES

This region experiences large tidal ranges and is vulnerable to tsunamis. The predominant coastal landforms include bluffs, rocky cliffs, and fjords. This part of Alaska is undergoing rapid isostatic rebound (uplift of the land) resulting in spatially complex relative sea level trends.

Figure 12. Map of the Prince William Sound, Glacier Bay and Lost Coast region with the named priority location highlighted by a yellow star.

Region-wide there is a need for water level data in support of navigation, spill response, and search and rescue - particularly along tanker, shipping, and cruise ship routes. Additional water level considerations in this part of Alaska include abundant small craft recreational activity. NWLON gap 4, within Glacier Bay, has been identified as the greatest priority for additional water level observations in this region and the National Park Service and National Forest Service are important partners in this portion of the state (Figure 12).

REGION 9 OF 9: ELFIN COVE TO KETCHIKAN

NWLON gaps 1-3.

NOTABLE FEATURES, NEEDS AND CHALLENGES

This region experiences large tidal ranges and is vulnerable to tsunamis. The predominant coastal landforms include rocky cliffs, and fjords. This part of Alaska is undergoing very rapid isostatic rebound (uplift of the land) resulting in spatially complex relative sea level trends with rapid sea level fall limiting coastal access and altering coastal hydrodynamics in some areas.

Region-wide there is a need for water level data in support of navigation, spill response, and search and rescue - particularly in very narrow passages where extreme tidal currents develop. Specific areas in need of additional water level observations in support of navigational requirements include the junction of Chatham and Frederick Straights, Petersburg, Wrangell Narrows, Klawock, and Hydaburg. The greatest navigational need is identified in NWLON Gap 1 where vessels have been grounded near Hydaburg. Additional water level considerations in this part of Alaska include abundant ecotourism and extreme storm events that have the potential to cause flooding in some of the developed areas (Figure 13).

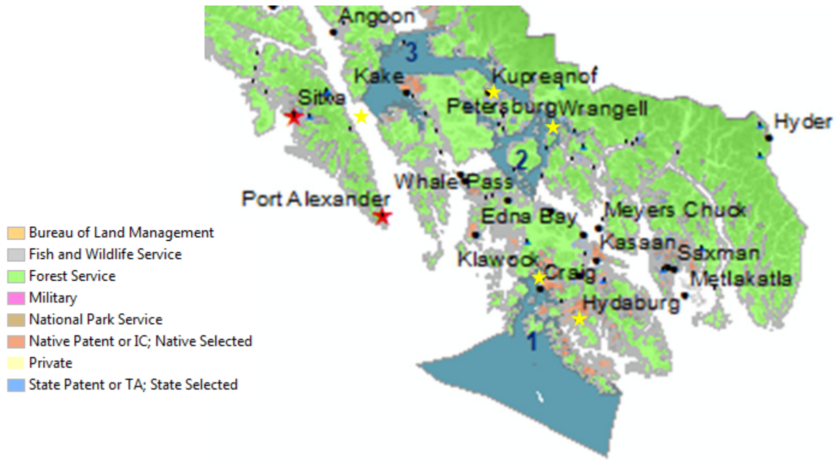

Figure 13. Map of the Elfin Cove to Ketchikan region with named priority locations highlighted by a yellow star.

Partners with a vested interest in new observations in this region include, but are not limited to: the State of Alaska Ferry system, Alaska Department of Transportation & Public Facilities, private sector fisheries and barges, aquaculture groups, the National Park Service, US Fish and Wildlife Service, Marine Exchange of Alaska, US Forest Service, US Army Corps of Engineers, US Geological Survey, the North Pacific Landscape Conservation Cooperative, Sitka Sound Science Center, Oceans Alaska, Sea Alaska Native Corporation and the pilot station near Kake.

Agency-Specific and Other Priorities

Over the course of the May 2015 workshop, various agencies or groups voiced interest in specific types of water level observations, or specific gaps of concern. These priorities are included in the previous summary by region but some are also included below, where appropriate.

National Weather Service

The National Weather Service is most interested in real-time total water levels for storm tracking and forecast support, but post-storm peak water levels are also critical for ocean model validation and improvement. Geographic priorities are primarily in western Alaska:

- Shishmaref
- Shaktoolik
- Newtok
- Emmonak
- Nunam Iqua (Sheldon Point)
- Hooper Bay
- Saint Michael
- Kotlik
- Kotzebue

Navigation Priorities

Gap priorities for water levels in support of safe navigation are based on feedback from private sector companies and the Coast Guard. Key areas of concern include the Chuckchi Sea coast (between Point hope and Barrow), the Kuskokwim River mouth and other areas in western Alaska where meteorological forcing leads to variable water levels that can impact maritime access (Shaktoolik, Hooper Bay, Tooksok Bay, Saint Michael), and areas of concern in southeastern Alaska (including Glacier Bay, Hydaburg, and Hawk Inlet).

Alaska Department of Transportation & Public Facilities

The Alaska Department of Transportation & Public Facilities is most primarily interested in the establishment of local tidal datums and the documentation of peak surge levels to support engineering designs. Geographic priorities as of 2015 include: Point Hope, Point Spencer, Hooper Bay, the Kuskokwim River delta and Golovin.

Recommended Next Steps

Top Priority Areas

A synthesis of statewide priority areas is provided in Figure 14. The top locations from each region are included as well as those that were specifically identified as gap that directly relates to the protection of life and property, either in support of coastal storm forecasting or navigational safety; additional details on the priority areas within each region may be found in the preceding section.

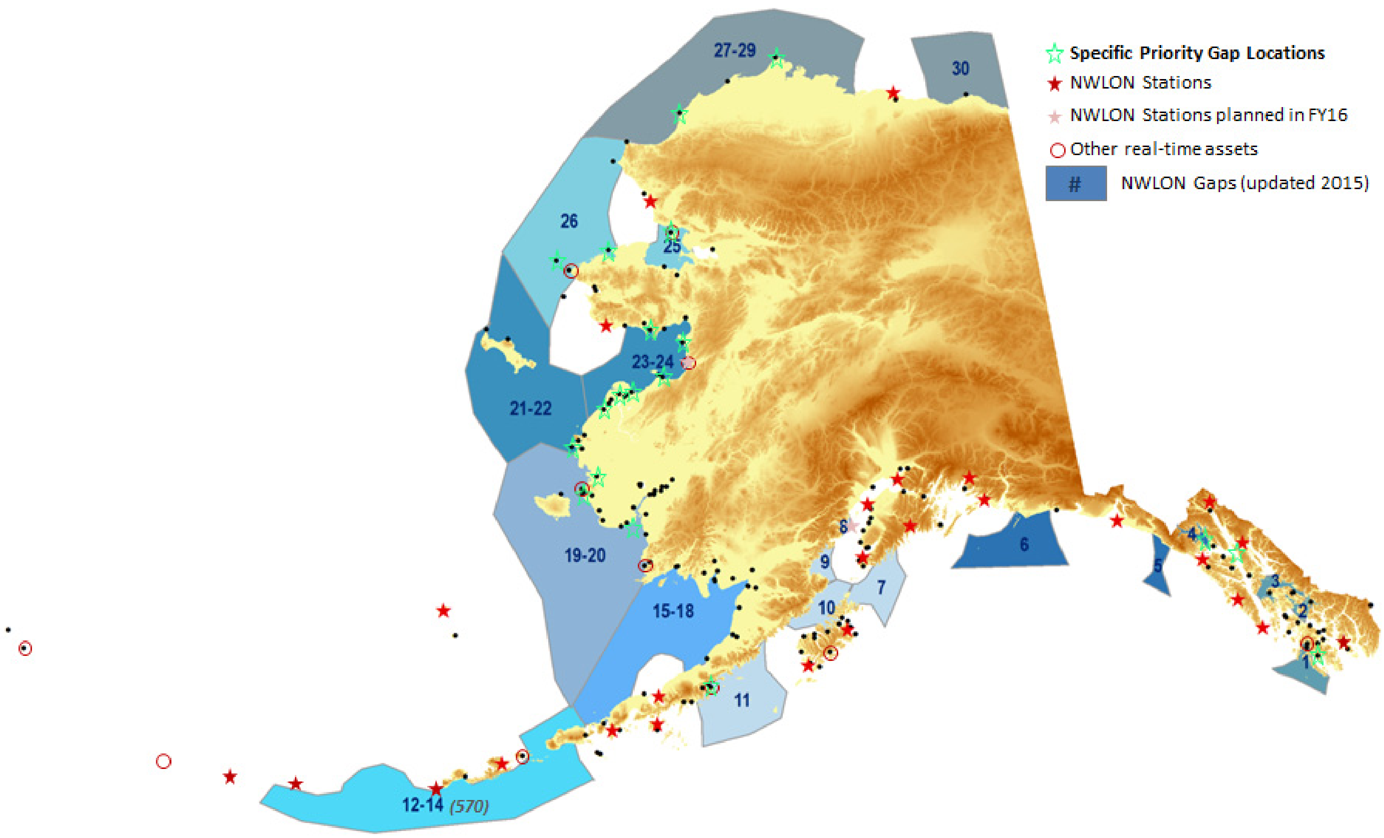

Figure 14. Statewide map of existing and upcoming active water level assets in Alaska overlain on the known NWLON Gaps with their associated reference numbers with specific priority gap areas highlighted by green stars.

Ongoing Activities and Leveraging Opportunities

Listed below are known water level instrumentation projects, relevant initiatives, and candidates for productive partnerships in the development of an integrated coastal and nearshore water level network for Alaska.

Sensor Development and Site Installations

- **Marine Sensor Innovation** is a collection of IOOS projects that support research to advance science and technology in support of increased observational capabilities, innovative marine sensor, and improved efficiency ocean monitoring. The **Sensor Evaluation** project is focused on the development and adoption of effective and reliable sensors and platforms for use in coastal, freshwater, and ocean environments, and the **Ocean Technology Transfer** project sponsors the transition of emerging marine observing hardware and software platforms, sensors, and data transfer technologies to operational mode for use in the ocean observing community (IOOS, 2016).

- The Ocean & Coastal Resources Branch, Water Resources Division of the National Park Service (NPS) is in the process of developing a new **Water Level Monitoring Program for Coastal Parks in the National Park Service**, under the guidance of NOAA CO-OPS, for the establishment of tide gauges and monitoring of sea level trends. This program has a goal of providing water level monitoring network coverage for all NPS Ocean and Coastal Parks, with data interpretation and application products provided to assist park managers in issues of coastal change and water level rise. The pilot tide gauges in this program are being installed in Alaska Region Parks, the first one is scheduled to go in at Snug Harbor in Lake Clark National Park and Preserve in 2016 and agreements are in place for these sites to be included in the NWLON network (DiDonato and Bell, 2014).

- The National Weather Service **River Forecast Center** maintains real-time inland and coastal water level sensors throughout Alaska; they also develop new sensor technologies for remote applications, such as the **iGage** acoustic sensors.

- NOAA's National Ocean Service supports a **Sentinel Site Cooperative Network** that promotes collaboration in support of coastal monitoring and data collection tools in coastal areas that have the operational capacity for intensive study and sustained observations to detect and understand physical and biological changes; primary objective are to protect natural resources, measure tides, and establish accurate height measurements. Each sentinel site cooperative in this national network consists of at least one National Estuarine Research Reserve or Sanctuary, a commerce center, and a ready management community. Presently, there is no Sentinel Site established in Alaska, however, basic platforms and sensors are already in use at NOAA's **Kasitsna Bay Laboratory** within the Kachemak National Estuarine Research Reserve.

- The **State of Alaska's Coastal Hazards Program** engages in projects and research that increase understanding about the coast, this research group is dedicated to improving the quality and quantity of critical baseline data in the coastal environment and has the unique ability to rapidly mobilize field campaigns to remote areas in Alaska.

- The **U.S. Army Corps of Engineers** (USACE) routinely installs tide gauges in support of engineering project designs; they also have the opportunity to design new coastal engineering projects to be more compatible with water level sensors. Under a new memorandum of agreement, NOAA CO-OPS now provides tidal datum calculations to USACE in order to assist with civil works regulations; the USACE Alaska District incurs a financial obligation for data transfers under this MOA. The Alaska District also maintains the historical database of **Floodplain Information** in Alaska and recently published a **Guide to Flood and Erosion Data Gathering Procedures** (USACE, 2012).

- The **Alaska Native Science and Engineering Program** (ANSEP) includes more than more than 100 corporations, philanthropic organizations, state and federal agencies, universities, high schools, middle schools, and more than 1,500 Alaska Native students and alumni. ANSEP supports both research and internships for Alaska Native scientists and engineers.

- The **University of Alaska** has three primary campuses (Anchorage, Fairbanks and Southeast) with numerous faculty and students in departments such as Ocean Science, Engineering, or Geoscience, with research interests in water level technology and data.

- The State of Alaska **Silver Jackets Flood Risk Management Team** is an inter-governmental collaboration focused on the development of comprehensive and sustainable solutions to flood hazard issues in Alaska. Their recent activities have centered on educational outreach and high water mark collection; they have occasional proposal opportunities for projects <$100k.

- **Private sector businesses**, such as those in the shipping, fishing, tourism, or resource development industries (including associated **professional groups** such American Waterways Inc., Marine Exchange of Alaska, or Coastal Villages), have a vested interest in the instrumentation of the coast. Barge companies report losses of up to $20k per day for each grounded vessel, and these losses as well as possible environmental impacts of more serious groundings would be reduced with improved water level data. An Open Geospatial Consortium (OGC) **Sensor Observation Service** (SOS) has been newly implemented by NOAA CO-OPS to serve out water level data consistent with the IOOS Data Integration Framework.

- The Department of National Homeland Security' s **Arctic Domain Awareness Center** (ADAC) of Excellence, housed at the University of Alaska Anchorage has the ability to work with students to develop and transition technology solutions and innovative marine products for challenges posed by the dynamic Arctic environment. ADAC also has the opportunity to partner with other universities, such as University of Alaska Fairbanks or Woods Hole Oceanographic Center, in these efforts.

Data Management and Sharing

- **Manual for Real-Time Quality Control of Water Level Data** (2014) is a publication from the IOOS Quality Assurance of Real Time Ocean Data (QARTOD) series. The manual is a living document that reflects state-of-the-art quality control testing and quality assurance procedures and techniques for real-time water level observations.

- **NOAA CO-OPS** has approved a **Revised Polity of Management and Dissemination of External Source Water Level Data** that will work towards adjusting NOAA's data management and to better incorporate water level data from external partners that does not align with existing CO-OPS standards. There is significant opportunity of the Alaska community to work with CO-OPS to access how this tiered data policy may be used to address some of the water level priorities in the region.

- An Open Geospatial Consortium (OGC) **Sensor Observation Service** (SOS) has been newly implemented by NOAA CO-OPS to serve out water level data consistent with the IOOS Data Integration Framework.

- **Alaska Sea Grant**, statewide marine research, education, and outreach program, has hired a Marine Advisory Coastal Community Resilience Specialist; this position will help to provide Alaska community residents with tools for hazard mitigation, economic resilience, and climate change adaptation planning.

- The NOAA **CO-OPS Resilience Program** leverages precise water level information for monitoring, management, planning applications that include coastal development and engineering, habitat restoration, long-term sea level assessments, storm surge monitoring, tsunami warning support, emergency preparedness, and HAZMAT response. This program is expanding CO-OPS products and services to meet emerging sea level trend, extreme water level, Arctic-specific, and other coastal management needs.

- The **Landscape Conservation Cooperative** (LCC) Network brings together resource managers and scientists with a common need for scientific information and interest in conservation. These

Cooperatives include federal, state, and local governments along with Tribes, non-governmental organizations, universities, and interested public and private organizations. These partners work collaboratively to identify best practices, connect efforts, identify science gaps, and avoid duplication through conservation planning and design. Five of the 22 LCCs exist within Alaska; in 2017 the Western Alaska LCC is scheduled to solicit project proposals on coastal issues.

- The **Global Sea Level Observing System (GLOSS)** is an international program conducted under the auspices of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC). GLOSS aims at the establishment of high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level research.

Key Recommendations

Following a synthesis of comments from the break-out sessions at the 2015 **Exploring Options for an Integrated Water Level Observation Network in Alaska meeting**, a list of general recommendations for advancing water level observations in Alaska has emerged. This list is presented in no particular order.

- Efforts need to be undertaken to ensure that static measurements, as well as new and existing sensors, are tied to appropriate vertical control so that they can be used by the widest possible collection of stakeholders.
- Any time new coastal infrastructure projects are proposed, opportunities to integrate water level sensors into the engineering designs should be explored.
- Whenever possible, continuously operating GPS receivers should be co-located with high-accuracy coastal water level stations to determine vertical land motion in support of documenting relative sea level trends (Gill and others, 2015).
- Meteorological stations need to be co-located with water level stations on micro-tidal (<2 m tidal range) coastlines from the North Slope to the Yukon Kuskokwim Delta due the large influence of that winds and barometric pressure have on total water levels in these areas.
- To best accommodate the wide array of environmental conditions, tidal ranges, and local needs, a mix of different sensor technologies may be appropriate to meet the needs of a sustained and comprehensive water level network in Alaska, however, this approach will require that a statewide data standardization scheme be adopted to establish data consistency and provide best practices independent of specific sensor types.
- Whenever feasible, it is advisable to install both a primary and backup sensor at each water level station for redundancy and data quality assurance.
- To meet the instrumentation requirements of very low grade coastal environments, gauging options that do not capture the full tidal range, such as Lowest Low Water, should not be fully discounted if they will capture peak surge events, be more easily sited, and require lower installation and maintenance costs.
- Opportunities to develop agreements with industry partners that have offshore or coastal platforms need to be routinely pursued.
- Technology transfer, data sharing, and research opportunities with international partners in the Arctic, such as Russia and Canada, may encourage new innovation and provide water level measurements from adjacent ocean and coastal areas of interest to Alaskan residents and scientists.

- An effort should be made to promote education and outreach to the general public (consider multi-lingual materials) about the location of existing water level assets, and about the differences between different water level products (e.g. modeled predictions vs. real-time measurements, or storm surge vs. total water levels), and about different vertical datums.
- The relationship between water levels and currents, particularly in areas such as the Bering Strait, have strong ecosystem relevance and projects that address the linkages between these ocean processes are of particular relevance to the broader oceanography community.
- Entities with an interest in improved water level observations in Alaska need to foster a skilled and Alaska-based workforce by investing in college-level educational opportunities.

Next Step Actions

Specific recommendations to guide projects that will most effectively address critical research and development gaps, as well as high priority areas in need of instrumentation are summarized below, roughly in order from lowest to highest expense (as applicable).

Filling the Gaps

- Any and all **existing coastal infrastructure** (statewide) that are suitable for water level instrumentation should be systematically reviewed and considered as possible observation sites.
- Alaska would benefit from the development of program that mirrors the USGS's **Rapid Deployment Gauge (RDG) network** for storm surge documentation on the Atlantic coast. A storm response program of this type for Alaska require research to adapt a logistical approach and engineering solutions that would allow these observations to be collected in a similar fashion without a road network or numerous marine facilities.
- Additional **real-time water level sensors** that capture **observations spanning the fall storm season** are critical to enhance decision support and emergency response activities associated with extreme events.
- Geographically, the coastal region of the **Yukon-Kuskokwim Delta, extending into the southern portion of Norton Sound**, (NWLON Gaps 19-24) is a distinct area of heightened need for additional observations (including both real time sensors and static data collection from extreme events). Additionally**, areas with small to moderate tidal ranges** (in western and northern Alaska) are also a high priority because the total water levels in these areas are strongly influenced by significant metrological, runoff, and/or barometric effects, which are challenging to model.
- Work is presently underway to install a new NWLON station in Unalakleet, Alaska in summer 2016. Based on the NWLON Gap Analysis, in combination with the stakeholder priorities outlined in this summary, **additional NWLON** station priorities would be Hooper Bay or Kotzebue.

Supporting Activities

- Alaska needs to develop and adopt a hierarchy of **standards and best practices** for the collection, formatting, quality evaluation, and distribution of coastal and nearshore water level data in support of different needs. This effort should include the audit of existing assets in the state, with the opportunity for possible improvements and modifications, to ease access to and archive more uniform data availability.
- Archived coastal flood levels (including USACE floods of record) and peak storm surge values need to be digitized, aligned to a common reference datum when possible, and merged with

contemporary measurements of this type (such as CO-OPS extreme water levels). By forming and maintaining a **digital directory of extreme water level events**, the NWS will be able to use these records in conjunction with observation portfolio values and modelers will have rapid access to consistently formatted data for validation purposes.

- The development of a **tool for provisional tidal datum calculations** would allow for determination of relevant tidal reference surfaces at sites without NOAA CO-OPS tide gauges; these calculations are highly important for ecosystem research, observations of relative sea level change, and for translating ocean models into the coastal environment.
- Investments in **research and development of new sensor technologies** to meet the specialized needs of Alaska coastal environments will greatly enhance instrumentation capabilities, particularly along Alaska's Arctic coastlines, and will reduce long-term costs association with water level observations in these settings.
- Exploring ways to **reliably level nearshore sensors** (mooring-type and buoy-type) for consistency with land-based equipment.
- Formal **gap analyses specific to different water level priorities**, such as a National Tsunami Warning Network gap analysis, will enhance future efforts to update this prioritization document.

Acknowledgements

Deepest thanks are extended to all of the enthusiastic participants and presenters at the May 2015 Water Level Workshop in Anchorage, Alaska (attendee list included in appendix), and to all those who were unable to attend but submitted priority areas to the organizing team. The May 2015 Workshop was hosted by the Alaska Ocean Observing System, and the development of this document was also funded, in part, by the Alaska Ocean Observing System and by the Alaska Division of Geological & Geophysical Surveys. This overview document was primarily compiled and edited by Nicole Kinsman, with additional reviews from Crane Johnson, Jeremy Kasper, Jacquelyn Overbeck, Laura Rear McLaughlin, Joel Reynolds, and others.

Appendix

Exploring Options for an Integrated Water Level Observation Network in Alaska, May 27 – 28, 2015, Anchorage, Alaska, i-ix.

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Exploring Options for an Integrated Water Level Observation Network in Alaska

May 27 – 28, 2015
Anchorage, Alaska

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Alaska Ocean Observing System

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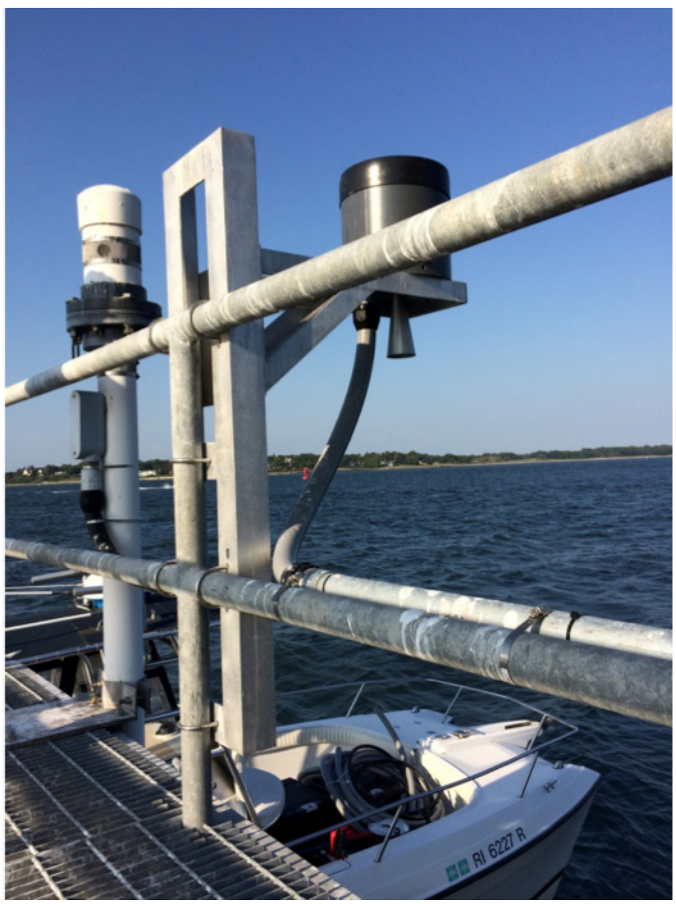

AOOS
Alaska Ocean Observing System

Executive Summary

Portions of Alaska's remote coastlines are among the Nation's most vulnerable to geohazards such as tsunami, extra-tropical storm surge, and erosion; and the availability of observations of water levels, ocean waves, and river discharge are severely lacking to support water level warnings and forecasts. Alaska is experiencing dramatic reductions in sea ice cover, changes in extra-tropical storm surge patterns, and thawing permafrost. These conditions are endangering coastal populations throughout the State. Gaps in the ocean observing system limit our State's ability to provide useful marine and sea ice forecasts, especially in the Arctic. A spectrum of observation platforms may provide an optimal solution for filling the most critical gaps in these coastal and ocean areas. Collaborating and better leveraging resources and capabilities across federal, state, and academic partners may provide the best opportunity for advancing our science capacity and capabilities in this remote region.

The Alaska Ocean Observing System, Alaska Department of Natural Resources, and NOAA jointly conducted a Water Level Workshop May 27-28, 2015. Participants included subject matter experts from fifteen different agencies involved in the collection, visualization, and use of water level observation data within the state of Alaska.

Workshop Participants described the programs within their agency collecting and/or using water level data and the types of instrumentation used through a series of informal presentations. Types of instrumentation presented varied from those used for academic research projects to casual observation data collected by local residents. Presentations were also given on existing databases including access, data formats, and visualization. A representative from each of the agencies involved gave a short presentation on observational assets currently in use and planned for deployment including any future plans for new sensor deployment. Participants also heard from some industry representatives about the need for accurate information on water levels within the state for a variety of uses.

Through the use of breakout groups focused on transportation, protection of life and property, ecosystems, habitats, and natural resources and using maps prepared for the workshop identifying existing assets the participants developed a comprehensive listing of assets needed to obtain full coverage within Alaska. The participants are currently prioritizing this listing.

All of the goals of the workshop were met and general agreement was made that there is a need for an integrated water level observation network in Alaska and participants look forward to participating further.

Table of Contents

Introduction

Alaska's extensive coastline ranges from the temperate rainforests of southeastern Alaska to the permafrost dominated landscapes of the Arctic. More than 64% of Alaska's population lives in communities on or near the coast (2010 Census). Most residents depend upon coastal access for a variety of reasons such as transportation of goods and services, subsistence, recreation and resource development. Climate change is affecting coastal processes and potentially the pattern and scope of coastal hazards. Flooding has become a major concern for remote coastal communities in western Alaska and observational data on water levels is a key step to enhancing resiliency at the local level. Three organizations with specific interests in water level observations collaborated in organizing this Water Level Workshop and while each organization has specific interests, all shared a general goal for the workshop to review the state of knowledge of remote sensing technologies and existing observational assets to identify and prioritize spatial gaps in water level observations.

The Department of Natural Resources, Division of Geology and Geophysical Surveys (DGGS) is tasked with identifying the potential geologic hazards to buildings, roads, bridges, and other installations and structures within the state. They collect and provide coastal baseline data encompassing shoreline change and coastal inundation information.

The Alaska Ocean Observing System (AOOS) works to increase access to existing coastal and ocean data, package information and data in useful ways to meet the needs of stakeholders, and increase observing and forecasting capacity in all regions of the state. Agency stakeholders have expressed a need for collaboration in leveraging resources to meet the increasing demand for data on water level changes as the state faces the impacts of climate change. This workshop was organized to begin work on designing a coastal water level network capable of protecting life and property from coastal storms and in guiding fish, game, and resource management. Additionally, this network could provide data for community and infrastructure planning for coastal resiliency.

Expected workshop outcomes included:

- A map identifying gaps in water level sensor coverage areas.
- A prioritized list of needed observational assets.
- A greater understanding of potential partnerships in the effort to achieve full coverage.

Current and Experimental Sensing Technologies

The workshop began with presenters giving an overview of the types of instrumentation being used by different stakeholder agencies in the state to collect water level observations. This section summarizes those presentations (attached)

National Water Level Observation Networks (NWLON) & Experimental Technologies

Laura Rear McLaughlin & Stephen Gill (NOAA, Center for Operational Oceanographic Products and Services)

NOAA's NWLON provides standards appropriate for navigational and charting purposes, these include sensor configurations and specifications for long-term 'archival'-quality data. These data are used in a range of summary data products such as tidal predictions, tidal datum calculations, characterization of both high and low frequency storm surge events, duration of inundation about a particular threshold, relative sea level change trends, etc. Stephen Gill talked about the most recent gap analysis conducted by NWLON and presented NOAA Technical Memorandum NOS CO-OPS 0048, A Network Gaps Analysis For The National Water Level Observation Network – Updated Edition, September 2014

This presentation outlines these standards, gaps in sensor coverage, and varying types of sensor configuration used by NOAA. In general, NWLON program wants to know water level relative to land w/in the order of 1 cm every 6 minutes.

Coastal Tsunami Gauges

Paul Whitmore & Michael Burgy (NOAA-Tsunami Warning Center)

NOAA's National Tsunami Warning Center collects and provides data pertaining to early detection of tsunami hazards. This presentation provides information about the type of sensor installations that are used and specifications needed for those installations. They are experimenting with different sensor types, looking at tradeoffs of equipment lifetime versus infrastructure requirements and logistics. Their gauge sites require open water but do not have vertical datum surveys, though there is the potential to tie to benchmark network if one exists nearby.

Advanced Hydrologic Prediction System (AHPS)

Crane Johnson (NOAA-National Weather Service, Alaska Pacific River Forecast Center)

NOAA's Alaska Pacific River Forest Center provides hydrologic data including river and flood forecasts that are directly related to the protection of life and property. This presentation covers the type of installations that monitor and record this data and provides an understanding of what is currently available through a variety of interfaces online. This program includes daily communication with local observers, especially during break up, etc. Their integration of information from multiple partners required they develop partner-specific computer code for ingesting and reformatting partner data into a common data standard. They acquire good measurements of river stage (except at low flows), but not actual discharge volume.

Bottom-mounted Pressure Sensors

Tom Weingartner (UAF, School of Fisheries and Ocean Sciences)

UAF in collaboration with NSB-Shell have interest in monitoring coastal currents and ice movement along the Northeastern Chukchi Sea by use of multiple water level sensors. Instrumentation was installed along the North Slope in Point Hope, Point Lay, Wainwright, barrow, and Kaktovik with deployment of instrumentations scheduled for 2015. UAF and NSB-Shell would like to see further implementations of additional instruments along the North Slope to monitor sea level variability and long-term measurements that can contribute to understanding storm surge inundation susceptible areas.

Existing Databases

The next part of the workshop included presentations on the existing databases housing water level data. This section summarizes those presentations.

Alaska Ocean Observing System Data Portal

Molly McCammon (AOOS)

The Alaska Ocean Observing System provides a variety of ocean and coastal data with the objective of making this information publicly available to a variety of users. This presentation includes specifics on the type of data, both social and scientific, that they provide through a number of online map interface databases.

Western Alaska Landscape Conservation Cooperative

Joel Reynolds (WALCC)

Western Alaska LCC promotes existing information delivery infrastructure (e.g., online data portals and curation sites) provided through agencies such as AOOS, GINA, and the USGS rather than provide data hosting services themselves. Western Alaska LCC and the Alaska Climate Science Center are hosting a workshop in late September, 2015 focusing on developing strategies to promote more efficient sharing and curation of hydrology data among federal and non-federal agencies and NGOs and other 'smaller entities' in Alaska; for concreteness, aspects of the discussion will focus on sharing and curating water temperature data.

United States Army Corps of Engineers

Dave Williams (USACE)

The US Army Corps of Engineers collects flood level data post-event that contributes to an online database and potential modeling of future events. This presentation includes information about the format for collecting flood level data in collaboration with FEMA as well as displaying importance of using this data for erosion and other coastal hazards analysis.

NOAA's Center for Operational Oceanographic Products and Services

Laura Rear McLaughlin (NOAA, Center for operational Oceanographic Products and Services)

NOAA's Center for Operational Oceanographic Products and Services collects and provides coastal and lake water level information with a specific data specifications and format. This presentation provides detailed information of data formatting, coverage of data in Alaska, and water level benchmark installation specifications.

Existing Assets

The second day of the workshop opened with several five minute presentations by participants detailing what observing instruments are hosted by their agencies and what new instruments may be planned for the immediate future. Those presentations are summarized in this section.

Louise Fode - National Weather Service

NOAA's National Weather Service is in need of water level and tide system gauges in a variety of locations along the coast of Alaska. Currently, the 2015-2016 plan is to install an NWLON in Unalakleet in collaboration with NOAA CO-OPS. Additional priority areas include Shishmaref, Shaktoolik, Newtok, Emmonak, Nunam Iqua, Hooper Bay, Saint Michael, Kotlik, and Kotzebue.

Lynda Bell - National Park Service

The National Park Service and NOAA are partnering to collect water level data and to grow a National NPS Water Level Monitoring Network with the objective of closely monitoring coastal parks that are vulnerable to changes in *long-term sea level. Currently there are coordinated plans to install a new water level monitoring site in Snug Harbor in collaboration with NOAA CO-OPS.*

Jeff Conaway – US Geological Survey
This presentation provided information on who is responsible for funding stream gauges including a correlation chart with significant economic events in Alaska's past. This includes a descriptive map of available stream gauges in Alaska including information gaps that cause problems with regression calculations.

Tatton L. Suter - US Army Corps of Engineers
Mr. Suter described the Silver Jackets program, which provides a formal and consistent strategy for an interagency approach to planning and implementing measures to reduce the risks associated with flooding and other natural hazards. The USACE does not host any water level sensors in the state but is looking to partner with other state and federal agencies in flood risk management. They have some funding available but cannot fund other federal agencies. They produce two requests for proposals per year for under $100K each. Currently they are working on a mapping program to update flood maps.

Stephen Okkonnen - UAF School and Fisheries and Ocean Sciences
UAF and NSB-Shell has enlisted the help of local residents to deploy water level sensors in lagoon areas near Point Hope, Point Lay, Wainwright, Barrow, and Kaktovik in 2014, to be retrieved in 2015. The sensors are raw-logging pressure transducers affixed to concrete blocks and there are no plans at this time to extend the project beyond 2015.

Joel Reynolds - Western Alaska Landscape Conservation Cooperative
The LCC has identified water level and tide observation systems as a common need for a broad range of stakeholders, including emergency management, infrastructure development, and natural resources management. Focusing on natural resource management, priority area for information is the Yukon-Kuskokwim Delta's coastal region, especially from Hooper Bay to Nelson Island. In FY18/19, the LCC will undertake a two year program focused on a TBD topic related to Coastal Systems.

Harvey Smith and Ruth Carter - ADOT&PF, Coastal Engineering Section
AKDOT&PF Coastal Engineering Section is in need of water level information because of the impact that tides and flooding have on infrastructure such as breakwaters, docks or mooring basins, and design requirements for roads and airports. The areas of interest that AKDOT&PF would like to see data for are Kivalina, Point Spencer, Point Hope, Hooper Bay, Y-K Delta.

Craig Leidersdorf - Coastal Frontiers
There is much need for permanent tide stations in the Chukchi Sea for engineering, navigation and bathymetric mapping purposes. Coastal Frontiers would like to see specific tide stations installed in Wainwright particularly in the Kuk River Inlet, Barrow, and Point Lay.

Molly McCammon - Alaska Ocean Observing System
Ms. McCammon talked about AOOS' role in partnering to provide assets in areas with great need. AOOS supports wave buoys, provides funding support to the Department of Natural Resources for color-coded shoreline water level maps, and other water level products.

Nicole Kinsman - DNR, Division of Geological and Geophysical Surveys
The Alaska Division of Geological and Geophysical Surveys collects and provides coastal baseline data encompassing shoreline change and coastal inundation information. This presentation provides information on prioritized locations along Alaska's coastline; 2015 installation of iGage stations in Port Heiden, Kaktovik and Goodnews Bay; and long-term plans on continued efforts to increase Alaska coastal baseline data.

Gap Analysis

Participants were divided into two breakout groups for the remaining portion of the workshop. The groups were provided with a map of the state identifying existing water level observation instruments and their specific collection purposes and asked to locate areas in need of additional instrumentation from two different perspectives. One group used the perspective of transportation and protection of life and property while the other group identified areas consistent with the information needs for ecosystems, habitats, and natural resources. Additionally each group was asked to prioritize their identified needs.

The two groups reconvened and the participants created a table indicating what sensors are needed by area and to serve navigation, emergency response, or ecosystems. In each case the reason for the need, specific location, frequency of observations, and potential partners were also listed. Additionally, areas identified as gaps in coverage in the 2014 NWLON gap analysis document were referenced in the table.

Outcomes

Workshop participants agreed that the workshop was valuable with a lot of information shared and that this was only a start. The initial map developed by Nicole Kinsman and Lauren Southerland at AKDNR was invaluable in the breakout sessions and may be further developed into either multiple layers or potentially an interactive product. Agencies involved in the collection and use of water level data in Alaska gained a better understanding of the additional efforts being made in Alaska to collect these data. With this knowledge participants began making contacts with colleagues to leverage agency support in the effort to fill in gaps. AOOS had hoped to conclude with a prioritized list of needed water level sensors for Alaska but the participants agreed to continue working towards that end in the coming months.
An important outcome of the workshop was the verified desire of all attendees to create an integrated water level observation network for Alaska.

A formal report serving as an interagency requirements document and including discussions during the workshop, a map product, and a prioritized listing of observational assets needed to fill vital information gaps in water level observations will be compiled in a white paper for publication by 2016.

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