Establishing Vertical Control & Geospatial Infrastructure for Monitoring Sea Level Rise

Conceptual design for local tidal and geodetic control networks with NSRS ties

National Park Service Northeast Region
SLR Kick-off Meeting

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What is the National Geodetic Survey?

NOAA's National Geodetic Survey (NGS) defines and manages a national coordinate system. This network, the National Spatial Reference System (NSRS), provides the foundation for transportation and communication; mapping and charting; and a multitude of scientific and engineering applications. Committed to making transportation and navigation safer, NGS conducts aerial photography surveys near airports in the United States and its possessions to position obstructions and aids to air travel. NGS also maps the coastal regions of the United States and provides data for navigational charts.

NGS State Geodetic Advisors are stationed in several states to work with local communities to expand surveying capabilities.
Bench Mark with Geodetic Control

Tide Gauge

Geodetic Control (NAVD88, etc.)

Initial Wetland Surface

Sea Level Rise

Wetland Flooding not predicted in Water Levels!

Upland

Subsided Wetland Surface

Deep Subsidence

Water Levels!
Need to monitor stability of SET benchmarks over time.
Continuous Operating (GPS)
Reference Stations (CORS)

Passive Bench Marks / Leveling

Land Elevation Trend -1.1mm/yr

Local Sea-Level Rise 3.29 mm/yr

Surface Elevation Tables (SETs)

Long Term Tide Stations

Wetland elevation dynamics
Geospatial Infrastructure Installation Initiative: (GI$^3$) Requirement Drivers

Potential Drivers for Establishing Vertical Control Throughout National Park System

- Habitat Mapping and Change Plan
- IOOS requirements for uniform and precise data from a variety of sources
- Baseline data for Sentinel Sites
Rational for establishing precise geodetic control in National Parks

- Observations taken at National Parks will enhance the investigation of global sea level change questions.
- For this to happen, all National Park observations need to be tied to their local water level devices and should be at the highest practical level of precision.
- All National Park measurements should be traceable back to the NSRS.
- Connecting National Park observational information to the NSRS will allow for relating that information on a national, rather than local, level throughout the National Park system.
Observation Systems Required for Sentinel Sites

• **Tide Stations**
  – Long term stations (NWLOM) required for determining sea level trends
  – Short term stations required for local tidal datums

• **CORS – Continuously Operating Reference Stations**
  – Backbone of the NSRS
  – Regional land motion (subsidence & uplift)

• **Surface Elevation Tables**
  – Local elevation change information in unconsolidated coastal sediments

A network of permanent survey control points are required to accurately measure the relative movements of these observing systems and to compare their data trends over time.
Surveying Methods for Establishing and Monitoring Vertical Control Networks

- **Static GPS** – For establishing control networks and monitoring stability of networks over time (subsidence)
  - 2 – 5 cm Accuracy (relative to NSRS)
  - Long occupation times (3 - 4 hours per point)
  - Relatively low technical expertise required

- **RTK GPS** – For creating Digital Elevation Models and positioning remote or hard to reach points.
  - 1 to 5 cm accuracy (relative to local network)
  - Short occupation times (1 second to 6 minutes)
  - High technical expertise required

- **Leveling** – Highest accuracy method for local network connections and monitoring of network and sensor stability.
  - Sub-Centimeter accuracy (local and NSRS)
  - Time commitment depends on distance of connections
  - Moderate to High Technical expertise required

- **Total Station** – Applications under investigation
Geospatial Infrastructure Installation Initiative:
12 Step Program for establishing baseline vertical control throughout NOAA’s NERR System

1. NOAA assists Reserve staff in accessing and prioritizing archived geodetic and tidal control information for each Reserve
2. Reserve staff conducts reconnaissance and finds control marks
3. Reserve staff submit on-line recovery forms and obstruction diagrams for all found marks

NOAA will continue to provide training and guidance documents for these first three steps.
4. NOAA consults with NERR staff on a case-by-case basis to design customized geodetic and tidal control networks based on individual scientific and management requirements at each Reserve.

Habitat Mapping & Change Plans will be a critical input to this step in the process. Draft plans can be used to establish basic networks. Local networks may be densified later when plans are complete.
GI³ 12 Step Program - Continued

5. Reserve staff install survey control monuments according to network designs. This includes both geodetic control points needed to bring accurate heights into Reserve sites as well as tidal marks required as control for SWMP stations.

NOAA will provide guidelines and training for mark setting. Additional local support may be available.
GI$^3$ 12 Step Program - Continued

6. Reserve staff pursue installation of temporary and/or long-term tide stations where necessary, including an associated tidal benchmark network and ties to geodetic reference.

CO-OPS to provide guidance on where stations should be located. As funding becomes available, CO-OPS will install long term stations (NWLOON) in Reserves that fall within identified NWLOON gaps. Reserves not in NWLOON gaps should secure funding and consult with CO-OPS on installation protocols.
GI³ 12 Step Program - Continued

7. NGS provides equipment loan and training for Reserve Staff to conduct static GPS surveys of control networks.

8. Reserve staff conduct GPS observations and submit data to NGS via Online Positioning Users Service (OPUS)

9. NGS provides adjusted positions for all observed control points, establishing baseline values for local network

NOAA to provide guidelines, training and possibly additional equipment. Local support may also be available on a case by case basis.
10. Reserve staff use new RTK-GPS and leveling equipment to survey SWMP water level loggers into control networks and collect elevation data in support of HMC Plans.

11. Reserves compute tidal datums from SWMP water level loggers and long-term NOAA tide stations.

Extensive technical training will be required. NOAA is committed to building capacity within the NERR System to accomplish these tasks and will provide technical support when possible. **Planning and coordination for these steps must begin now.**
GI³ 12 Step Program - Continued

12. Repeat surveys must be conducted over time (indefinitely) to track stability of vertical control networks, SWMP stations, and SETs.

Once the baseline values are established for the vertical control networks, surveys must be conducted to track changes. These surveys will not only track the relative motion of the observing systems but will provide information about physical processes impacting the structure of the coastal zone.
Establishing a Local Geodetic Network at each Park

**Tool:** Static GPS

**Result:** Sub-decimeter accuracy to the National CORS network.

- Minimum of three geodetic control markers at each reserve.
- Observations at all markers, during two separate GPS constellations.
- Observe for as long as practicable, a minimum of 4 hours is required.

- Use OPUS to reduce GPS data and select option to “submit to database”.
- Final positions are the average of the two independent solutions.
Connecting National Park sensors to the Local Geodetic Network

**Tool:** Geodetic Leveling

**Result:** Sub-Centimeter relative accuracy to the local network

- Double run level loop (per NGS guidelines) through all Control Monuments, SWMP Station, or NWLON station if available, and as many SETs or other sensors as can be leveled to.

- Data are reduced using LOCUS tool.

- Averaged OPUS GPS Derived Heights held at one Control Monument.

- OPUS results from other monuments archived for future comparison.
Connecting National Parks sensors to the Local Geodetic Network

Tool: Kinematic GPS

Result: Centimeter level relative accuracy to the local network.

• Following NGS RTK Guidelines, use RTK to determine position information for all sensors and other measurements not accessible by geodetic leveling.

• All RTK observations are conducted with the base station set up at one of the 3 local control marks.
Current Status of NERRS measurement connections to the NSRS

• Historically NERRS SET observations were relative only to the “bench mark” which accommodated the SET arm.

• NGS has written guidelines for connecting SET benchmarks to the NSRS.

• To determine water level information, each reserve has either a NWLON station or a SWMP station. Water level information determined from these sensors is not directly tied to the SETs, or any other measurements conducted at the reserves.
OPUS-DB Datasheet

All that is needed is a dual-frequency GPS, a digital camera and time.

A minimum of 4 hours of data is required.
Tide Station Benchmark Datasheet

To reach the tidal bench marks from the intersection of State Routes 137 and 28 in Chatham, proceed west on State Route 28 for 5.3 km (3.3 mi) to a rotary, go one-quarter of the way around the rotary to Stage Harbor Road. Then proceed south on Stage Harbor Road for 1.9 km (1.2 mi) to Chaplain Road, proceed west on Chaplain Road for 0.2 km (0.1 mi) to Port Fortune Lane, then make a left onto Port Fortune Lane and proceed south for 0.2 km (0.1 mi) to Hoyts Pier. The bench marks are near the pier, near the fishing pier east of Hoyts Pier, and on the drawbridge on Bridge Street. The tide guage and staff were located on the SW corner of Hoyts Pier.

TIDAL BENCHMARKS

PRIMARY BENCHMARK STAMPING: BM NO 4 1952
DESIGNATION: 844 7505 TIDAL 4
MONUMENTATION: Bench Mark disk
AGENCY: US Coast and Geodetic Survey (USCGS)
SETTING CLASSIFICATION: Concrete sea wall

The primary bench mark is a disk set in the east end of the sea wall located at the NW end of Hoyts Pier, 36.01 m (124.7 ft) east of the extended centerline of Port Fortune Lane, 18.11 m (59.4 ft) SSW of the SW corner of the storage building located north of the pier, 3.51 m (11.5 ft) SSW of the SW corner of the Holt Trap Company dock, 0.30 m (1.0 ft) west of the east end of the sea wall, and 0.49 m (1.6 ft) below the level of the dock.

BENCHMARK STAMPING: 7505 A 1992
DESIGNATION: 844 7505 A TIDAL
MONUMENTATION: Tidal Station disk
AGENCY: National Ocean Service (NOS)
SETTING CLASSIFICATION: Concrete sea wall

The bench mark is a disk set in the top of a north-south oriented concrete sea wall located west of Hoyts Pier, 5.70 m (18.7 ft) west of the centerline of Port Fortune Lane, 40 m (130 ft) west of the NW corner of the storage building located north of the pier, 5.37 m (17.3 ft) north of the south end of the sea wall, 4 m (13 ft) south of the southernmost concrete post along the sea wall.
Tide Station Benchmark Datasheet

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service

Station ID: 8447505
Name: CHATHAM, STAGE HARBOR
MASSACHUSETTS
NOAA Chart: 13248
USGS Quad: CHATHAM

PUBLICATION DATE: 02/05/2004

Latitude: 41° 40.0' N
Longitude: 69° 58.0' W

TIDAL DATUMS

Tidal datums at CHATHAM, STAGE HARBOR based on:

LENGTH OF SERIES: 2 MONTHS
TIME PERIOD: August 1992 - September 1992
TIDAL Epoch: 1983-2001
CONTROL TIDE STATION: 8449130 NANTUCKET ISLAND, NANTUCKET SOUND

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

- MEAN HIGHER HIGH WATER (MHHW) = 1.395
- MEAN HIGH WATER (MHW) = 1.283
- NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.818
- MEAN SEA LEVEL (MSL) = 0.712
- MEAN TIDE LEVEL (MTL) = 0.681
- MEAN LOW WATER (MLW) = 0.079
- MEAN LOWER LOW WATER (MLLW) = 0.000

National Geodetic Vertical Datum (NGVD 29)

Bench Mark Elevation Information In METERS above:

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